PROCEDURES FOR REGIONAL ASSESSMENT OF HABITATS FOR SPECIES OF CONSERVATION CONCERN IN THE SAGEBRUSH ECOSYSTEM

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CONTENTS

TABLES

Table 6. Interpretations of the levels of risk that cheatgrass will displace existing sagebrush in the Great Basin Ecoregion (from Wisdom et al. 2003).

FIGURES

Figure 1. Sagebrush ecoregions and adjacent ecoregions of the western United States. Ecoregions are described and defined in detail by The Nature Conservancy (Groves et al. 2000; Nachlinger et al. 2001). Green pixels depict existing sagebrush cover types in the ecoregions, based on the 90-m sagestitch map (Comer et al. 2002) developed from the vegetation classification system of Reid et al. (2002). For context, green pixels of existing sagebrush cover types are overlaid on the historical range of the two recognized species of sage grouse, Greater sage-grouse and Gunnison sage-grouse, shown in blue (from Schroeder 2002).

Figure 2. Historical and current range of sage grouse in western North America (from Schroeder 2002). The ranges depicted include those of both Greater sage-grouse and Gunnison sage-grouse.

Figure 3. Illustration of the concepts of spatial extent and spatial grain, which compose the spatial scale of a regional assessment. Spatial extent refers to the size and type of boundaries selected; in this case, hydrologic extents are used. Spatial grain refers to the size and type of mapping unit used to estimate vegetation or other environmental features. In this case, pixels are used, ranging from coarse to fine grains, which in turn affect the resolution of associated habitat estimates. See text for additional discussion of these concepts.

Figure 4. Illustration of "top-down" versus "bottom-up" processes in relation to ecological and administrative scales of spatial analysis and land use planning.

Figure 5. Percentage of species of conservation concern associated with sagebrush habitats in the sagebrush ecosystem, summarized by taxonomic groups. Species of conservation concern are defined as species with rare or declining habitats or populations.

Figure 6. Criteria and decision diagram for selecting species of conservation concern for ecoregion assessment of habitats.

Figure 7. Examples of four species' ranges: (1) large, interacting; (2) large, disjunct; (3) small, isolated; and (4) small, fragmented. In these examples and in our procedures, the range of a species is defined as the outer boundaries of a species' occurrence, or a polygon of occurrence, for a given population. Importantly, this definition does not address the evenness of population distribution within a polygon. Ranges identified as large, interacting (one large population within one large polygon) and large, disjunct (two large but spatially separated populations) would be suitable for regional assessment. Ranges identified as small, isolated (one restricted population) or small, fragmented (two or more restricted populations) would not be suitable for regional assessment if such ranges are <100,000 hectares. Once the species' range is mapped, all source habitats for the species within its range are evaluated as part of the regional assessment.

Figure 8. Case example of threat posed by pinyon-juniper displacement of sagebrush in the Great Basin Ecoregion during the next 30 years (from Wisdom et al. 2003). Categories of risk of displacement are defined as low, moderate, and high, as defined and described in our prototype assessment (Wisdom et al. 2003). In this example, levels of risk of sagebrush displacement are mapped in relation to all sagebrush cover types that currently exist in three ecological provinces, without explicit association to any species' habitats. Results would vary by species in relation to differences in species' ranges and habitat associations.

Figure 9. Conceptual diagram of the direct and indirect effects of management activities on population persistence of species of conservation concern.

Figure 10. Case example of threat posed by cheatgrass displacement of sagebrush and other susceptible cover types in the Great Basin Ecoregion during the next 30 years (from Wisdom et al. 2003). Categories of risk of cheatgrass displacement are defined as low, moderate, and high, as described in our prototype assessment (Wisdom et al. 2003). In this example, levels of risk of displacement of sagebrush and other susceptible cover types are not mapped explicitly in relation to any species' habitats. Instead, risk to all susceptible cover types is shown. Results would vary by species of concern in relation to each species' range and habitat associations.

Figure 11. Conceptual example of threat posed by existing or proposed powerlines in the sagebrush ecosystem, based on use of powerlines by avian predators of species of concern. Levels of risk are based on the generalized size of the home range of large, avian predators (shown as oblong circles) that would benefit from the presence of powerline structures as nesting platforms and hunting perches, which, in turn, would result in higher predation rates on species of concern that are prey. In this example, habitat within the central core of the avian predator's home range, when the center is placed along the powerline, is defined as high risk of being unsuitable, owing to high rates of avian predation on species of concern. Habitats outside the central core, but inside the home range, are characterized as moderate risk. Habitats outside the home range are defined as low risk.

Figure 12. Conceptual example of threat posed by energy development in the sagebrush ecosystem. Levels of risk are based on the distance of each pixel of habitat to the nearest development, defined as the energy site itself and the associated network of roads. Pixels of habitat within the development boundaries are classified as being at high risk of loss or degradation to the point of being unsuitable, owing to habitat conversion to energy sites and roads, to habitat fragmentation, to facilitation of exotic plant invasions, and other human-associated factors of disturbance described by Braun (2002), Noon (2002), and Noss and Wuerthner (2002). In this conceptual example, pixels outside the development boundaries, but within specified distances from the boundaries are defined as moderate or low risk of being lost or degraded to the point of being unsuitable. These distance estimates would vary by the species being evaluated, according to differences in home range, dispersal characteristics, and response to habitat fragmentation and disturbance.

Figure 13. Habitat abundance and risk of habitat loss from cheatgrass, for sagebrush vole (A) and Greater sage-grouse (B), in the Great Basin Ecoregion (Wisdom et al. 2003).

Figure 14. Conceptual framework of using species groups to assess and manage species of conservation concern in an ecoregion (from Wisdom et al. 2000). In this process, information on all individual species of concern is retained and considered for management, but the information is summarized at varying levels (groups of species and "families of groups") for efficient consideration in management. However, any management direction set for groups of species can be checked as to its effect on individual species. Moreover, needs of individual species, particularly those whose needs are not represented well by groups of species, can also be addressed in management.

Figure 15. A conceptual approach for grouping species for assessment at the scale of an ecoregion, based on varying combinations of each species' association with sagebrush in relation to other habitats.

Figure 16. Habitat network characterized for sagebrush-associated species in the Interior Columbia Basin (from Wisdom et al. 2002*c*). Watersheds in Condition 1 contain habitats that have undergone little change since the historical period. Watersheds in Condition 2 are characterized by habitats of moderate resiliency and quality. Watersheds in Condition 3 contain habitats of relatively low abundance or low resiliency and quality. Watersheds with extirpated habitats are defined as those containing habitat historically but no habitat currently. Watersheds with rare habitats are defined as those containing >0% but <1% of habitat area.

APPENDICES

Appendix 1: Glossary of Terms

Appendix 2: Identifying Species of Conservation Concern in the Sagebrush Ecosystem

Appendix 3: Examples of Effective Regional Assessments

Appendix 4: Federal Agencies and Associated Laws and Policies Relevant to Management of Species of Conservation Concern

Appendix 5: Short-cut Approaches to Multi-species Assessment

EXECUTIVE SUMMARY

Rationale and Purpose

We developed procedures for regional assessment of habitats for species of conservation concern (species with declining or rare habitats or populations, also called species of concern) in the sagebrush (*Artemisia* spp.) ecosystem. We define a regional assessment as a spatial or temporal analysis of environmental conditions for species of conservation concern that is conducted for areas typically encompassing ≥100,000 hectares (≥250,000 acres), and often encompassing areas >1 million hectares (>2.5 million acres). Our procedures are designed to assess environmental conditions for species whose habitats can be mapped accurately over these large areas. Consequently, our working definition of habitat is the cover types on which a species depends, for those species whose associated cover types can be mapped accurately for areas typically encompassing ≥100,000 hectares.

Cover types and associated alliances, such as those defined under the vegetation classification system of Reid et al. (2002) and used by Comer et al. (2002) for mapping sagebrush, meet our working definition of habitats for regional assessment of species of concern (see *Glossary* [Appendix 1] for definitions of terms used in this document). By contrast, local habitats in small or restricted areas are not included as part of our procedures, as such habitats cannot be mapped accurately as cover types in regional assessments. Consequently, species of conservation concern that are local endemics, whose habitats by definition can be assessed only with local knowledge, are not addressed in this document.

Our procedures were developed for consistent and credible application on federal lands in ecoregions containing sagebrush in the western United States (Figure 1, Table 1). Ecoregions have been identified and mapped by The Nature Conservancy (TNC) (Groves et al. 2000; http://gis.tnc.org/data/MapbookWebsite/map_page.php?map_id=9). Ecoregions dominated by sagebrush include the Columbia Plateau, Great Basin, Wyoming Basins, and adjacent areas (Figure 1). These ecoregions encompass the sagebrush ecosystem, defined by Comer et al. (2002) as 43 million hectares (106 million acres) of sagebrush-dominated lands in the western United States, the boundaries of which closely follow those of the historical range of Greater sage-grouse (*Centrocercus urophasianus*) and Gunnison sage-grouse (*C. minimus*) (Figures 1, 2).

Procedures outlined here are needed because of the prospect of continued and extensive habitat and population declines for many species associated with the sagebrush ecosystem (Knick 1999, Paige and Ritter 1999, Miller and Eddleman 2000), and the resulting high risk of regional extirpation for many species (Raphael et al. 2001). In particular, there is a compelling and unmet need for regional assessment procedures that address, in a holistic manner, the environmental threats associated with habitats for sagebrush-associated species. Knowledge gained from such assessments can be used to guide conservation and restoration planning for sagebrush habitats, holistically and efficiently across large areas, as part of ecosystem management.

Our procedures are presented as analytical steps. The steps are designed to evaluate a comprehensive set of species, and to allow efficient application with spatial data currently available as continuous coverages across the sagebrush ecoregions. We also illustrate the application of our procedures in an example, prototype assessment for the Great Basin

Ecoregion, as described in a companion document available in summer of 2003 (Wisdom et al. 2003).

Regional habitat assessments are essential in establishing regional management strategies as context for efficient and credible development and implementation of local land use plans. At the same time, regional management strategies can be refined with feedback from local planning. The interaction of regional management strategies with local planning fits the concept of "top-down" and "bottom-up" processes (Figures 3, 4). Both processes are essential in addressing land use issues that are both regional and local in scale. Accordingly, we assume that results of regional assessments will be considered in tandem with finer-scale evaluations of habitats as part of local management. Ultimately, the utility of regional assessments depends largely on the successful integration of both regional and local management strategies and their implementation.

Goals, Objectives, and Analytical Steps of Regional Habitat Assessments

An effective regional assessment requires clear goals, objectives, and supporting analytical steps. An example of a compelling, over-arching goal for species of conservation concern is to gain regional knowledge about species' habitats for effective use in maintaining or improving the probability of habitat and population persistence. Key objectives can be tiered to such goals, such as the following examples: (1) identify and evaluate habitats for a comprehensive set of species of conservation concern in sagebrush ecoregions; (2) evaluate trade-offs between management for individual species versus a comprehensive set of species; (3) summarize results at desired scales; and (4) provide guidance about use of results for effective multi-species planning.

In support of such example objectives, the following steps can be used for effective regional assessment. Because the sagebrush ecosystem continues to experience swift and extensive loss and degradation of habitats, we emphasize steps that focus on threats to existing habitats, and the risks posed by each threat. These steps, described in detail later, are designed for spatial analysis in sagebrush ecoregions during the current time period.

Example steps are:

(1) identify the ecoregion and associated spatial extents for regional assessment;
(2) identify species of conservation concern in the ecoregion;
(2) delineate species ranges;
(3) estimate habitat requirements of species;
(4) identify regional threats and effects of such threats on habitats;
(5) estimate and map the risks of habitat loss or degradation posed by each threat;
(6) calculate species-habitat effects from risks of all threats;
(7) form species groups to generalize results across species;
(8) summarize results for species and groups at desired spatial extents; and
(9) list major assumptions, limitations, and guidelines for management.

Importantly, procedures that focus on threats to habitats are of high utility for the design and implementation of appropriate conservation and restoration practices. For example, mapping sagebrush habitats that are highly vulnerable to invasion by cheatgrass (*Bromus tectorum*), versus areas highly vulnerable to encroachment by pinyon-juniper (*Pinus* spp. and *Juniperus* spp.) woodlands, provides spatially-explicit knowledge needed to target each threat with the appropriate management prescriptions, and to estimate the area, time, and resources required to apply the prescriptions. Alternatively, mapping areas where such threats are not imminent allows managers to understand where fewer resources may be needed. Knowledge of threats to habitats can be used for multi-species evaluations, described later.

Our procedures are built on the assumption that habitats for species of concern can be assessed at regional scales, using the recently completed 90-meter by 90-meter (0.81 hectare, or 2 acres) pixel map that composes the "sagestitch" layer (referred to here as the 90-m sagestitch map [Comer et al. 2002, Reid et al. 2002]). The sagestitch map layer currently provides the only continuous coverage of sagebrush across the entire sagebrush ecosystem (Figure 1). Accuracy of the 90-m sagestitch map is considered sufficient to assess habitats at coarse resolution for species of concern at spatial extents of an ecoregion, and for ecological provinces, subbasins, or other large spatial extents nested within each ecoregion (Figures 3, 4). Our procedures also can be applied with more accurate vegetation layers of large spatial extents, such as the 30-meter by 30-meter pixel map of sagebrush cover types now under development (Comer et al. 2000).

INTRODUCTION

Status of the Sagebrush Ecosystem

The sagebrush ecosystem occupies 43 million hectares of semi-arid, sagebrush-dominated lands in the western United States (Table 1). As such, this vast area composes one of the largest ecosystems in North America (Center for Science, Economics and Environment 2002). Although the sagebrush ecosystem remains large, it has been substantially reduced in area and quality. Causes for loss and degradation are many and varied. Invasion of exotic vegetation, altered fire regimes, road development and use, mining, energy development, climate change, encroachment of pinyon-juniper woodlands, intensive grazing by livestock, and conversion to agriculture, to urban use, and to non-native livestock forage all have contributed to the ecosystem's demise (Noss et al. 1995, Tausch et al. 1995, Knick 1999, Miller and Eddleman 2000, Bunting et al. 2002).

The combination of detrimental land uses and undesirable processes has prompted scientists to identify the sagebrush ecosystem as one of the most endangered in the United States (Noss et al. 1995); almost 20% of all plants and animals associated with such systems may be at risk of extirpation (Center for Science, Economics and Environment 2002). Millions of hectares of the ecosystem have been altered or eliminated during the past century (Hann et al. 1997, West 1999), and <10% of the ecosystem remains unaltered by human activities (West 1999). Moreover, loss and degradation on federal lands, where most native sagebrush remains, is increasing rapidly (Hemstrom et al. 2002).

As a consequence, federal land managers are increasingly concerned about the fate of the sagebrush ecosystem and its associated species. A variety of scientific assessments have documented the myriad problems in the ecosystem (Hann et al. 1997, West 1999, Miller and Eddleman 2000), yet efforts to halt or reverse loss and degradation have been unsuccessful at large scales (West 1999, Hemstrom et al 2002). In particular, cheatgrass and other exotic plants continue to displace native sagebrush communities following intensive grazing and large, intense wildfires (Billings 1994, Hann et al. 1997, Bunting et al. 2002), and this form of habitat loss is accelerating on federal lands (Hemstrom et al. 2002). Calls for more intensive, sustained, and extensive conservation and restoration efforts in the ecosystem are growing, coupled with the realization that such efforts require monumental spatial and temporal scales of application to be effective (Knick 1999, Bunting et al. 2002, Hemstrom et al. 2002).

Perhaps the most notable indication of problems in the sagebrush ecosystem has been the significant and continuing decline in habitats and populations of Greater sage-grouse (Connelly and Braun 1997; Schroeder et al. 1999). A variety of detrimental land uses pose major threats to this species' persistence (Schroeder et al. 1999; Connelly et al. 2000; Raphael et al. 2001; Hemstrom et al. 2002; Wisdom et al. 2002*a, b*). New guidelines were developed recently (Connelly et al. 2000) to help managers conserve and restore habitats for the species at the stand scale, but similar guidelines do not exist for regional scales that encompass all or major portions of the species' range. The cumulative effects of management at these large scales can greatly influence the likelihood of regional extirpation of sage grouse (Raphael et al. 2001). Moreover, recent research over extensive sagebrush landscapes (Wisdom et al. 2000; Raphael et al. 2001; Hemstrom et al. 2002; Wisdom et al. 2002*a, b, c*) has provided new and compelling knowledge about status, trends, and risks for sage-grouse habitat that could be used for effective conservation and restoration planning across the species' range.

In addition to sage grouse, many plants and animals are associated with the sagebrush ecosystem and are of conservation concern. Wisdom et al. (2000) identified 30 species of vertebrates in the Interior Columbia Basin that are closely associated with sagebrush habitats, and that are of concern because of declining or rare habitats or populations. Suring et al. (in prep.) recently identified >350 species of sagebrush-associated plants and animals of conservation concern within the historical range of sage grouse (Figures 2, 5, Appendix 2). Similar lists have been developed by State Natural Heritage Programs and by state and federal agencies. Yet, few procedures have been developed and applied to efficiently assess regional habitats for individual species of concern, such as sage grouse, in concert with regional habitat assessment of a comprehensive set of species associated with the sagebrush ecosystem. These procedures are urgently needed by the USDI Bureau of Land Management (BLM), USDA Forest Service (FS), and USDI Fish and Wildlife Service (FWS) to gain regional knowledge for effective conservation and restoration of sagebrush habitats, owing to the high likelihood of regional extirpation events for many sagebrush-associated species (Raphael et al. 2001).

Distribution and Abundance of Sagebrush at Regional Scales

We define the sagebrush ecosystem (Figure 1) as semi-arid, sagebrush-dominated lands in the western United States that encompass the approximate boundaries of the historical range of Greater sage-grouse and Gunnison sage-grouse (Figure 2). The SAGEMAP Project, when established, focused on the collection and dissemination of spatial data layers that occur within the historical range of sage-grouse (http://sagemap.wr.usgs.gov; Comer et al. 2000). Our work is designed to use many of the spatial layers available from SAGEMAP. Consequently, the spatial extent of the sagebrush ecosystem used in our work follows that defined by SAGEMAP.

Ten sagebrush cover types, spanning 19 ecoregions in the western United States were delineated in the 90-m sagestitch map recently completed by the SAGEMAP Project (Table 1; Comer et al. 2002). Although 19 of the ecoregions defined by TNC contain sagebrush, three ecoregions—Columbia Plateau, Great Basin, and Wyoming Basins—support the majority (70%) of area in these cover types (Table 1). The Columbia Plateau and Great Basin Ecoregions, in particular, support >50% of all remaining sagebrush, with extensive concentrations in northern Nevada, southeastern Oregon, and southwestern Idaho (Table 1; Figure 1).

Extensive and large concentrations of sagebrush also are evident throughout the state of Wyoming, encompassing the Wyoming Basins Ecoregion and the southern portion of the Northern Great Plains Steppe Ecoregion. Miller and Eddleman (2000) describe the distribution and ecology of the sagebrush ecosystem, and Reid et al. (2002) describe the recently revised classification of sagebrush alliances and associations.

Objectives of this Document

In response to the urgent need to conserve and restore habitats at regional scales in the sagebrush ecosystem, our objectives were to (1) identify regional assessment procedures that can be used efficiently and credibly to evaluate conditions for a comprehensive set of species of conservation concern in the sagebrush ecoregions, with emphasis on federal lands and the needs of federal land managers; (2) develop methods by which trade-offs between the needs of individual species versus a comprehensive set of species can be addressed systematically and defensibly at regional scales for land use planning; (3) demonstrate the use of regional assessment procedures with spatial data currently available as continuous coverages across all sagebrush ecoregions (Figure 1); and (4) provide guidance regarding use of the procedures for effective multi-species planning at regional versus local scales as part of ecosystem management.

As context for our procedures, we provide examples of regional assessments recently completed for species of concern in other, non-sagebrush ecosystems (Appendix 3). We also illustrate the application of our procedures in a companion document (Wisdom et al. 2003) that features an example, prototype assessment for species of conservation concern in the Great Basin Ecoregion of California, Nevada, and Utah (Figure 1). These procedures and their prototype application will help guide conservation and restoration planning for sagebrush-associated species on federal lands in the sagebrush ecosystem.

Our procedures are designed to complement related work for sagebrush habitats and associated species, such as the SAGEMAP Project (http://sagemap.wr.usgs.gov) led by USDI Geological Survey (USGS), the Great Basin Restoration Initiative led by BLM (USDI Bureau of Land Management 1999), ecoregion assessments by TNC (e.g., Freilich et al. 2001, Nachlinger et al. 2001), state-level conservation strategies for sage-grouse and associated habitats (e.g., Canadian Sage Grouse Recovery Team 2001; Neel 2001; Anonymous 1997), and local assessments underway by BLM and FS. Implementation of our procedures also would provide state agencies with new, regional information to help meet their goals related to sagebrush-associated species. The procedures and prototype assessment also are designed to coordinate with interagency committees on sage grouse and sagebrush management, and will be available for use by these committees to meet interagency needs of federal and state agencies.

Target Audience

The primary audience for this document consists of resource specialists, spatial analysts, and scientists with backgrounds in landscape ecology, conservation biology, and spatial assessment. This primary audience, because of their expertise, is presumed to be familiar with the concepts, terms, and basic approaches outlined here, but not necessarily familiar with the details described here for sagebrush-associated species of concern. Owing to their expertise, we assume that this primary audience could apply our procedures in a credible and defensible manner for regional assessment of habitats for species of concern in the sagebrush ecosystem.

A secondary audience, for sections on why regional assessments are needed, and for general information in other sections, includes resource managers and resource specialists in state and federal agencies, tribal nations, and private organizations who administer management programs for species of conservation concern, but who have less experience in the subject areas listed for the primary audience. This secondary audience is not expected to understand all concepts, terms, and procedures in full detail. Such understanding requires prior working experience on regional assessments or regional mapping; providing adequate details to ensure understanding by all resource managers and specialists is beyond the scope of this document. The comprehensive list of literature cited in this report can be referred to for a fuller understanding of materials presented here.

Importantly, the secondary audience is expected to be the primary user of results from the application of our procedures. Effective use of such results is the ultimate expectation that prompted development of our paper.

WHY CONDUCT REGIONAL SAGEBRUSH ASSESSMENTS?

A regional habitat assessment, as defined here, is a spatial or temporal analysis of environmental conditions for species of conservation concern conducted for areas typically encompassing 100,000 hectares or larger, and often encompassing areas >1 million hectares (see example regional assessments, Appendix 3). The need for regional assessment of sagebrush habitats for species of concern is based on five points:

1. Habitats and populations of sagebrush-associated species continue to decline across vast areas. The prospect of continued habitat and population declines for sagebrush-associated species (Knick and Rotenberry 1999, 2000; Paige and Ritter 1999; Wisdom et al. 2000) across large areas, and the associated high risk of large-scale extirpation events for these species (Raphael et al. 2001), point to the urgent need for regional assessments. Use of regional assessments can capture these top-down processes that manifest over vast areas, allowing for greater management efficiencies.

2. The number of sagebrush-associated species of concern is daunting, and many of these species have extensive ranges compatible with regional assessments. Hundreds of species of conservation concern are associated with sagebrush habitats (Suring et al. in prep., Figure 4), illustrating the need for holistic assessment procedures that can efficiently serve management needs of all species. In addition, many of these species have ranges that encompass millions of hectares and span multiple states and administrative units. Habitat conditions across these wide ranges cannot be managed effectively or efficiently if each BLM Field Office or National Forest is assessed and managed independently of one another. Evaluation of habitat at broad scales provides information to be considered in development of regional management strategies, such as the Great Basin Restoration Initiative by BLM (USDI Bureau of Land Management 1999).

Such strategies can serve as an "umbrella," under which local land use plans can evolve in a consistent and efficient manner, while still adhering to local needs and conditions.

3. Threats to sagebrush habitats are regional in scale. Invasion by exotic plants, ineffective suppression of undesirable wildfires, road development and use, mining, energy development, and other detrimental processes in sagebrush habitats are not local, isolated events. Instead, the processes that pose threats to sagebrush habitats occur across large areas, with cumulative effects that pose high risks to persistence of sagebrush-associated species. Pervasive, regional threats to habitats are best addressed at regional scales, which allow the cumulative effects of a variety of threats to be addressed consistently and holistically across large areas.

4. Regional knowledge facilitates development of consistent, efficient, and credible regional management strategies for a comprehensive set of species. If threats to sagebrush habitats are regional in scale, then regional knowledge of these threats and the underlying processes is needed to develop regional strategies that can address these problems efficiently, consistently, and credibly across large areas. The alternative is local plans that address local problems with local solutions, but by definition are not designed to address threats to habitats consistently across multiple planning areas in an ecoregion. In particular, there is an unmet need for regional assessments that address, in a holistic manner, the conditions and threats associated with a comprehensive set of species associated with sagebrush habitats. Such an approach was developed recently as part of a regional habitat network for sagebrush-associated species in the Interior Northwest (Wisdom et al. 2002*c*). This type of large-scale, multi-species approach would be useful as part of regional assessments for conservation and restoration planning in all sagebrush ecoregions.

5. Regional knowledge provides essential context for local land use planning. Land use plans for individual National Forests or BLM Field Offices depend on defensible justification as to why particular management issues are of interest and focus. Local needs and issues are obvious topics for planning within a National Forest or BLM Field Office. The addition of regional knowledge, however, provides essential context for, and complements, local planning issues. Neither regional knowledge nor local knowledge is independent in terms of land use planning. That is, regional knowledge can identify the dominant spatial and temporal patterns that manifest consistently across large areas, referred to as "top-down" processes (Peterson and Parker 1998). These patterns are in contrast to the finer patterns unique to local areas and conditions, referred to as "bottom-up" processes. Both sets of processes (Figures 3, 4) must be addressed for effective conservation and restoration of sagebrush habitats, described later.

WHY FOCUS REGIONAL SAGEBRUSH ASSESSMENTS ON FEDERAL LANDS?

Managers of federal land are uniquely positioned and responsible for management of habitats for sagebrush-associated species for 2 main reasons:

1. Most remaining sagebrush habitats occur on federal lands, and habitat loss and degradation on these lands are substantial and accelerating. As stated earlier, the sagebrush ecosystem has been characterized as critically endangered (Noss et al. 1995). Nearly 70% of the ecosystem is managed by state or federal agencies, with almost 65% under federal control (Table 2). The BLM and FS administer most of the sagebrush under federal management, managing 52% and 9%, respectively, of all existing sagebrush. These patterns emphasize the key role of federal land management in the conservation of biological diversity in the sagebrush ecosystem and adjacent ecosystems (Stein et al. 1995). While historically most losses of sagebrush habitat occurred on non-federal lands, such losses are currently accelerating on federal lands. Future loss and degradation of sagebrush on federal lands are projected to accelerate, owing to a variety of detrimental processes and land uses (Hemstrom et al. 2002).

2. Federal land managers have legal responsibilities for effective management of habitats for sagebrush-associated species of conservation concern. Responsibilities of federal agencies to conserve and restore species of conservation concern and their habitats are well defined in legislation and policy (Appendix 4). The Federal Land Policy and Management Act (FLPMA) directs the BLM to provide habitat for fish and wildlife and to protect the quality of ecological values. BLM has a variety of policies, based on FLPMA, that are designed to conserve federally and state listed species and their habitats, and to develop and implement effective restoration strategies for such species (Appendix 4). Similarly, the National Forest Management Act (NFMA) directs the USDA Forest Service to "…provide for diversity of plant and animal communities based on the suitability and capability of the specific land area in order to meet overall multiple-use objectives…" In regulations developed to implement NFMA, the following direction is provided: "Fish and wildlife habitat shall be managed to maintain viable populations of existing native and desired non-native vertebrate species in the planning area" (Appendix 4). Similar direction is provided to the FWS in managing National Wildlife Refuges: "In administering the [National Wildlife Refuge] System, the Secretary shall . . . ensure that the biological integrity, diversity, and environmental health of the System are maintained…" (Appendix 4). The FWS also administers the Endangered Species Act, whose premise is based on preemptive management designed to prevent federal listings of species, a concept directly pertinent to conservation and restoration of habitats for species of conservation concern in the sagebrush ecosystem (Appendix 2). The U.S. Department of Defense (DOD) also has legal and policy direction to balance military activities on DOD lands with biological diversity (Appendix 4).

SETTING GOALS AND OBJECTIVES IN THE CONTEXT OF SPATIAL AND TEMPORAL SCALES OF ASSESSMENT

An effective regional assessment requires clear goals and objectives. As mentioned earlier, an example of a compelling, over-arching goal for a regional assessment of habitats for species of conservation concern is to gain regional knowledge about these species' habitats for effective use in improving the probability of habitat and population persistence. Regardless of specific goals and objectives, completion of the process of setting the goals and objectives is critical. Without explicit goals and objectives, direction for the regional assessment will be unclear, and its intended benefits may not be realized.

When defining goals and objectives, consideration of spatial scale is essential (Maurer 2002). Spatial scale is characterized by extent, grain, and accuracy (Figure 3, Peterson and Parker 1998). Extent refers to the size and boundaries of the area under evaluation. For example, the spatial extent of an ecoregion follows ecological boundaries and encompasses millions of hectares, in contrast to an individual patch that may occupy <1 hectare (2.5 acres). Estimates of habitat characteristics over large spatial extents often reveal different patterns than those derived from smaller spatial extents. Neither estimate is incorrect. Instead, patterns revealed at different extents are complementary and informative for multi-scale planning.

Grain is the resolution at which spatial patterns are measured (Figure 3). Resolution of spatial data affects how well the true conditions are estimated for a given size and type of mapping unit. Typical mapping units consist of pixels or polygons. Pixels are a grid of cells, such as squares or hexagons, into which the spatial extent is subdivided. By contrast, polygons consist of vector boundaries of irregular shapes that subdivide the analysis area. Spatial grain is influenced strongly by the minimum size of pixels or polygons used to estimate habitat characteristics. For example, the resolution associated with a 30-m pixel is substantially higher than that associated with a 1000-m pixel, with estimates that are lower in bias (i.e., closer to the true value) and higher in precision (i.e., produce more consistent results).

Consequently, spatial grain affects the accuracy of estimates made over a specified spatial extent, with accuracy defined as the combination of bias and precision associated with spatial estimates for a given time and place. In spatial evaluations of accuracy, measures of bias often are referred to as classification accuracy; this form of accuracy is typically expressed as the percentage of times a spatial estimate correctly identifies the true attribute. For example, 70% classification accuracy might refer to the percentage of times that a particular type of sagebrush habitat was correctly mapped, given a specified spatial grain and extent.

The map pixels of Figure 3 illustrate the differences in accuracy of habitat estimates resulting from differences in spatial grain. For a given spatial extent, the coarser the grain, the lower the accuracy. For example, although the spatial extent covered by the coarse pixel is dominated by Habitat 3, it contains appreciable area of Habitats 1 and 2. The coarse pixel is classified, however, as only one habitat type (Habitat 3), owing to Habitat 3 being the dominant type. In this instance, appreciable amounts of Habitats 1 and 2 are not classified because of the coarse spatial grain and therefore are not included in the estimate, representing a reduction in accuracy. By contrast, if one were to use fine-grained pixels to classify the same sized area as the coarse pixel (compare habitats across the coarse, moderate, and fine pixels in Figure 3), the fine pixels would classify the area as a combination of Habitats 1, 2, and 3, with Habitat 3 as most abundant, and Habitat 1 as least abundant. The result would a more accurate portrayal of the habitat types within that spatial extent of interest.

Hann et al. (1997) and Wisdom et al. (2000) summarized the accuracy of regional assessments based on spatial data estimated at coarse resolution (1-km^2 pixels) in the Interior Columbia Basin. They found that vegetation data were of acceptable accuracy to meet assessment goals when summarized at the largest spatial extents, such as the basin (58 million hectares, or 144 million acres), ecological province (>1 million hectares), or subbasin (>300,000 hectares, or >740,000 acres). By contrast, vegetation data estimated for smaller spatial extents, such as for a watershed (20,000 hectares, or 50,000 acres) or subwatershed (8,000 hectares, or 19,000 acres), were not sufficiently accurate unless data were summarized for large groups of watersheds or subwatersheds.

Specifying temporal scale also is vital in regional assessments; that is, whether past or future changes will be considered, over what time periods such changes will be estimated (temporal extent), and how different methods of estimating conditions at different time periods will be reconciled (Noon and Dale 2002). Different methods used to obtain habitat estimates for each time period affect the spatial grain and accuracy at each point in time, in turn affecting the estimates of habitat change over time. As with spatial scale, the objectives of a temporal analysis determine the extent and accuracy of habitat estimates that are required.

ANALYTICAL STEPS TO MEET OBJECTIVES

Suggested Procedures for Spatial Analysis in Sagebrush Ecoregions

The following steps are intended for application at large spatial extents, such as ecoregions, as well as ecological provinces, subbasins, or other large areas (≥100,000 hectares) nested within each ecoregion (Figure 3). We consider these steps to be the minimal procedures needed to conduct a regional assessment for a comprehensive set of species of conservation concern. As such, these steps are a starting point, to which many complementary analyses can be added. For example, analyses of habitat fragmentation, connectivity, or patch size (Knick and Rotenberry 2002) can be completed after mapping species-habitat threats and risks, and the results used in change detection research. That is, fragmentation, connectivity, and patch size of sagebrush habitats could be measured and mapped before and after the projected loss of habitat that may result from various threats. Such analyses could be completed for individual species or groups of species, based on differences in species' responses to patterns of habitat loss. Examples of such complementary analyses are described later (see *Other Procedures for Spatial and Temporal Analysis*).

Our analytical steps are not necessarily linear; that is, the numbered steps need not be completed in sequence. For example, the first step, *Identify Species of Conservation Concern*, requires knowledge of species ranges, which is part of step 2, *Delineate Species Ranges*. Step 1 requires simple knowledge of whether the range of a given species in the ecoregion is large enough (≥100,000 hectares) for the species to be included in the regional assessment. By contrast, step 2 requires delineation of the specific boundaries of occurrence, so that habitats for each species can be assessed within its respective range. Accordingly, the chronology and details of the following steps can be modified and adapted to meet the specific needs of a given regional assessment.

1. Identify the Ecoregion and Associated Spatial Extents—Ecoregions within the sagebrush ecosystem have been identified and mapped by TNC (Figure 1). These ecoregions, and the amount of sagebrush in each, are listed in Table 1. The reasons for selecting a given ecoregion for regional assessment can be varied and complex, and should be stated clearly. Reasons might include concerns about habitat loss from specific threats, such as energy development (Braun et al. 2002, Noss and Wuerthner 2002). Alternatively, interest in the status of habitats for high-profile species, such as pygmy rabbit (*Brachylagus idahoensis*) or sage-grouse, may drive the selection of an ecoregion. Moreover, knowledge of habitat conditions for such high-profile species in relation to those for a larger set of sagebrush-associated species may be of keen interest in selecting an ecoregion.

Once the ecoregion is chosen, the associated spatial extents of interest can be identified for further assessment. For example, ecoregions follow ecological boundaries, but management typically follows administrative boundaries, such as those of State and Field Offices of the BLM (Figure 4). Consequently, results can also be assessed for these large administrative extents that are nested within an ecoregion, or that overlap largely with ecoregion boundaries. Accordingly, Wisdom et al. (2003) assessed sagebrush habitats for the Great Basin Ecoregion, but also summarized results statewide for Nevada, and for BLM Field Offices within Nevada.

Assessments can include other spatial extents beyond ecological and administrative boundaries. Hydrologic extents, such as watersheds or subbasins, often are used for management planning. The Great Basin Restoration Initiative, for example, focuses on restoration planning by watershed within the Initiative's boundaries, which encompass large portions of the Great Basin and Columbia Plateau Ecoregions (USDI Bureau of Land Management 1999). See Step 9, *Summarize Results for Species and Groups at Desired Spatial Extents*, for additional details about summarizing results for regional assessments at a variety of large spatial extents.

2. Identify Species of Conservation Concern for Assessment in the Ecoregion**—**A comprehensive list of species of conservation concern in the sagebrush ecosystem was recently compiled by Suring et al. (in prep., Appendix 2). This master list can be used to identify the species of conservation concern for regional assessment in a given sagebrush ecoregion. Identification of these species involves a multi-step screening process (Figure 6). The initial steps are (1) consult the master list of species of conservation concern that exist in the sagebrush ecosystem (Appendix 2); (2) identify those species on the master list that occur within the ecoregion of interest; and (3) identify the species from step 2 that are ranked S1, S2, S3, or S4 by NatureServe (NatureServe 2001) for any state in the ecoregion.

Species with rankings of S1, S2, S3, or S4 are screened further by determining whether their ranges are ≥100,000 hectares (step 4, Figure 6). Any species whose range in the ecoregion is <100,000 hectares is dropped, owing to uncertainties about the accuracy of mapping the small areas occupied by such species (Figures 3, 7). Range maps are available (e.g., Opler et al. 1995, Wilson and Ruff 1999) to estimate whether range size is sufficient to include each species of concern in the regional assessment. (See the following section, *Delineate Species Ranges,* for definitions and procedures for mapping a species' range.) Importantly, the availability of more accurate spatial data in the future will allow habitats for species with smaller ranges to be mapped adequately in relation to goals and objectives of a regional assessment.

The remaining species are then evaluated as to whether they are associated with macro-habitats that can be accurately mapped with coarse spatial data (e.g., Comer et al. 2002) currently used for ecoregion assessments (step 5). Species associated with micro-habitats, which cannot be mapped accurately with coarse spatial data, are dropped. (See Appendix 1 for definitions of macro- versus micro-habitats.)

Species associations with macro- versus micro-habitats can be evaluated by researching the species' life history and associated habitat requirements: if habitats for the species can be mapped at coarse resolution, such as that provided by the 90-m sagestitch map (Comer et al. 2002), and summarized over large spatial extents, the species is suitable for regional assessment (step 5, Figure 6). Species that respond primarily to micro-habitats must be evaluated at local scales, and are not suitable for regional assessment (step 5). For example, the availability of local roost sites, a critical requirement for many species of bats, cannot be detected or mapped at regional scales. Similarly, many species are local endemics, requiring knowledge of site-specific conditions in relatively small areas. Habitats for such species must be assessed at local scales that allow accurate mapping of these fine-scale features.

A final step in identification of species of concern is to consult sources beyond those considered by Suring et al. (in prep., Appendix 2), to determine whether additional species can be considered for ecoregion assessment (step 6, Figure 6). Examples of such lists include conservation targets identified by TNC for conservation planning within ecoregions (e.g., Nachlinger et al. 2001), and species identified as sensitive or having other designations of special status by state agencies in the ecoregion.

The final step is for species experts to review and refine the list (step 7, Figure 6). This review can ensure that all species of concern are identified, that species are correctly targeted for regional versus local assessment, and that existing knowledge about habitats and populations of each species is summarized correctly and sufficiently as part of the assessment.

***3. Delineate Species Ranges*—**Knowledge of the range of each species is needed because differences among ranges for many species can result in differences in habitat status and response to management. We define a species' range as the polygon or polygons that encompass the outer boundaries of a species' geographic occurrence within an ecoregion. A species' range can consist of one or more polygons, with each polygon encompassing an interacting population (Figure 7). Species with ranges composed of two or more polygons are assumed to have disjunct populations (Figure 7), with little or no interaction of populations across polygons.

Importantly, our definition of a species' range says nothing about the spatial structure of the population inside each polygon, except to assume that one interacting population exists. This definition contrasts strongly with distribution maps of populations, often generated from documented occurrences of a species. Our definition also differs strongly from maps of predicted distribution of habitats for species, such as those produced by GAP analysis (Scott et al. 1993).

Four example ranges are shown in Figure 7: (1) large, interacting; (2) large, disjunct; (3) small, isolated; and (4) small, fragmented. For broadly-distributed species with one interacting population, the range is depicted as one large polygon that encompasses areas of both used and unused habitats. For common species with disjunct populations, range maps reflect the outer extent of individual populations, and the ranges consist of two or more separate polygons, representing two or more separate populations that have little or no interaction (Figure 7). Locally endemic species or species with small, scattered populations can have ranges expressed as one small polygon (one small, isolated population) or a series of small populations (a set of small, fragmented populations) (Figure 7).

Delineation of each species' range in a regional assessment is a key step because of the above-mentioned spatial differences in habitat conditions, and response to management, that can result from non-overlapping portions of ranges. For example, the range of sage grouse has contracted substantially since historical times (Figure 2); this reduced range contrasts strongly with other sagebrush-associated species, such as the sage sparrow (*Amphispiza belli*) and sagebrush vole (*Lemmiscus curtatus*), whose ranges extend over a larger area of the sagebrush ecosystem (Carroll and Genoways 1980, Martin and Carlson 1998). Consequently, results of a regional assessment for these 3 species could vary substantially, thus complicating short-cut management approaches like "umbrella species," as proposed for sage grouse (e.g., Rich and Altman 2001). (See Appendix 5, "*Short-cut Approaches to Multi-species Assessment.*")

For most species included in a regional assessment, published range maps are available and typically can be used for assessment without modification. Range maps for birds are included in species accounts of The Birds of North America series (Birds of North America, Inc., www.birdsofna.org). Range maps for mammals include those provided by Hall (1981), Zeveloff (1988), Wilson and Ruff (1999), and mammalian species accounts (American Society of

Mammalogists, www.science.smith.edu/departments/Biology/VHAYSSEN/msi/default.html). Stebbins (1985) includes range maps for reptiles and amphibians of the western United States. Ranges of plants and invertebrates are available from many local sources, such as Albee et al. (1988), Morefield (2001), Opler et al. (1995), and Utah Division of Wildlife Resources (2002).

Range maps can be digitized and clipped to the boundaries of the ecoregion under assessment. Habitat assessment for a given species is then conducted within the boundaries of the species' range, as nested within the ecoregion or smaller spatial extents inside the ecoregion.

4. Estimate Species Habitat Requirements**—**A critical part of any multi-species assessment is to identify the habitats on which each species depends. For this purpose, we define habitat in a specific way, referred to as "source habitats." Wisdom et al. (2000, vol. 1:4-5) defined source habitats specifically for the purpose of regional assessments:

"Source habitats are those characteristics of macro-vegetation that contribute to stationary or increasing rates of population growth for a species in a specified area and time. Source habitats contribute to source environments (Pulliam 1988, Pulliam and Danielson 1991), which represent the composite of all environmental conditions that result in stationary or increasing rates of population growth for a species in a specified area and time. The distinction between source habitats and source environments is important for understanding a regional habitat evaluation and its limitations. For example, source habitats for a bird species during the breeding season would include those characteristics of macro-vegetation that contribute to successful nesting and rearing of young, but would not include non-vegetative factors, such as the effects of pesticides on thinning of eggshells, which also affect production of young.

Consideration of both vegetative and non-vegetative factors that contribute to population persistence requires an evaluation of source environments, which is beyond the purpose and scope of most regional assessments of habitat. As part of the process of identifying and evaluating vegetation characteristics that contribute to stationary or increasing population growth, however, we defined and identified source habitats as being distinctly different from habitats that are simply associated with species occurrence, which may or may not contribute to viable, long-term population persistence. That is, in contrast to source habitats, those habitats in which species occur can contribute to either source or sink environments (Pulliam and Danielson 1991). Consequently, species occurrence by itself indicates little or nothing about the capability of the associated environment to support long-term persistence of populations (Conroy and Noon 1996, Conroy et al. 1995). Consequently, data based strictly on species occurrence does not meet objectives to identify those characteristics of macro-vegetation that support long-term population persistence, which we defined as source habitats."

For regional assessment of sagebrush-associated species, source habitats can be considered, at a minimum, to be the cover types on which each species depends or is thought to depend. This is in contrast to more typical designations of species-habitat association, in which habitats listed are those in which the species is predicted to occur (e.g., Scott et al. 1993). Such designations reveal little about whether the habitat is a "source" or a "sink," as discussed above.

Every species is affected to some degree by non-vegetative factors, and such factors also can be addressed in a regional assessment. For example, Raphael et al. (2001) identified three habitat and two non-habitat factors affecting Greater sage-grouse in their regional assessment:

habitat quantity, as measured by the area of sagebrush cover types; two indices of habitat quality, indicating the degree to which native grasses and forbs in the understory of sagebrush were present, degraded, or absent; and two indices of human disturbance effects on populations.

Identifying each species' requirements in relation to the classification system of vegetation used for mapping, or to other spatial layers of non-vegetative factors that index a species' requirements, is an important part of a regional assessment. At a minimum, the cover types that function as source habitats need to be identified, along with supporting rationale. As an example, the 57 land cover types classified in the 90-m sagestitch map can be used to designate source habitats for each sagebrush-associated species (Table 3), using the following process. First, identify the vegetation coverage to be used, in this case the 90-m sagestitch map. Second, associate each species with the cover types known or considered to be source habitats, based on literature review and an evaluation by species experts with specialized knowledge of each taxon (e.g., birds). Example habitat associations are shown for sage grouse and loggerhead shrike (*Lanius ludovicianus*; Table 3). Last, identify other habitat and non-habitat factors beyond source habitats that also could affect species' persistence, such as population size or presence of roads (e.g., Lee 2000, Marcot et al. 2001). Identification of these additional factors will allow regional assessments to be more comprehensive in evaluating conditions for individual species of concern.

5. Identify Regional Threats and Potential Effects**—**Identification of regional threats and their potential effects is perhaps the most fundamental and essential component of any regional assessment for species of conservation concern. A plethora of threats to the sagebrush ecosystem and its associated species have been identified (Table 4); this list can be used as a starting point to identify and evaluate threats in a regional assessment. The importance of these threats in any particular sagebrush ecoregion will vary, depending on local environments, both ecological and political. For example, loss of sagebrush from cheatgrass invasion is a major threat for the Great Basin and Columbia Plateau Ecoregions (e.g., Nachlinger et al. 2001). By contrast, energy development is a more pervasive threat in the Wyoming Basins Ecoregion (e.g., see USDI Bureau of Land Management 2001*a*, Braun et al. 2002). In addition, the significance of various threats to the sagebrush ecosystem has changed over time: some issues, such as large-scale conversion of sagebrush to cropland, have diminished, while others, such as invasion of exotic species, have expanded.

Beyond a simple list of threats, risk assessment involves "obtaining quantitative or qualitative measures of risk levels" (Burgman et al. 1993:13). Estimating risks to habitats for species of concern is essential to informed decision-making. Without such estimates, management decisions may be based on unrealistic perceptions of risk. Risks that are less amenable to control often are perceived to be less important than those that can be addressed easily (Burgman et al. 1993).

Results from risk assessment provide information that decision-makers can use to allocate limited resources for species conservation and management. For example, one could estimate the risk of invasion by pinyon-juniper woodlands into sagebrush based on elevation, precipitation, taxon of sagebrush, proximity to pinyon-juniper, and other factors (Figure 8). Sagebrush sites at high risk of invasion could be targeted for removal of nearby pinyon and juniper (Wisdom et al. 2003). In addition, mapping sagebrush stands by risk would allow managers to identify areas where less attention is currently warranted, as well as areas where immediate action is needed to reduce the risk of woodland invasion. An example of mapping this threat is provided in our prototype assessment (Wisdom et al. 2003), and illustrated in Figure 8. Importantly, the spatial and temporal scales of management treatments must be evaluated to ensure their effectiveness to reduce risk over time and space in relation to management objectives.

Threats to a species' persistence in the sagebrush ecosystem can be broadly categorized as environmental (indirect) or population (direct) (Figure 9). Environmental effects pose indirect threats to populations by first degrading the environment on which the species depends, which in turn affects population characteristics (Figure 9). Environmental effects often are amenable to management, are primarily deterministic, and include such changes as habitat loss, habitat degradation, or environmental contamination (Andelman et al. 2001). Population effects often are stochastic, and come into play when small population sizes occur in response to some combination of direct and indirect threats. Population effects and the resulting problems include genetic considerations, such as inbreeding depression, and demographic effects, such as Allee effects (Figure 9; Andelman et al. 2001). Ultimately, managers are concerned about all threats to population persistence, which can increase the likelihood of population extirpation, or even the extinction of a species (Figure 9).

Efforts to classify threats according to their potential effects (e.g., whether the threats affect populations directly, indirectly through the environment, or both; Table 4 and Figure 9) are confounded by the synergism of many threats, as well as the multiple ways in which single threats may be expressed in the system. For example, excessive or inappropriate livestock grazing can simultaneously reduce the quality of habitat for foraging by, and increase predation pressure on, Greater sage-grouse. Overgrazing leads to 1) removal of perennial grasses and forbs that support insects and other prey items, and 2) the loss of forbs that serve as key forage items in the spring (environmental effect of habitat degradation; DeLong 1993, Gregg et al. 1994). Removal of grasses may also increase predation rates on nests by decreasing nesting cover (a second example of habitat degradation; Gregg et al. 1994, DeLong et al. 1995).

Decisions about which threats to address in a particular assessment area can be based on any of several criteria, including:

- Spatial extent or pervasiveness of the threat across the ecoregion;
- Capability to quantify and map the threat;
- Agreement among those conducting the assessment about the relative importance of the threat to sagebrush habitats in the ecoregion;
- Public opinion about the threat;
- Available resources to address the threat;
- Timeframe required to implement effective treatments across the ecoregion;
- Costs versus benefits of addressing the threat; and
- Potential effects of addressing the threats on non-target species.

Any combination of these criteria can be used to identify the dominant, regional threats for a given ecoregion. Obviously, the more criteria considered, the better the justification for conducting a regional evaluation of threats. Identification of regional threats and their potential effects on species of concern can draw substantially on knowledge from rangeland management specialists, wildlife biologists, endangered species specialists, and other resource professionals working in the assessment area, along with published literature. At a minimum, the list of dominant threats and potential effects can be reviewed and refined by local and regional experts to derive a list like that shown in Table 4, customized for the ecoregion.

***6. Estimate and Map the Risks Posed by each Threat*—**Once the regional threats are identified and their potential effects described, the risks posed by each threat can be estimated and mapped to evaluate the spatial effects on habitats for species of concern. While Table 4 can be used as a master list to identify the regional threats that may be pertinent, and to describe their general effects, specific risks may be difficult to quantify (Burgman et al. 1993). Consequently, we suggest the following process be used. First, define the risk levels posed by the threat. Risk levels can be expressed as probabilities, from 0.0 to 1.0, which estimate the likelihood that habitats will be lost or degraded over a specified period of time, based on the threat. Alternatively, risk levels can be defined as categories, such as high, moderate, and low, with explicit descriptions of the meaning and interpretations of each category. For example, levels of risk that sagebrush will be displaced by cheatgrass were defined by Wisdom et al. (2003) for the Great Basin Ecoregion (Table 5). Note that these definitions identify levels of risk, as well as the time period over which the associated habitat loss may occur.

Second, develop a spatial rule set for mapping each risk level in a geographic information system (GIS); in the case of cheatgrass displacement of sagebrush in the Great Basin, a rule set based on elevation, aspect, slope, and landform was used (Wisdom et al. 2003). Third, summarize the amount of sagebrush area by risk level; for example, the area of sagebrush at low, moderate, and high risk of displacement by cheatgrass (Figure 10). And fourth, interpret and describe the potential implications of the results for management, particularly in relation to time, area, and resources needed to mitigate various risk levels. Example interpretations and implications for the threat posed by cheatgrass are shown in Table 6.

As part of this process, it is important to identify ecological thresholds, if any, in relation to levels of risk. For example, areas of sagebrush at moderate risk to displacement by cheatgrass are considered to be slightly above the threshold for displacement; once the threshold is crossed, conversion to cheatgrass may be permanent (Wisdom et al. 2003). By contrast, areas of sagebrush at low risk are considered to be well above this threshold, while areas at high risk have likely passed through the conversion threshold (Table 6; Wisdom et al. 2003). These patterns suggest that resources available for reducing the risk of cheatgrass displacement are best directed toward mitigating the threat to areas at moderate risk.

The two case examples described above for risks posed by pinyon-juniper and cheatgrass (Figures 8, 10) illustrate the results of estimating and mapping the dominant, regional threats to sagebrush across an ecoregion. In addition, we provide two conceptual examples for estimating and mapping risks to sagebrush habitats from powerlines (Figure 11) and from energy development (Figure 12). Each process is spatially explicit, based on rules that define conditions or zones where effects vary by risk level.

To evaluate effects of powerlines, levels of risk are based on home range size of large, avian predators (shown as oblong circles) that would benefit from the use of powerline structures as nesting platforms and hunting perches, which, in turn, would result in higher predation rates on species of concern that are prey (Figure 11). In this example, habitats within the central core of the predator's home range, when the center is placed along the powerline, are defined as being at high risk of being unsuitable, owing to high rates of avian predation on species of concern. Habitats outside the central core, but inside the home range, are characterized as moderate risk. Habitats outside the home range are defined as low risk.

Critical assumptions for estimating such risks include: size and shape of the home range of selected avian predators; placement of the home range in relation to the powerline; degree to which predation rate within the home range varies by distance from the core of the home range; the species of conservation concern that would be preyed upon by the avian predators; and the distribution of the prey species in relation to the powerline. Species experts can review and refine these assumptions, and provide supporting empirical rationale and evidence for the approach taken.

To evaluate effects of energy development, levels of risk are based on the distance of each pixel of habitat to the nearest development, defined as the energy site itself and the associated network of roads, which compose the development boundaries (Figure 12). Pixels of habitat within the development boundaries are classified as being at high risk of being lost or degraded to point of being unsuitable for species of concern. This high risk is due to habitat conversion to energy sites and roads, to habitat fragmentation, to facilitation of exotic plant invasions, and other human-associated factors of disturbance described by Braun (2002), Noon (2002), and Noss and Wuerthner (2002).

In the example shown in Figure 12, pixels outside the development boundaries, but within specified distances from the boundaries, are defined as moderate or low risk of being lost or degraded to the point of being unsuitable. These distance estimates would vary by the species being evaluated, according to differences in home range, dispersal characteristics, and the species' response to habitat fragmentation and disturbance. Methods for estimating such risks include (1) defining and mapping the development boundaries; and (2) estimating the degree to which habitat becomes non-functional by distance from site and by species.

Estimation of spatially pervasive threats can be used as the foundation for more specific evaluations of habitat conditions and threats for single and multiple species of concern, as applied to individual species ranges, as well as to the collective range of all species. Our prototype assessment for the Great Basin provides further examples of how threats and associated risks can be evaluated for individual species and for groups of species (Wisdom et al. 2003).

7. Calculate Species-Habitat Effects from Risks of all Threats**—**The process of identifying regional threats and associated risks can be used to map and calculate the current amount of habitat for each species, within its range, by the type of threat and the risk levels posed by each threat. This process involves the following steps:

(1) For a given species, sum the number of 90-m pixels that are source habitats for the species, and calculate the area (hectares or acres) occupied by these habitats; and

(2) For a given threat, overlay the risk levels of habitat loss or degradation associated with each pixel of the species' source habitats; then sum the number of 90-m pixels at high, moderate, low, and no risk of habitat loss or degradation for the species, and

calculate the area (hectares or acres) of source habitats associated with each of these risk levels.

This analysis is straightforward when addressing a single threat, as illustrated for Greater sage-grouse and sagebrush vole in the Great Basin Ecoregion (Figure 13). The process becomes more complex, however, when multiple threats and associated risks are considered. In this case, the combination of multiple threats to a species' habitat may be difficult to summarize, owing to complexities of many categories of combined risks, the potential interactions among threats, and the more difficult interpretations for management. For example, three levels of risk from cheatgrass invasion and three levels from pinyon-juniper invasion combine to form nine categories of collective risk to sagebrush habitats (Wisdom et al. 2003).

Managing for different levels of risk from multiple threats requires substantial experience, collective judgment, and supporting rationale. In the case of the combined risks of sagebrush displacement by cheatgrass and pinyon-juniper, the following management implications are noteworthy: (1) areas at high risk of displacement by cheatgrass, but also at high risk of displacement by pinyon-juniper, may be difficult or impossible to maintain as sagebrush habitats, considering the management challenges posed by the combined risks; (2) areas at low risk of displacement by both cheatgrass and pinyon-juniper are most resilient to disturbance regimes of fire, grazing, and recreation; these areas therefore have a high probability of responding in a positive or neutral manner to a variety of management activities, excluding land use changes that eliminate habitat through conversion to urban, agricultural, mining, or energy development; and (3) areas at moderate risk to both cheatgrass and pinyon-juniper displacement are likely to be sensitive to fire, grazing, and other land management disturbances; that is, such disturbances in these areas may increase the vulnerability of sagebrush habitats to invasion and displacement by cheatgrass and pinyon-juniper. Consequently, areas at moderate risk may demand the most management attention, and are likely to respond positively to appropriate improvements (Wisdom et al. 2003).

With these points in mind, the process of calculating habitat area for a given species can be done in a variety of ways in relation to the combination of threats to the species' habitats. The most appropriate process is one that is both ecologically sound and has the most straightforward management implications, particularly in relation to prevention of threshold effects. That is, an appropriate summary of habitat area in relation to multiple threats would be a summary that portrays the various combinations of habitat threats in a manner that allows managers to design practices that prevent thresholds from being crossed, from which restoration of habitats may be impractical or infeasible.

The following guidelines can aid decisions about how best to combine and map different levels of risks from multiple threats for species' habitats:

- Describe the potential cumulative effects of risk from multiple threats in a clear and defensible manner.

- Identify the most severe and the most benign of the potential effects from the multiple threats, to illustrate the range of possible effects. Contrast these extremes with moderate levels of combined risk to illustrate more plausible effects.

- Describe potential synergies among multiple threats, and explain how these synergies might be reduced or avoided with appropriate management.

- Develop a clinical list of all mitigating actions, their effectiveness, and their costs. Describe trade-offs of resource inputs needed to mitigate the combined risks, versus the benefits of achieving the mitigation.

- Identify species and associated habitats that may be at greatest risk from the multiple threats. Refine the mitigating actions and trade-off analyses based on consideration of these species and their habitats.

8. Form Species Groups to Generalize Results Across Species**—**Regional assessment of vast areas such as an ecoregion typically calls for evaluation of 50 or more species of conservation concern (e.g., Wisdom et al. 2000), and can include hundreds or even thousands of species altogether (e.g., Thomas et al. 1993*a,* 1993*b*, Marcot et al. 1998, Nachlinger et al. 2001; Appendix 3). For land managers, individual attention to 50 or more species can be impractical. To address these inefficiencies, various "shortcut" methods have been proposed to eliminate or reduce the number of individual species that are explicitly considered in an assessment and in subsequent management. Among the more popular shortcuts are (1) umbrella species; (2) surrogate species; (3) focal species; (4) landscape indicators; and (5) species groups (see Appendix 5 for detailed descriptions of these and other approaches).

In contrast to shortcut methods that use single species or landscape indicators, the use of species groups, as defined by Wisdom et al. (2000), is an explicit attempt to address the needs of both single and multiple species in a hierarchical fashion (Figure 14). In the most optimistic sense, use of species groups, in combination with individual species, may enable managers to (1) address either single- or multi-species needs, depending on objectives; (2) identify regional habitat patterns that affect multiple species similarly; (3) address the needs of many species efficiently and holistically with the use of regional strategies for the groups; (4) determine how well the regional strategies for groups of species meet the needs of individual species within the groups; and (5) summarize results for species and groups at multiple spatial extents to maximize flexibility in the design and implementation of regional strategies. In the most pessimistic sense, use of species groups may not reflect robust patterns among species, may fail to account for key requirements of individual species, and may provide a false sense of confidence for managers unwilling to consider the unique needs of individual species.

Consequently, we recommend the use of species groups in regional assessments in the sagebrush ecosystem, but with the caveat that assumptions about how well the species groups represent the needs of all individual species of concern be tested as part of management implementation in partnership with research (Appendix 5). Depending on objectives, species can be grouped by various criteria, such as commonality among habitat associations, life-history traits, or threats to persistence (Wisdom et al. 2001, Appendix 5). Using the conceptual approach in Figure 14, each species is placed in one of five example groups (Figure 15), based on the degree to which the species is associated with sagebrush cover types (e.g., nearly exclusively, or more broadly with a combination of sagebrush and other cover types).

Placing species in the five example groups (Figure 15) can be accomplished in several ways, ranging from simple rule sets to formal analyses such as hierarchical cluster analysis (Wisdom et al. 2000, 2001). The following process is one means of placing species in the five example groups, based on a simple rule set to establish the initial groups and cluster analysis to finalize the groups. The rules are based on the degree of a species' dependence on sagebrush versus non-sagebrush cover types. For example, if >75% of the cover types identified as source habitats for a species are sagebrush types, the species is considered a "sagebrush obligate" (Figure 15). By contrast, if 25-75% of the source habitats for the species are sagebrush types, and the remainder dominated by salt desert scrub, by woodlands, or by grasslands, the species is placed in the appropriate group: sagebrush-arid shrubland, sagebrush-woodland, or sagebrush-grassland (Figure 15). Species not placed using the above rules fall into the category of "sagebrush generalists." An alternative rule set is one based on the amount of each cover type used as source habitat by each species in the analysis area, rather than on the number of cover types. For example, if 80% of a species' source habitats are in sagebrush cover types, and 20% in salt desert scrub, but the actual habitat present for the species in the ecoregion is 10% sagebrush and 90% salt desert scrub, it may be difficult to justify placing the species in the sagebrush obligate group. Instead, the species may fit more appropriately in the sagebrush-arid shrubland group (Figure 15).

Cluster analysis can provide further insight about similarities in habitat associations among the species (SAS Institute, Inc., 1989, Wisdom et al. 2000). Hierarchical cluster analysis allows examination of how each species is joined into groups based on similarities with other species' habitats. Each species constitutes a "group" at one end of a hierarchical tree, until all species are joined together to form 1 inclusive group at the other end. Alternatively, the number of desired groups can be specified. Species membership in each group, while varying the numbers of groups, can be examined in relation to knowledge of similarities among species' habitats. A statistician or quantitative ecologist is best qualified to conduct the cluster analysis and can assist in interpreting its meaning.

Results of the cluster analysis can be used to adjust membership of species in the groups, and to adjust the number of groups. Species membership in the modified groups can be reviewed by species experts, along with supporting rationale for why species were placed in each group. This process can iterate many times until agreement is reached about the appropriate membership of species in the groups, and about the desired number of groups needed to meet objectives.

In general, land managers want to minimize the number of groups to be dealt with in land use decisions, but ecologists are likewise reluctant to include too many diverse species in the same group. One solution is to establish multiple levels of grouping for regional assessment, ranging from evaluation of individual species, to groups of species, and to "families of groups" (Figure 14; Wisdom et al. 2000). In this way, managers can use results for the "families of groups" to establish regional habitat strategies, and ecologists can check the efficacy of the approach for individual species and groups of species within each "family" (Wisdom et al. 2000).

***9. Summarize Results for Species and Groups at Desired Spatial Extents*—**Results of regional assessments can be summarized across all sagebrush ecoregions, for each sagebrush ecoregion, and for a variety of large spatial extents (areas ≥100,000 hectares) within each ecoregion (Figure 3). Spatial extents within an ecoregion can include hydrological, ecological, and administrative boundaries (Figure 4).

Example hydrological extents include watersheds (5th hydrologic unit codes, with a mean area ≥100,000 hectares for multiple watersheds) or subbasins (4th hydrologic unit codes, with a mean area of approximately 300,000 hectares per subbasin). Ecological extents include ecological provinces, such as the 14 provinces established by West et al. (1998) and Miller et al. (1999) in the Columbia Plateau and Great Basin Ecoregions (mean area of approximately 5 million hectares [15 million acres] per province), or the 13 Ecological Reporting Units developed by Hann et al. (1997) for the Interior Columbia Basin (mean area of approximately 2.4 million hectares [5.9 million acres] per Reporting Unit). The Nature Conservancy's portfolio sites for conservation (Groves et al. 2000, Nachlinger et al. 2001) are another example of useful ecological extents at which results of regional assessments can be summarized.

Other ecological extents might include a moving window analysis (see Glossary) based on varying sizes of home ranges for the species of concern. For example, two moving windows could be established, one based on home range sizes typical of wide-ranging species, such as sage grouse, and another based on home ranges typical of species with smaller area requirements, such as sagebrush vole.

Administrative extents include the national level, encompassing all areas of BLM and FS ownership across all sagebrush ecoregions, as well as intermediate and finer administrative extents, ranging from BLM State Offices or FS Regional Offices to field units of both agencies (Figure 4). Findings summarized to administrative extents can be crudely cross-referenced to summaries made at hydrological and ecological extents, and vice versa; this can be accomplished by selecting administrative, hydrological, and ecological extents that are similar in size and boundaries. Note, however, that different results should be expected from results summarized for different types of spatial extents, owing to differences in size and boundaries.

Summarizing results for individual species and for species groups at the desired spatial extents is one of the final steps in a regional assessment. Wisdom et al. (2002*d*) summarized habitat conditions for groups of species for each watershed in the Interior Columbia Basin (Figure 16). Each watershed was characterized as one of three conditions for each species group. Watersheds in Condition 1 contained habitats that have undergone little change in quality or abundance since the historical period. By contrast, watersheds in Condition 2 or 3 contained habitats that have changed from historical conditions, but in different ways. Watersheds in Condition 2 had habitats of high abundance but moderate resiliency and quality. Watersheds in Condition 3 contained habitats of low abundance or low resiliency and quality, and contained large spatial gaps where habitat had been lost (Figure 16).

This map of habitat conditions for groups of species is referred to as a "habitat network" (Wisdom et al. 2002*d*). This network, or mosaic, of habitat conditions for each species group appears to have high utility for regional planning (USDA Forest Service and USDI Bureau of Land Management 2000). For example, information about the network could be used by managers as guidance to maintain habitats in a relatively unchanged state from historical conditions (Condition 1), to improve habitats where quality and resiliency have declined (Conditions 2 and 3), to restore habitats in areas of extirpation or low abundance (Condition 3), and to improve connectivity where spatial gaps have developed (Condition 3). See Hobbs (2002) for a detailed discussion regarding the use of habitat networks for conservation planning.

A similar network could be characterized at desired spatial extents for groups of sagebrush-associated species within an ecoregion. For example, for a given species group, each watershed in an ecoregion could be characterized as one of four conditions: (1) habitats are of high abundance and generally at low risk of being lost to regional threats; (2) habitats are of high abundance but mostly at moderate or high risk of being lost; (3) habitats are of low or moderate abundance and mostly at moderate or high risk of being lost; and (4) habitats are of low or moderate abundance but generally at low risk of being lost. Watersheds in Condition 1 may require little or no management change. By contrast, watersheds in Conditions 2 and 3 may require careful management attention to reduce the risks of habitat loss. Moreover, watersheds in Conditions 3 and 4 may need attention in terms of increasing the abundance of habitats. Regional strategies could be developed for watersheds in each condition to identify the appropriate conservation and restoration prescriptions needed to meet management goals for the species group. In turn, spatial priorities for allocating limited resources for conservation and restoration could be mapped for each watershed based on the conditions.

***10. List Major Assumptions, Limitations, and Guidelines for Management*—**Regional assessments have sometimes been criticized as being too coarse to reflect ecological patterns and processes that affect species of conservation concern, and consequently, as having little management utility. While particular criticisms are warranted for any assessment, regional or local, criticisms of regional assessments as being "too coarse" often lack context regarding the objectives the assessment is intended to serve. For example, results from regional assessments may not be too coarse to meet evaluation objectives for large spatial extents such as an ecoregion or ecological province. Alternatively, the same assessment data may indeed be too coarse for use in a local area <100,000 hectares in size, which often represents the area encompassed by local management projects.

These points suggest that all assessments, regardless of scale, require an explicit listing of assumptions and limitations for appropriate management use as a fundamental step in the process. The following assumptions, limitations, and guidelines are likely to apply to management use of results from regional assessments of sagebrush habitats. Additional assumptions, limitations, and guidelines can be added to reflect the specific qualities of a given regional assessment for species of conservation concern.

- The primary audience for application of these procedures consists of spatial analysts, scientists, and resource specialists with strong backgrounds in landscape ecology, conservation biology, and spatial analysis. Resource managers and resource specialists without this expertise are not expected to fully understand all details of the document, nor are they expected to apply the procedures. That is, not all staffs at all levels of the agencies would be expected to apply the procedures. For example, this approach would be something that the BLM National Science and Technology Center in Denver or the USGS SAGEMAP Project in Boise would be expected to successfully apply. By contrast, an individual BLM District or Field Office may not have the resources and expertise to apply the procedures. However, such Districts and Field Offices would be expected to use the results of regional assessments as context for local land use planning.

- The cover types associated with each species, identified here as "source habitats," may not include all environmental conditions that determine whether a population is growing, declining, or stationary. For example, areas containing abundant source habitats may not support persistent populations of some species because of the negative effects of non-vegetative conditions, such as factors associated with roads; that is, source habitats may contribute to stationary or increasing population growth, but the road effect may override the habitat effect, thereby resulting in a sink environment. Knowledge about the negative effects of non-vegetative factors (Figure 9) is therefore an important, complementary component to proper management of vegetation identified as source habitats.

- Estimates of habitat amount are based on the spatial extent of cover types, and these cover types are based on the dominant plant species present in the overstory of each pixel or polygon used for mapping. As such, these estimates do not reflect the quality of understory vegetation that may render some cover types unsuitable as habitat. For example, areas dominated by sagebrush may contain highly variable vegetation in the understory, ranging from the abundance of a variety of native grasses and forbs to complete dominance by exotic plants. Because the coarse pixel resolution used for regional assessments cannot map understory conditions, the amount of source habitats for some sagebrush-associated species may be overestimated. For example, sage grouse depend on an understory of native grasses and forbs for nesting and brood-rearing, and some areas identified as source habitats for this species may be unsuitable due to displacement of native understory plants by exotic grasses.

- Amount of source habitats and associated threats do not directly correlate with population effects. Loss of habitat projected from risks posed by various threats, however, is likely to be positively correlated with trends in populations of the associated species, but the degree of positive correlation is uncertain and likely varies by species and the effects of factors not accounted for in the regional assessment (Knick and Rotenberry 2002).

- Estimates of habitat amount with the use of coarse-pixel resolution, and subsequent estimates of habitat amount by levels of risk posed by threats, are of sufficient accuracy to meet regional assessment goals when results are summarized to spatial extents of the ecoregion, ecological province, subbasin, or other large areas generally $100,000 hectares (Hann et al. 1997; Wisdom et al. 2002; Figure 3). The 90-m sagestitch map should not be used to derive estimates for local areas. Exceptions to this rule may apply to particular analyses. In general, local analyses require data mapped at finer resolution than a 90-meter pixel. Such fine-resolution data are not available in continuous coverage format over large spatial extents, owing to exorbitant costs and processing demands associated with deriving such maps over millions of hectares.

- Habitat estimates are of lower accuracy for cover types that occur in small or linear patches, and often are substantially underestimated in relation to their true spatial extent. Consequently, linear features such as roads, narrow riparian strips, and smaller streams cannot always be mapped accurately at the 90-meter x 90-meter pixel size (0.81 hectare) used for the sagestitch map. Cover types that occur in small patches of <0.40 hectare (1 acre), for example, may not dominate a pixel, and thus not be mapped. Similarly, cover types that have an average patch size <1/4 the area of a 90-meter x 90-meter pixel (that is, <0.20 hectare [0.5 acres]) would not be mapped unless such cover types occur as multiple patches within the pixel. Cover types that occur as multiple patches within a pixel and that have an average patch size >1/4 the area of a 90-meter pixel (that is, >0.20 hectares), however, are typically mapped because some of these patches will be large enough to dominate the pixel. Importantly, many sagebrush cover types occur in patches that can be mapped with a 90-meter pixel size at sufficient accuracy to meet most or all objectives of regional assessments.

- Knowledge of habitat requirements is better for commodity species (game or furbearer species) or threatened or endangered species (TE species, as listed under United States Endangered Species Act) than for species that have neither commodity nor TE status (Wisdom et al. 2002*d*). Knowledge also is better for birds than mammals and for mammals than reptiles and amphibians (Wisdom et al. 2002*d*). These varying levels of knowledge about species habitat requirements are indexed by like differences in the number of studies conducted on TE and commodity species versus species that are neither TE nor commodity, and on birds versus mammals versus reptiles and amphibians. Consequently, higher uncertainty is associated with habitat estimates for reptiles and amphibians than for birds or mammals, particularly birds and mammals that are TE or commodity species (Wisdom et al. 2002 d).

- Results for groups of species are intended for use in regional planning and management, allowing large numbers of species with similar habitat requirements to be managed efficiently. Each species occupies its own niche, however, and habitat estimates based on species groups do not always reflect conditions for individual species within a group. Consequently, any regional management strategy based on an assessment of species groups needs to be evaluated for its effect on individual species (Figure 15). The regional strategy can then be improved through a number of iterations of its development, in concert with checking its effect on individual species.

- Management use of the results for species groups is a coarse-filter approach that can be effective as regional context for local planning, analysis, and implementation. Coarse-filter management assumes that managing an appropriate amount and arrangement of all representative land areas and habitats will provide for the needs of all associated species (Appendix 5). Without such coarse-filter approaches for large spatial extents, the basis for management decisions at local scales may be unclear or could fail to consider the cumulative effects of past management on species of conservation concern. For example, an evaluation of sagebrush habitats for pygmy rabbit in a particular BLM Field Office may indicate that such habitats are abundant and at low risk from various threats. On the scale of the Field Office, this result might imply little need for special management. Results from the Ecoregion analysis may imply otherwise, however, suggesting a high risk of regional extirpation because of more widespread problems. In this case, special management of habitats within the Field Office may be important as part of a larger strategy to conserve and restore habitats for pygmy rabbit over a larger area beyond the boundaries of the Field Office.

- A major assumption of regional assessments is that research will be conducted to corroborate key patterns or processes that are mapped or modeled, and that may lack empirical certainty. That is, results from the regional assessment serve as regional hypotheses for testing and validation through large-area management experiments (Walters 1986). If validation research does not address the major sources of uncertainty associated with results of a regional assessment, the credibility of the assessment, and its management uses, could be seriously questioned. Follow-on research to evaluate key knowledge gaps is a required part of regional assessments.

- Another major assumption is that results of regional assessments will be considered in tandem with finer-scale evaluations of habitats as part of local management. Results from regional assessments provide regional context for designing local conservation and restoration practices. Likewise, the effectiveness of addressing regional threats and regional habitat problems depends on effectively addressing these problems through local management plans. Ultimately, the utility of regional assessments depends largely on the success of both regional and local management strategies and their implementation.

Other Procedures for Spatial and Temporal Analysis

The 10 analytical steps described above are not comprehensive. Instead, these steps should be considered an essential starting point, or foundation, for a regional assessment. These steps can be augmented in a variety of ways with other analyses that add detail and depth to the regional assessment in relation to the targeted species.

The following sections identify additional, complementary means by which regional assessments can be used to evaluate conditions for species of concern. These methods are challenging to use, however, in that they require empirical data that are currently lacking for many species. Consequently, it is important to identify the major assumptions on which such analyses are based, both for testing in research and for understanding their implications in management.

***Fragmentation, Connectivity, and Patch Size Analyses*—**Fragmentation, connectivity, and patch size are important concepts of landscape and population ecology that have direct relevance to regional assessments. Unfortunately, these terms are used in myriad ways and often poorly defined by users, leading to misinterpretation and loss of utility (Haila 2002, Villard 2002). For example, each term can be defined in relation to habitats, populations, or both. Moreover, each term can be used generically as a landscape metric, or applied specifically to a particular species or set of species (Fahrig 2002). Consequently, formal definitions for use in regional assessments are needed to avoid misinterpretation.

Accordingly, we suggest that fragmentation, connectivity, and patch size be defined and used in regional assessments to evaluate the configuration of habitats; that is, to evaluate habitat edge relative to area (fragmentation), habitat arrangement (connectivity), and habitat size (patch size). Such measures are useful for regional assessments because they depict the "patterning" of habitats across large spatial extents that can affect species in a variety of ways (Donovan and Flather 2002, Knick and Rotenberry 2002). Definitions for use of these terms to evaluate habitat configuration in regional assessments follow:

- *Fragmentation:* The degree to which habitats are subdivided into smaller and more isolated patches, where subdivisions are measured by the relation between the length of habitat edge and the size of habitat patches. Long length of habitat edge relative to low size of habitat patches denotes high fragmentation, while short length of edge relative to high size of patches indicates low fragmentation. Many variations of this basic definition are described by McGarigal and Marks (1995).

- *Connectivity:* The degree to which habitats for a species are continuous or interrupted across a spatial extent, where habitats defined as continuous are within a prescribed distance over which a species can successfully conduct key activities (e.g., effective dispersal distance of seeds or juveniles, mean distances moved for foraging, nesting, and brood-rearing), and habitats defined as interrupted are outside the prescribed distance. As an example, Raphael et al. (2001) defined habitats as being "connected" if patches were within one-half the mean dispersal distance for juveniles of a given species; habitat connectivity was then summarized as the percentage of habitat area that was connected for the species, as measured over millions of hectares in each species' range.

- *Patch Size:* The area (hectares) constituting a separate piece of habitat for a species, where the piece is defined as the pixels of habitat adjacent to one another (pixels touching one another on any side or corner), or the piece is defined by some alternative rule set designed specifically for a species. For watersheds or larger spatial extents, the mean or median size of habitat patches present may be a useful summary, in tandem with a display of the frequency distribution of patch sizes.

While the conceptual basis for using these measures of habitat configuration is straight forward, their operational use is not. The following points should be considered if measures of habitat configuration are included in a regional assessment:

- Effects of change in habitat configuration are not well documented for most species of concern (McGarigal and Cushman 2002). Different species respond in different and sometimes contradictory ways in relation to a given spatial configuration of habitats (Haila 1997). Different landscape models, assumptions, and metrics are likely required to assess configuration effects on different species of concern, assuming effects are known.

- Results of fragmentation, patch size, and connectivity analyses will vary with pixel resolution. Use of coarse pixels (Figure 7) results in a "smoothing" of habitats into fewer patches with larger patch sizes and higher connectivity. Use of fine pixels results in more discrete mapping of habitats into smaller, less well-connected patches. The appropriate pixel resolution is the one most compatible with the species' ecology. For example, a coarse pixel resolution is more appropriate for an animal species that moves over large areas and selects habitats with less discrimination than an endemic plant species with stringent, site-specific requirements.

- Measures of habitat configuration are often correlated with measures of habitat abundance (Haila 2002). For example, increased habitat fragmentation invariably reflects decreased habitat abundance. Furthermore, simple measures of habitat abundance often account for substantially more variation in predicting species' extinction than measures of habitat configuration (Fahrig 1997, 2002). Measures of habitat configuration therefore are complementary but secondary to analyses of habitat abundance.

Consideration of Non-vegetative Factors Affecting Species of Concern—Source habitats are defined as characteristics of macro-vegetation that contribute to stationary or increasing rates of population growth for a given species (Wisdom et al. 2000). This definition implicitly acknowledges that factors beyond macro-vegetation can affect population persistence (Figure 9). Consequently, effective management of habitats must proceed in tandem with management of other factors that affect persistence. Knowledge about the negative effects of non-vegetative factors therefore is an important, complementary component to proper management of vegetation identified as source habitats.

Examples of non-vegetative factors that affect species' persistence include (1) over-hunting, over-trapping, poaching, excessive collection for the pet or medicinal trades, or other forms of non-sustainable take; (2) high rates of predation, particularly when changes in habitat predispose species to increased predation; (3) roads or other human disturbances that act as barriers to dispersal, cause avoidance, or disrupt life cycles; (4) indiscriminate, excessive use of pesticides or other chemicals; and (5) anomalies of severe weather or other catastrophes. These examples are not inclusive, but illustrate the diversity of factors that may override the effects of beneficial management of habitat.

Lee (2000) and Marcot et al. (2001) developed the use of Bayesian Networks to integrate the effects of all such variables, biotic and abiotic, which affect species of concern. Raphael et al. (2001) used Bayesian Networks to develop landscape models for a variety of sagebrush-associated species of concern. This form of model performed well as a tool to evaluate landscapes for environmental quality and estimate the probability of regional extirpation for Greater sage-grouse (Wisdom et al. 2002b).

Change Detection Studies—Specification of the desired temporal scale is an important consideration for regional assessments. That is, deciding whether to estimate changes in habitats over time, selecting the proper time periods for estimating such changes (temporal extent), and ensuring that potential biases associated with different methods of estimating conditions at different time periods are reconciled (Noon and Dale 2002). In particular, using different methods to estimate habitats for each time period will affect the spatial grain and accuracy, in turn affecting estimates of habitat change over time. As with spatial scale, the objectives of a temporal analysis determine requirements for extent and accuracy.

By definition, any analysis of risks posed by threats to species or their habitats (e.g., Table 5) is a temporal analysis. That is, identifying sagebrush cover types as being at varying levels of risk from a given threat explicitly assumes that such effects will occur at some point in the future. This time point needs to be specified (e.g., Figures 8 and 10), as risks change with different periods of time over which they are estimated.

The following points may be helpful in considering the use of change detection studies as part of a regional assessment:

- Resources needed for change detection studies are substantial: variables of interest must be estimated at multiple points in time, and consistent methods used to analyze differences over time.

- Narrow time periods may reveal little change in habitat conditions, incorrectly suggesting that change has been minimal. Or, narrow time periods may capture effects of an infrequent but large episodic event, falsely suggesting that change has been substantial.

By contrast, changes measured over multiple time points, spanning longer time periods, are more likely to reveal past dynamics of habitat change that are easier to interpret.

Different methods often must be used to estimate conditions at different time periods. In general, estimates become increasingly coarse in resolution as one goes farther back in time. By contrast, estimates made closer to the present often rely on the same or similar methods of estimating conditions. Differences in methods used for different time points must be accounted for in the analyses and subsequent inferences.

USING RESULTS IN LAND USE PLANNING

Regional assessments are essential in establishing regional management strategies as context for efficient and credible development and implementation of local land use plans. At the same time, regional management strategies can be refined with feedback from local planning. The interaction of regional management strategies with local planning fits the concept of "top-down" and "bottom-up" processes (Figure 4). Both processes are essential in dealing with land use issues that are simultaneously regional and local in scale.

For example, an ecoregion map of risks to sagebrush habitat from powerlines could be invaluable in setting regional management strategies (Figure 11). Based on the regional assessment, the regional strategy could focus on management practices designed to mitigate or reduce the high risk of habitats becoming unsuitable from powerline development. Such strategies might call for rerouting some proposed powerlines that pose pervasive effects that are deemed unacceptable to managers.

Alternatively, effective management of sagebrush habitats in relation to powerline development requires local knowledge of the best management practices deemed to be effective for mitigation. In that way, local management strategies and associated goals, standards, and guidelines are critical for meeting goals of a regional strategy. Moreover, local knowledge can be used to "inform" the regional management strategy about areas where the regional strategy may be more effective than in other areas. Again, this illustrates the adaptive nature of combining "top-down" and bottom-up processes in land management.

Another complementary aspect of regional (top-down) versus local (bottom-up) management strategies is the need to consider species whose habitats can be included in a regional assessment, versus those species' habitats that can be assessed only within local areas. Many species of concern are local endemics, requiring local assessment with the use of fine-scale spatial data or field surveys. Overlaying the results of these local assessments with results for regional assessments is an important part of integrating the needs of local endemics versus species whose needs are assessed over larger areas. Typically, consideration of results from local assessments will allow managers to establish management strategies for small areas, or for specific conditions related to the needs of local endemics. Simultaneously, managers can consider the broad conditions and risks depicted by regional assessments as a complement to local assessments.

Another benefit from regional assessments is the opportunity to project future outcomes and effects of land management on species of concern. One example is the effects analysis of the risk of species extirpation based on the land management alternatives proposed by the FS and BLM in the Interior Columbia Basin (Marcot et al. 2001, Raphael et al. 2001). Projections of future outcomes can be compared against goals for future management, to determine whether the goals will be met under the land management alternatives (USDA Forest Service and USDI Bureau of Land Management 2000).

Finally, results from regional assessments can be used to develop adaptive management plans in relation to strategies, goals, and expected outcomes from future management. In the scientific world, adaptive management calls for management activities to be developed and implemented as experimental treatments, to be tested through large-scale research experiments (Holling 1978, Walters 1986). Such experimental approaches are particularly helpful when the risks posed from various threats are high, and the scientific certainty about how best to manage the risks is low (Walters 1986). Such is the case for management of sagebrush habitats, where conservation and restoration management is a relatively new field, fraught with challenges of addressing the vast spatial and temporal scales needed to achieve effective recovery (Hemstrom et al. 2002, Monsen et al. in press). Moreover, the high degree of technological uncertainty about the effectiveness of sagebrush restoration complicates the challenges of scale even further (West 1999, McIver and Starr 2001). Regional assessments play a key role under such conditions, as a means of synthesizing the best available scientific information available about species of concern and their habitats, summarized in a manner that can be efficiently and credibly dealt with as part of a research-management partnership.

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Table 1. Abundance of sagebrush cover types by ecoregion within the sagebrush ecosystem, based on the 90-meter sagestitch map developed by Comer et al. (2002), available from the SAGEMAP Project (http://sagemap.wr.usgs.gov).

Ecoregion	Area of sagebrush[a] (ha)	Percentage of ecosystem	Percentage of all sagebrush in ecosystem
Black Hills	1,460	0.1	0.0
Canadian Rocky Mountains	47,548	0.2	0.1
Central Shortgrass Prairie	16,472	0.1	0.0
Colorado Plateau	841,092	4.3	2.0
Columbia Plateau	14,064,004	48.3	32.6
Fescue-Mixed Grass Prairie	11,450	0.1	0.0
Great Basin	8,844,892	30.2	20.5
Klamath Mountains	44	0.0	0.0
Middle Rockies - Blue Mountains	3,389,493	15.8	7.9
Modoc Plateau and East Cascades	589,075	10.1	1.4
Mojave Desert	240,946	1.8	0.6
Northern Great Plains Steppe	3,290,725	5.1	7.6
Okanagan	288,010	3.3	0.7
Sierra Nevada	71,916	1.4	0.2
Southern Rocky Mountains	1,389,004	8.6	3.2
Utah High Plateaus	816,128	17.8	1.9
Utah-Wyoming Rocky Mountains	1,825,576	16.7	4.2
West Cascades	5,512	0.1	0.0
Wyoming Basins	7,366,521	55.1	17.1
Total	43,099,867		100.0

[a]Sagebrush is defined by Reid et al. (2002) and mapped by Comer et al. (2002) as consisting of 10 cover types: (1) Wyoming and basin big sagebrush (*Artemisia tridentata wyomingensis, A. t. tridentata*, and *A. t. xericensis*); (2) black sagebrush (*A. nova*); (3) low sagebrush (*A. arbuscula arbuscula*, *A. a. longiloba*, *A. a. longicaulis*, and *A. a. thermopola*); (4) low sagebrush-mountain big sagebrush (*A. a. thermopola* and *A. t. vaseyana)*; (5) low sagebrush-Wyoming big sagebrush (all subspecies of low sagebrush listed except *thermopola*; *A. t. wyomingensis*); (6) mountain big sagebrush (*A. t. vaseyana*); (7) rigid sagebrush (*A. rigida*); (8) silver sagebrush (*A. cana viscidula*/*bolanderi* and *A. cana cana*); (9) threetip sagebrush (*A. tripartita tripartita* and *A. t. rupicola*); and (10) Wyoming big sagebrush-squawapple (*A. t. wyomingensis* shrubland alliance). See Reid et al. (2002) for detailed descriptions of these cover types, as developed under an international classification system of mapping dominant vegetative types.

See the SAGEMAP Project **(http://sagemap.wr.usgs.gov)** for details.

Table 2. Area and percentage of the sagebrush ecosystem by ownership and management agency. Estimates are from maps developed by Comer et al. (2002), available from the SAGEMAP Project (http://sagemap.wr.usgs.gov).

Ownership/ management agency	Area of sagebrush ecosystem (sq. km)	Percentage of total
Public lands/Bureau of Land Management	224,102	52.1
National forest/Forest Service	36,612	8.5
Wildlife refuges/Fish & Wildlife Service	5,007	1.2
Military reservation/ Department of Defense	4,800	1.1
Department of Energy	3,327	0.8
National parks & monuments/National Park Service	1,592	0.4
Other federal management	2,749	0.6
State management	20,909	4.9
Native American reservations	10,907	2.5
Private	120,336	28.0
Other	659	trace
Total	431,000	100.0

Table 3. An example matrix of source habitats and their abundance (percent area) for Greater sage-grouse and loggerhead shrike in the Great Basin Ecoregion (from Wisdom et al. 2003). Cover types marked with an "X" are source habitats, defined by Wisdom et al. (2003) as those characteristics of macro-vegetation that contribute to stationary or increasing rates of population growth for a species in a specified area and time. See text for details.

		Source habitats	
Cover type[a]	Percent area of the Great Basin Ecoregion[b]	Greater Sage-Grouse	Loggerhead Shrike
Wyoming-basin big sagebrush	17.9	X	X
Black sagebrush	5.1	X	
Low sagebrush	1.1	X	
Low sagebrush-mountain big sagebrush	0.4	X	X
Low sagebrush-Wyoming big sagebrush	0.2	X	X
Mountain big sagebrush	3.7	X	X
Silver sagebrush	<0.1	X	X
Threetip sagebrush	<0.1	X	
Agriculture	2.8		X
Ash	<0.1		
Alpine	<0.1		
Aspen	0.2		
Barren/rock/lava	4.1		
Bitterbrush	0.5		X
Blackbrush	0.7		X
Black greasewood	4.4		X
Bunchgrass	3.3	X	
Chaparral	<0.1		X
Creosote-bursage	<0.1		X
Desert grassland	0.4		
Dunes	0.1		
Exotic	<0.1		
Forbland	<0.1		
Forest	1.7		
Juniper	<0.1		X
Marsh/wetland	0.5		

Cover type[a]	Percent area of the Great Basin Ecoregion[b]	Source habitats	
		Greater Sage-Grouse	Loggerhead Shrike
Mesic shrubs	<0.1		
Mesquite	<0.1		X
Mojave mixed scrub	0.1		X
Mountain mahogany	0.1		X
Mountain shrub	1.1		
Pinyon pine	4.4		X
Pinyon-juniper	6.1		X
Playa	1.5		
Rabbitbrush	0.1		X
Riparian	0.4		
Salt desert scrub	25.2		X
Saltbush	0.1		X
Shadscale	2.8		X
Snow/ice	<0.1		
Spiny hopsage	0.4		X
Utah juniper	2.4		
Water	2.9		
Western juniper	<0.1		
Wet meadow	<0.1	X	X
Winterfat	0.3		X
Recently burned	4.1		

[a] See Reid et al. (2002) for descriptions of these cover types, as developed under an international classification system of mapping dominant vegetation types.

[b] Estimates of percent area occupied by each cover type are based on the 90-meter sagestitch map developed by Comer et al. (2002), available from the SAGEMAP Project (http://sagemap.wr.usgs.gov). See text for details.

Table 4. Threats and associated risks to habitats and species in the sagebrush ecosystem, with example references.

Threat	Associated Risk	Example	References
Conversion of sagebrush to cropland or to pasture for livestock	*Environmental* – habitat loss	Removal of sagebrush cover (e.g., via brush-beating, chaining, disking, or burning) and planting with crops, such as alfalfa, or with non-native perennial grasses (e.g., crested wheatgrass) for livestock forage	Vale 1974, Dobler 1994, Fischer et al. 1997, Braun 1998, Knick 1999, Schroeder et al. 1999, West 1999, Miller and Eddleman 2000, Johnson and O'Neil 2001
	Environmental – habitat fragmentation	Removal of sagebrush may lead to fragmentation of remaining sagebrush habitats, resulting in interference with animal movements and dispersal or population fragmentation	Knick and Rotenberry 1997, Johnson and O'Neil 2001
	Population – direct mortality	Nest and egg destruction, or directly mortality of animals, from mechanical or other methods used to remove sagebrush or to cultivate lands adjacent to sagebrush	Patterson 1952
Domestic livestock	*Environmental* – habitat degradation	Overgrazing by domestic stock, especially cattle and sheep, leading to loss of native perennial grasses and forbs in the understory (changes in composition and structure), with resulting declines in forage and habitat for species of concern and their prey (e.g., insects); trampling may destroy burrows used by animals such as burrowing owls	Bock et al. 1993, Fleischner 1994, Saab et al. 1995, Guthrey 1996, Schroeder et al. 1999, Beck and Mitchell 2000, Miller and Eddleman 2000, Johnson and O'Neil 2001, Holmes et al. in press
	Population – direct mortality	Mortality from trampling of nests	Fleischner 1994, Beck and Mitchell 2000, Holmes et al. in press
Overgrazing by wild horses	*Environmental* – habitat degradation	Loss of native perennial grasses and forbs in the understory	USDI BLM et al. 2000, Young and Sparks 2002
Altered fire regimes	*Environmental* – habitat loss	Increases in catastrophic wildfires, often related to invasions of cheatgrass, have resulted in complete removal of sagebrush cover (i.e., type conversion) in some areas, especially in Wyoming sagebrush communities	Whisenant 1990, D'Antonio and Vitousek 1999, Knick and Rotenberry 1999
	Environmental – habitat degradation	Fire suppression has led to altered fire cycles in sagebrush ecosystems, resulting in changes in vegetation composition and structure, e.g. encroachment of woodlands into sagebrush	Schroeder et al. 1999, Miller and Eddleman 2000
Invasions of exotic plants	*Environmental* – habitat loss and degradation	Altered fire regimes and habitat degradation (e.g., from excessive livestock grazing) have led to increases in exotic plants (e.g., cheatgrass) in sagebrush ecosystems	Yensen 1981, Billings 1994, Knick 1999, West 1999, Miller and Eddleman 2000
Expansion of juniper and other woody species in sagebrush communities	*Environmental* – habitat loss and degradation	Fire suppression and changes in climate have led to expansion of juniper into sites previously occupied by sagebrush, especially in mountain big sagebrush and Wyoming big sagebrush	Burkhardt and Tisdale 1976; Miller and Rose 1995, 1999; Commons et al. 1999; Miller and Eddleman 2000
Application of pesticides	*Environmental* – habitat degradation	Decrease in forage base by killing of insects used as prey by sagebrush-associated species	Johnson 1987, Holmes et al. in press

Threat	**Associated Risk**	**Example**	**References**
	Population – mortality	Direct mortality of birds and other vertebrates exposed to pesticides, and indirect mortality through consumption of contaminated insects	Patterson 1952, Blus et al. 1989, Blus 1996
Application of herbicides	*Environmental* – habitat loss and fragmentation	Herbicides used extensively prior to the 1980s for conversion/removal of sagebrush, especially if native understories were in relatively good condition	Best 1972, Braun and Beck 1977, Braun 1998, Connelly et al. 2000, Miller and Eddleman 2000
Power lines	*Environmental* – habitat fragmentation	Removal of sagebrush cover from power line corridors can fragment habitats in the sagebrush ecosystem	Braun 1998
	Population – increased predation	Poles and towers serve as additional perches and nest sites for raptors that prey on sagebrush-associated species	Braun 1998, F. Hall, pers. comm.
	Population – direct mortality	Birds may collide with power lines, resulting in injury or death; electrocution of raptors and other birds also occurs	Harmata et al. 2001
Fences	*Environmental* – habitat fragmentation	Construction of fences in sagebrush ecosystems can fragment habitats and interfere with animal movement (e.g., American pronghorn)	Braun 1998
	Population – direct mortality	Animals can collide with fences or become entangled, leading to injury or death	Oakley and Riddle 1974, Fitzner 1975, Call and Maser 1985, Todd 2001
Oil and natural gas field development	*Environmental* – habitat fragmentation	Pipelines, roads, and associated collection facilities fragment habitats	Anonymous 1997, Braun 1998, Braun et al. 2002
	Population – disturbance	Disturbance and potential abandonment of habitat due to vehicular traffic, noise, and related human activity at well sites	Warrick and Cypher 1998, Lyon 2000, Braun et al. 2002
Mine development	*Environmental* – habitat loss and fragmentation	Fragmentation and outright loss of habitat to surface mines and associated mine tailings and roads	Braun 1998
	Population – disturbance	Disturbance and potential abandonment of habitat due to traffic, noise, and related human activity at mine site	Braun 1998
Reservoirs, dams, and other water developments	*Environmental* – habitat loss	Loss of habitat from establishment of reservoirs in sagebrush habitat	Braun 1998, Schroeder et al. 1999
Roads and highways	*Environmental* – habitat loss	Creation of roads and highways and their associated rights-of-way result in direct loss of habitat	Forman et al. 1997
	Environmental – habitat fragmentation	Creation of roads and highways and their associated rights-of-way fragments sagebrush habitats	Forman et al. 1997, Braun 1998
	Population – barrier to migration	Roads may serve as movement or migration barriers to less mobile species	Mader 1984, Bennett 1991
	Population – direct mortality	Death or injury from collisions with vehicles	Patterson 1952, Olendorff and Stoddart 1974, Blumton 1989, Todd 2001

Threat	**Associated Risk**	**Example**	**References**
Recreation	*Population* – human disturbance	Recreational activities, such as off-road vehicle use in sagebrush habitats, may affect species of concern, e.g., displacement or nest abandonment. Recreational shooting of small mammals can also affect populations directly.	Berry 1980, White and Thurow 1985, Braun 1987, Schroeder et al. 1999
	Environmental – habitat degradation	Off-road vehicle use can degrade habitats in the sagebrush ecosystem	Berry 1980
Urban development	*Population* – human disturbance	Increases in human activities in human settlements may negatively affect populations of sagebrush-associated species by displacement or abandonment. Predation rates on wildlife in sagebrush habitats also may increase from domestic dogs and cats in urban and rural settings.	Berry et al. 1998, Millsap and Bear 2000, Arrowood et al. 2001
	Environmental – habitat loss	Development of urban areas and "ranchettes" surrounding urban sites results in direct loss of sagebrush habitats	Braun 1998
Military training	*Environmental* – habitat fragmentation	Training exercises in sagebrush habitats result in loss of shrubs from both wildfire and destruction from tracked vehicles, and may lead to habitat fragmentation	Knick and Rotenberry 1997; Holmes and Humple 2000
Weather, climatic changes, and catastrophes	*Environmental* – habitat degradation	Gradually increasing temperatures have contributed to drought and more severe and frequent wildfires, escalating the spread of invasive plants such as cheatgrass in sagebrush ecosystems. Drought years in close succession can lead to losses of key forbs used by sagebrush-associated species in those years.	Tausch et al. 1993, Miller and Eddleman 2000
	Population – stochastic events	Catastrophic events such as floods and severe drought can lead to extirpation of small populations	Andelman et al. 2001
Herbivory effects from wild ungulates	*Environmental* – habitat degradation	Excessive herbivory by native ungulates can lead to degraded understories in sagebrush ecosystems (e.g., changes in species composition and structure) and reductions in sagebrush densities and canopy cover	McArthur et al. 1988, Singer and Renkin 1995, Wambolt and Sherwood 1999
Parasitism by cowbirds	*Population* – direct mortality	Populations of some bird species (e.g., sage and vesper sparrows) in the sagebrush ecosystem may be affected by parasitism from brown-headed cowbirds, a species which increases in human-altered environments (e.g., livestock and farm operations)	Friedmann and Kiff 1985, Robinson et al. 1995
Selenium and other environmental contaminants	*Population* – direct threat of mortality	Poisoning of animals from uptake of selenium in contaminated aquifers, primarily from agricultural runoff	Lemly 1997
Predation	*Population* – direct mortality	Increased vulnerability of species of concern to predators due to altered habitats (e.g., reductions in nesting or hiding cover).	Gregg et al. 1994, Delong et al. 1995

Table 5. Risk levels defined for the probability that sagebrush and other susceptible native cover types will be displaced by cheatgrass in the Great Basin Ecoregion (from Wisdom et al. 2003).

Risk level	Definition
Low	The probability that cheatgrass will displace existing sagebrush or other susceptible cover types is minimal; native plants are likely to dominate the understory of these stands at the current time.
Moderate	The probability that cheatgrass will displace sagebrush or other susceptible cover types is moderate, but lower than for types at high risk; either cheatgrass or native plants can dominate the understory at the current time.
High	The probability that cheatgrass will displace sagebrush or other susceptible types is very likely; cheatgrass is likely to dominate the understory (vs. native plants) at the current time.

Table 6. Interpretations of the levels of risk that cheatgrass will displace existing sagebrush or other susceptible native cover types in the Great Basin Ecoregion (from Wisdom et al. 2003).

Risk	Understory dominance of cheatgrass versus native grasses	Resiliency after disturbance	Vulnerability to disturbance effects	Relation to restoration threshold
Low	Native grasses	High	Low to moderate	Above
Moderate	Variable	Variable	High	Above but close to dropping below
High	Cheatgrass	Low or very low	High to very high	Below

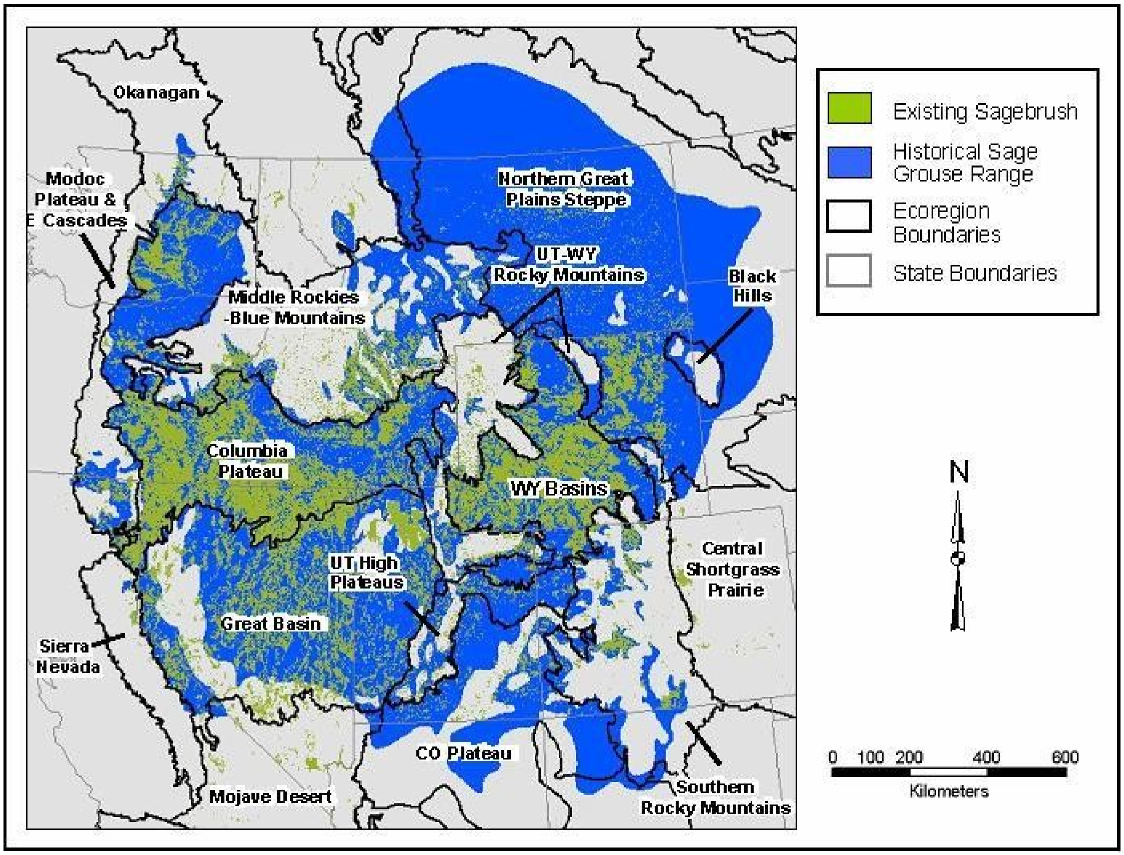

Figure 1. Sagebrush ecoregions and adjacent ecoregions of the western United States. Ecoregions are described and defined in detail by The Nature Conservancy (Groves et al. 2000; Nachlinger et al. 2001). Green pixels depict existing sagebrush cover types in the ecoregions, based on the 90-m sagestitch map (Comer et al. 2002) developed from the vegetation classification system of Reid et al. (2002). For context, green pixels of existing sagebrush cover types are overlaid on the historical range of the two species of sage grouse, Greater sage-grouse and Gunnison sage-grouse, shown in blue (from Schroeder 2002).

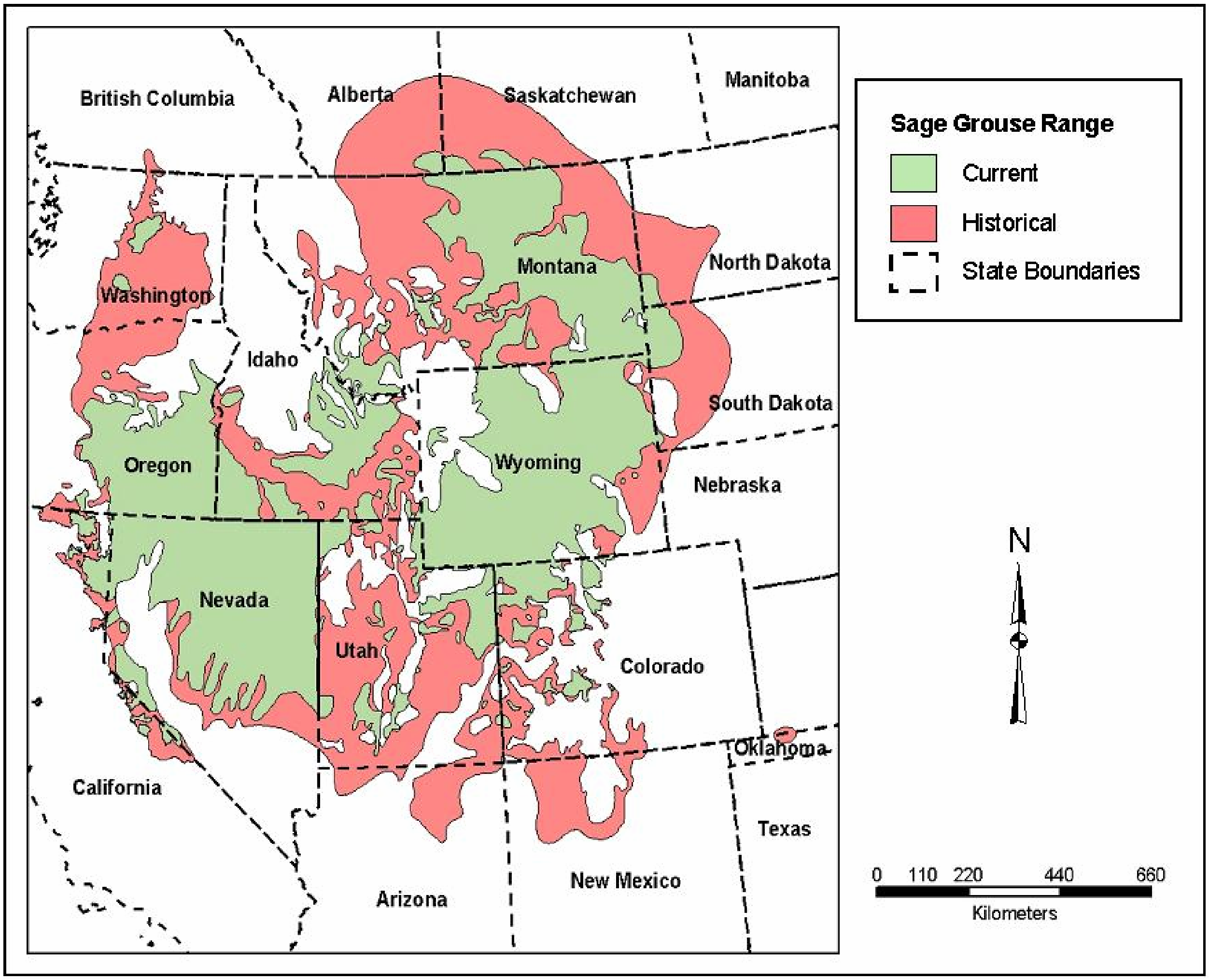

Figure 2. Historical and current range of sage grouse in western North America (from Schroeder 2002). The ranges depicted include those of both Greater sage-grouse and Gunnison sage-grouse.

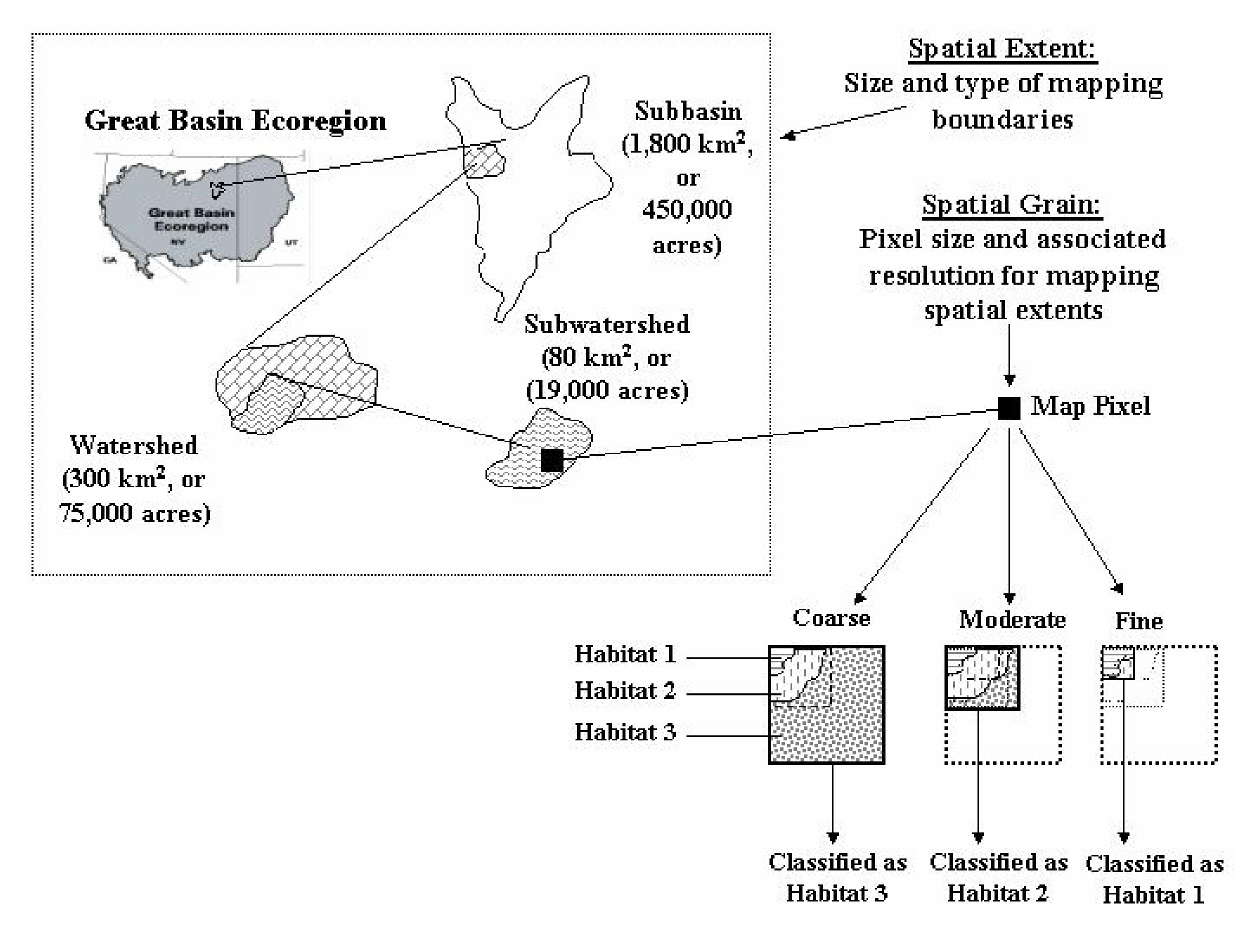

Figure 3. Illustration of the concepts of spatial extent and spatial grain, which compose the spatial scale of a regional assessment. Spatial extent refers to the size and type of boundaries selected; in this case, hydrologic extents are used. Spatial grain refers to the size and type of mapping unit used to estimate vegetation or other environmental features. In this case, pixels are used, ranging from coarse to fine grains, which in turn affects the resolution of associated habitat estimates. See text for additional discussion of these concepts.

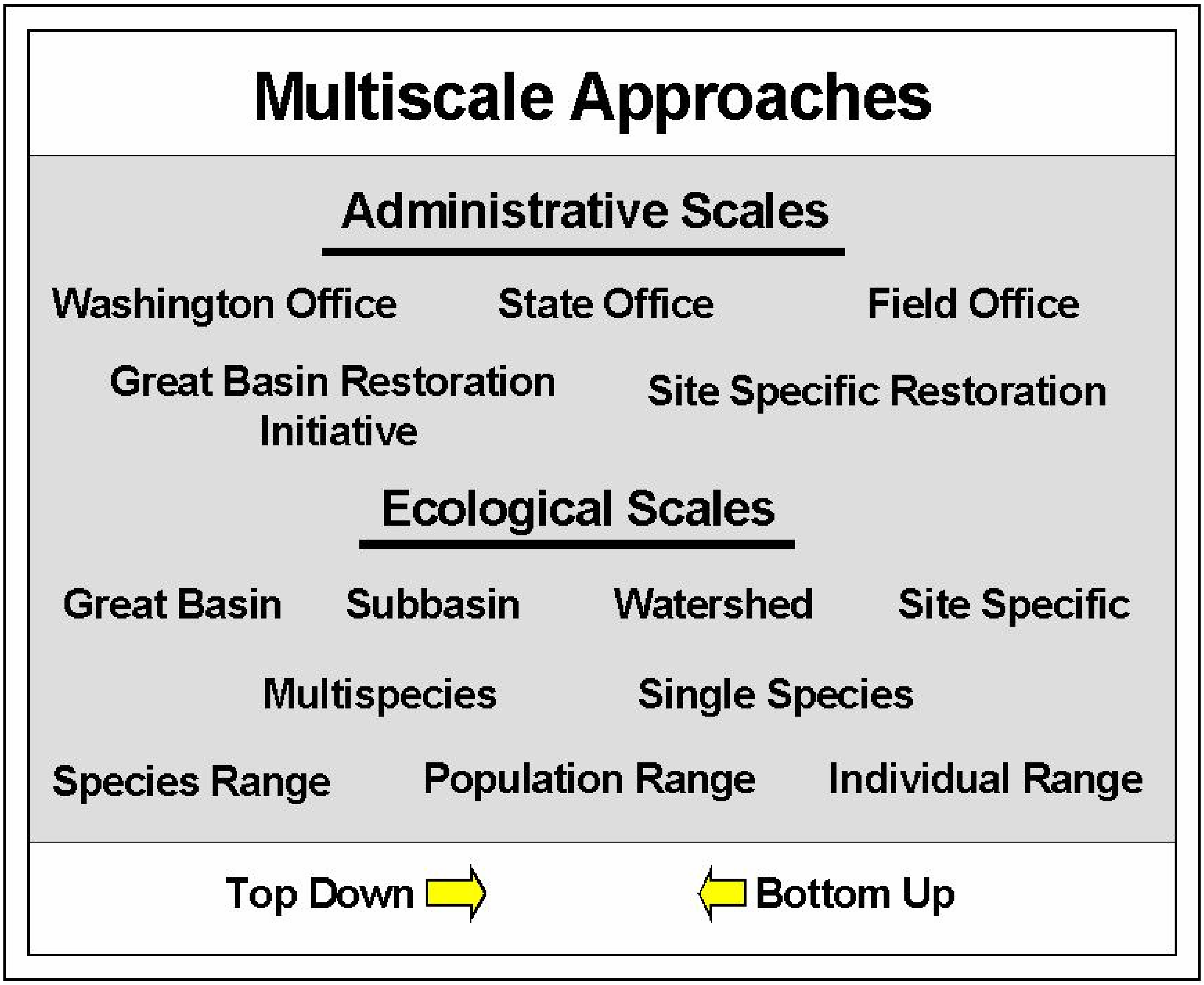

Figure 4. Illustration of "top-down" versus "bottom-up" processes in relation to ecological and administrative scales of spatial analysis and land use planning.

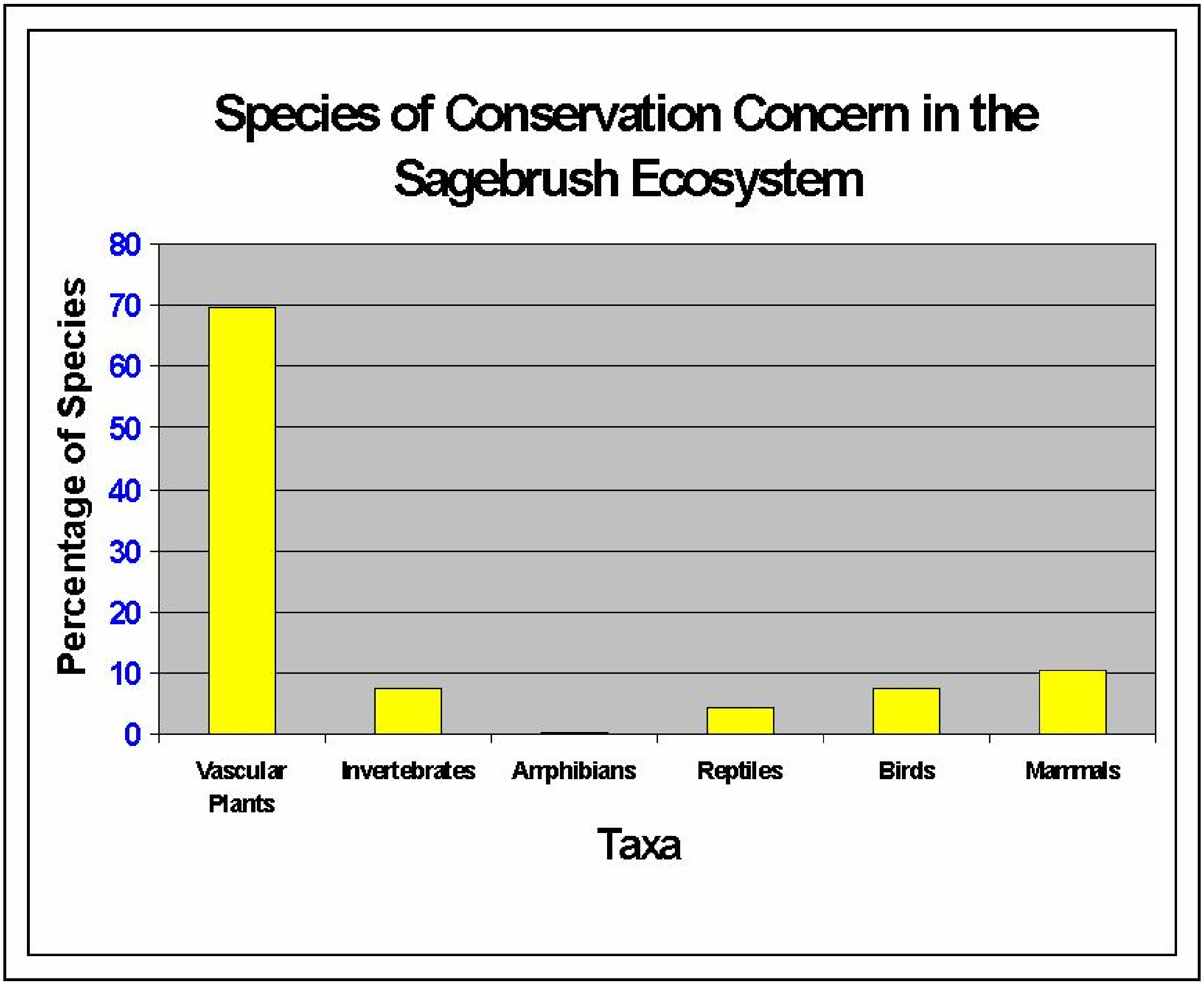

Figure 5. Percentage of species of conservation concern associated with sagebrush habitats in the sagebrush ecosystem, summarized by taxonomic groups. Species of conservation concern are defined as species with rare or declining habitats or populations.

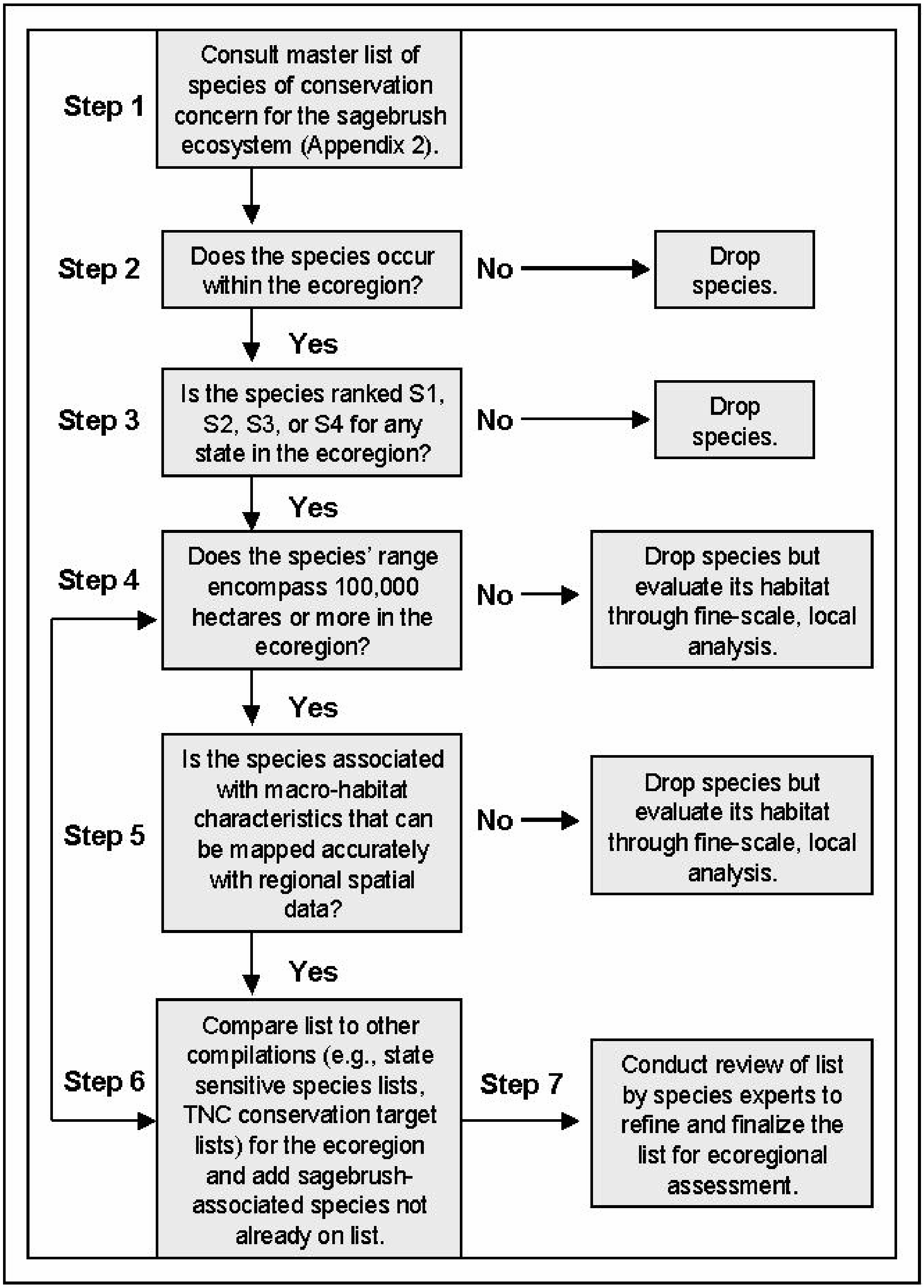

Figure 6. Criteria and decision diagram for selecting species of conservation concern for ecoregion assessment of habitats.

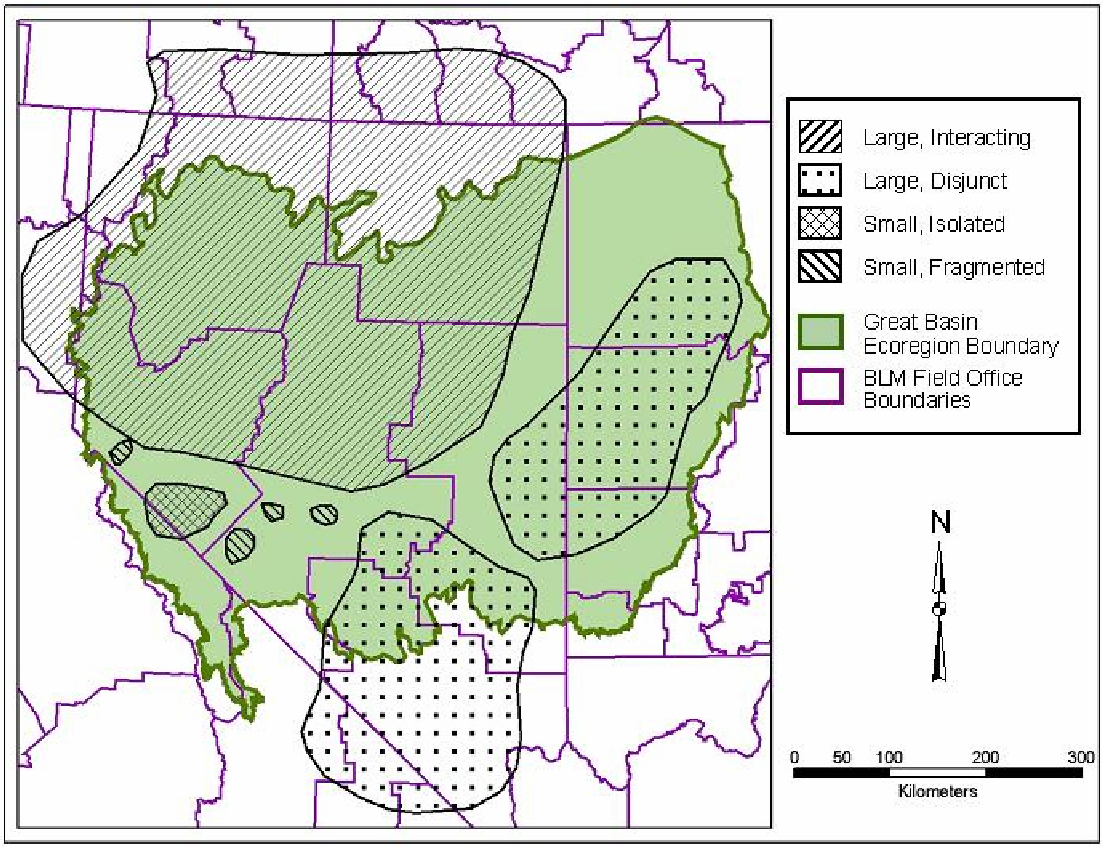

Figure 7. Examples of four species' ranges: (1) large, interacting; (2) large, disjunct; (3) small, isolated; and (4) small, fragmented. In these examples and in our procedures, the range of a species is defined as the outer boundaries of a species' occurrence, or a polygon of occurrence, for a given population. Importantly, this definition does not address the evenness of population distribution within a polygon. Ranges identified as large, interacting (one large population within one large polygon) and large, disjunct (two large but spatially separated populations) would be suitable for regional assessment. Ranges identified as small, isolated (one restricted population) or small, fragmented (two or more restricted populations) would not be suitable for regional assessment if such ranges are <100,000 hectares. Once the species' range is mapped, all source habitats for the species within its range are evaluated as part of the regional assessment.

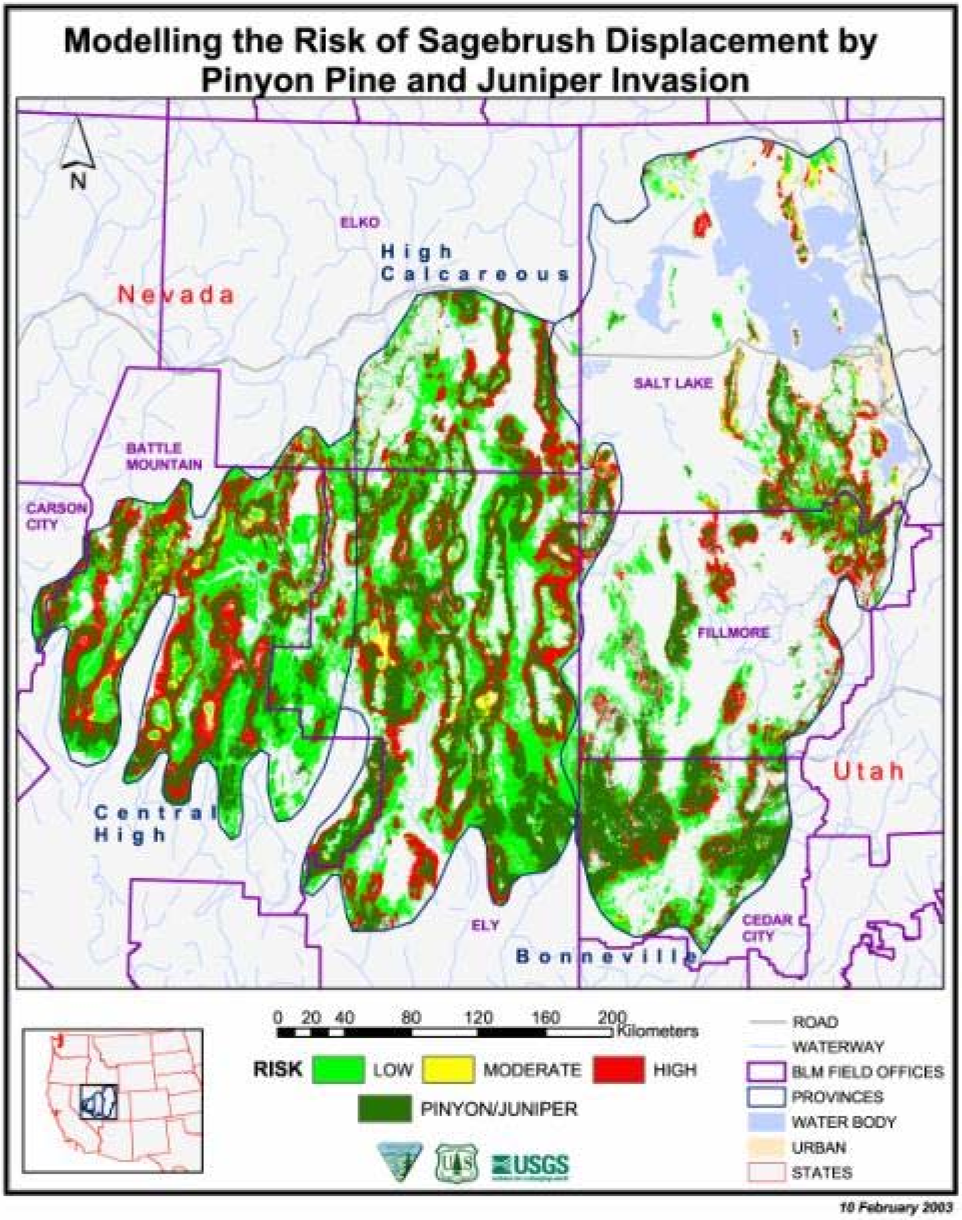

Figure 8. Case example of threat posed by pinyon-juniper displacement of sagebrush in the Great Basin Ecoregion during the next 30 years (from Wisdom et al. 2003). Categories of risk of displacement are defined as low, moderate, and high, as defined and described in our prototype assessment (Wisdom et al. 2003). In this example, levels of risk of sagebrush displacement are mapped in relation to all sagebrush cover types that currently exist in three ecological provinces, without explicit association to any species' habitats. Results would vary by species in relation to differences in species' ranges and habitat associations.

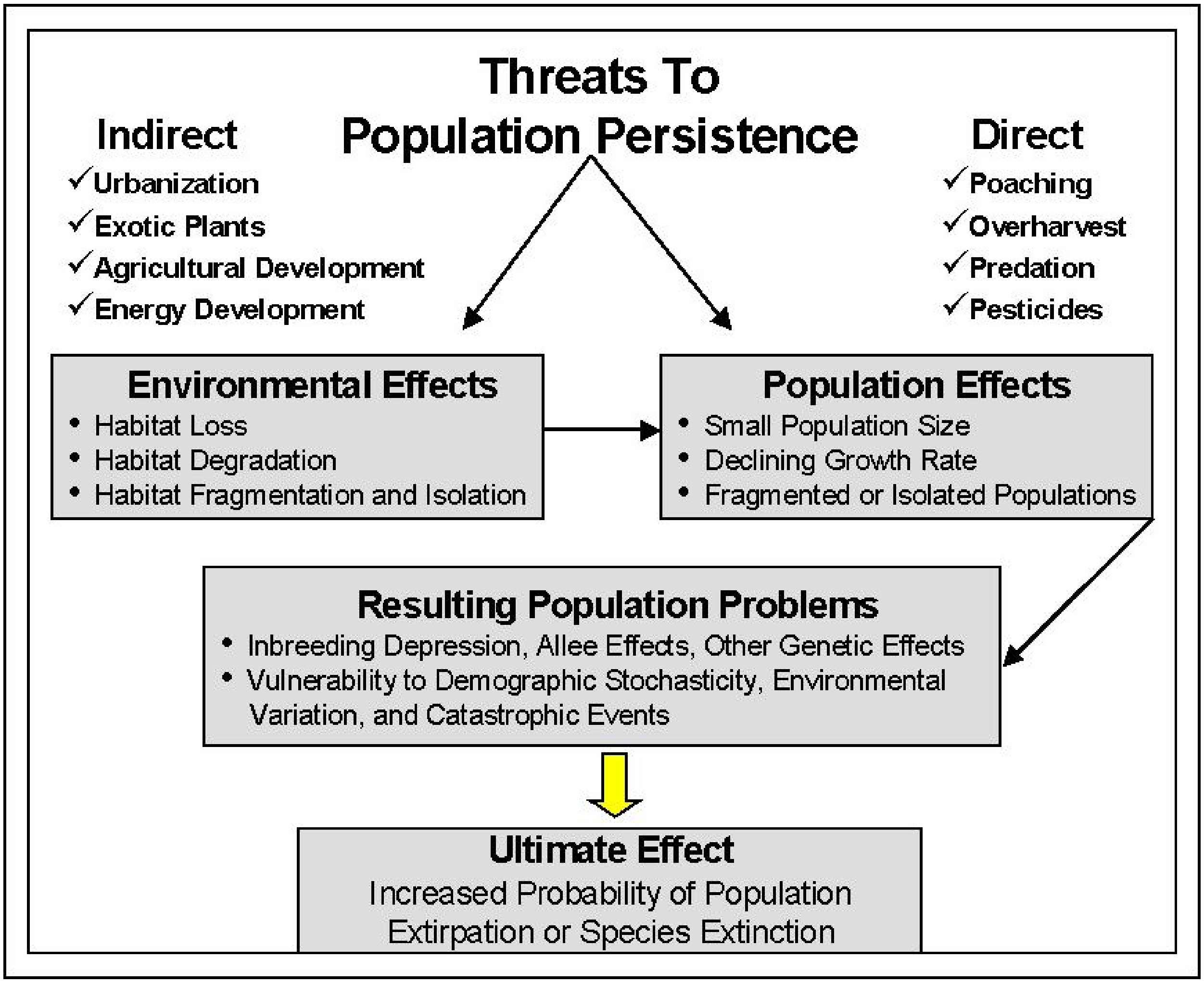

Figure 9. Conceptual diagram of the direct and indirect effects of management activities on population persistence of species of conservation concern.

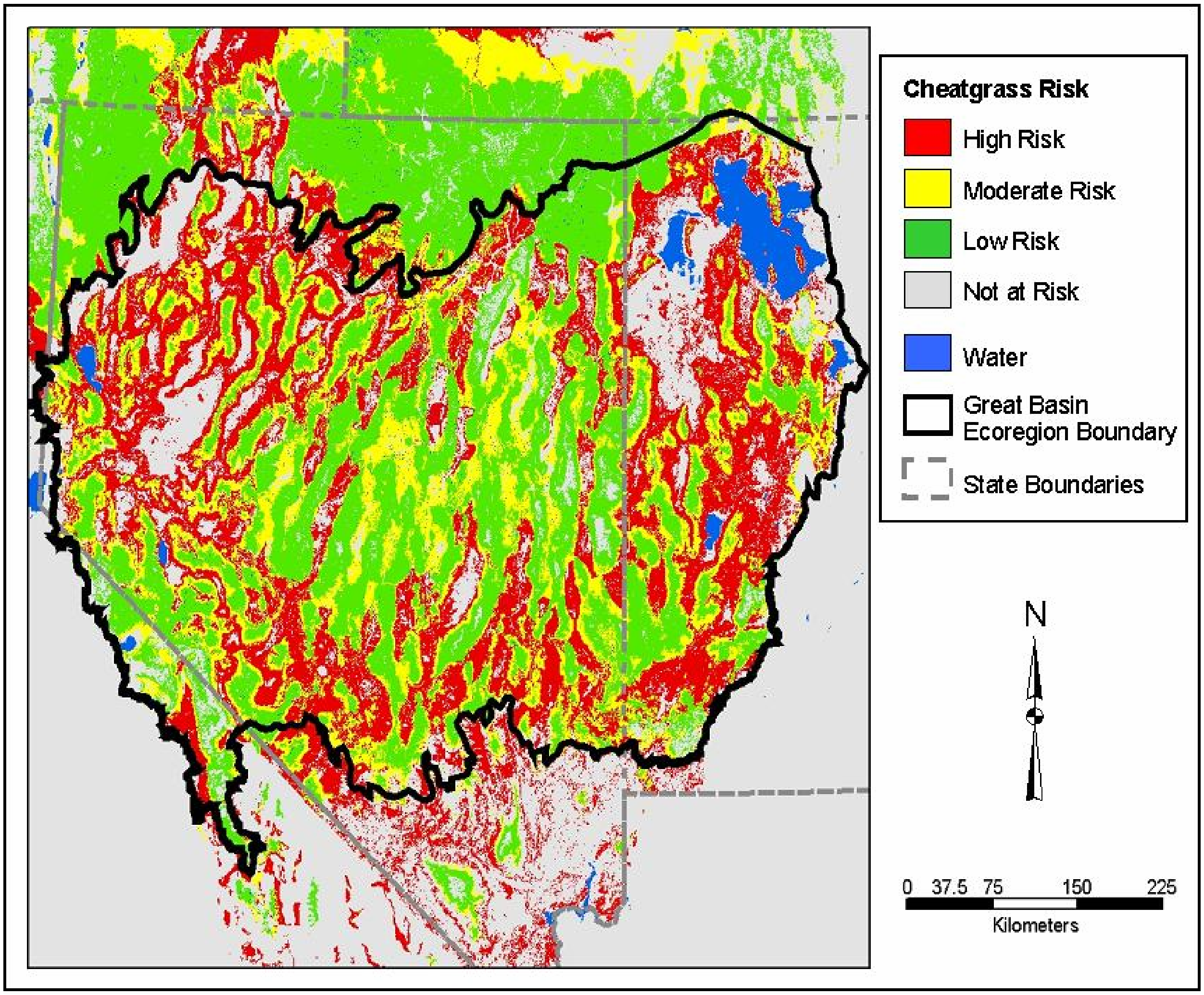

Figure 10. Case example of threat posed by cheatgrass displacement of sagebrush and other susceptible cover types in the Great Basin Ecoregion during the next 30 years (from Wisdom et al. 2003). Categories of risk of cheatgrass displacement are defined as low, moderate, and high, as described in our prototype assessment (Wisdom et al. 2003). In this example, levels of risk of displacement of sagebrush and other susceptible cover types are not mapped explicitly in relation to any species' habitats. Instead, risk to all susceptible cover types is shown. Results would vary by species of concern in relation to each species' range and habitat associations.

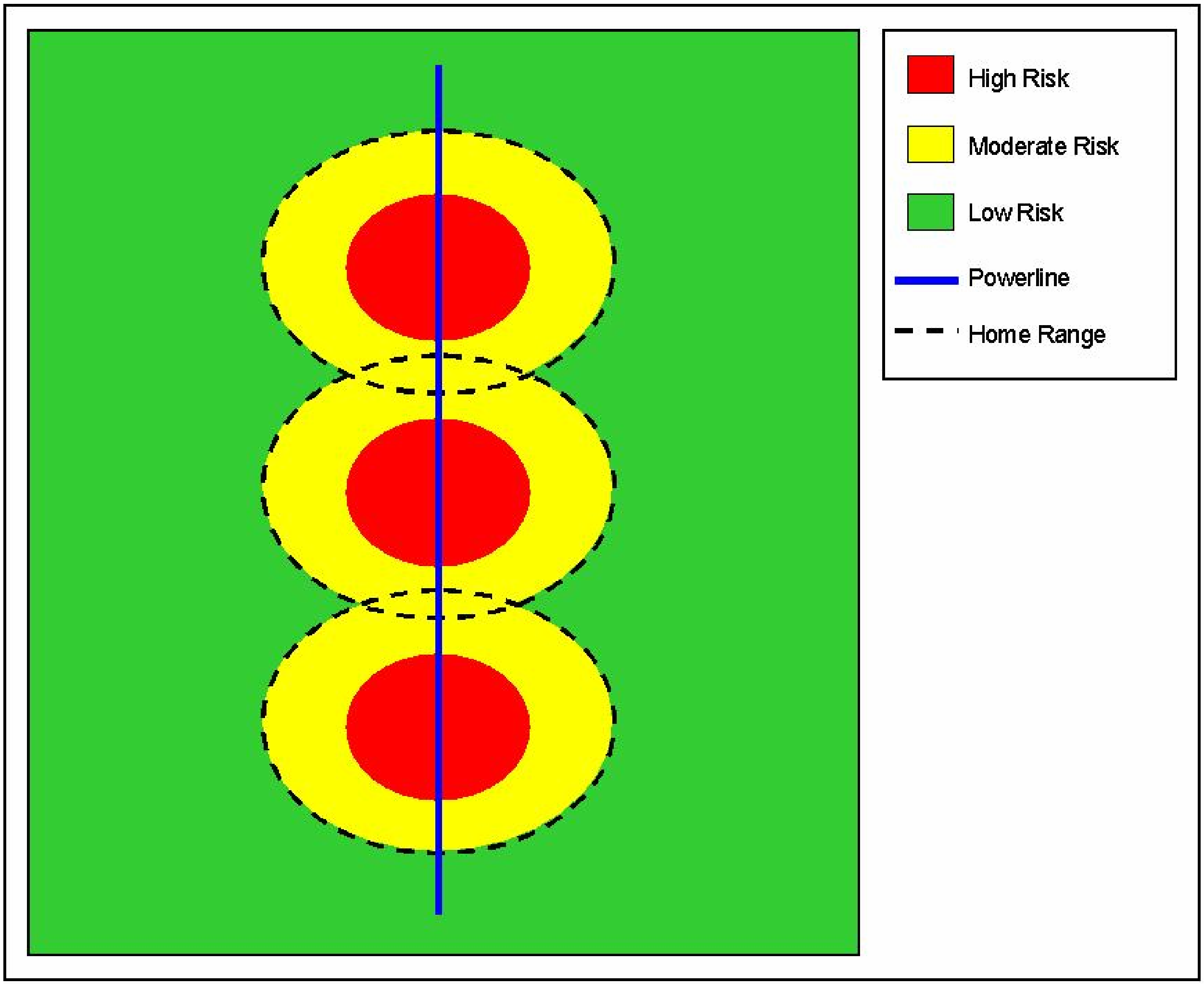

Figure 11. Conceptual example of threat posed by existing or proposed powerlines in the sagebrush ecosystem, based on use of powerlines by avian predators of species of concern. Levels of risk are based on the generalized size of the home range of large, avian predators (shown as oblong circles) that would benefit from the presence of powerline structures as nesting platforms and hunting perches, which, in turn, would result in higher predation rates on species of concern that are prey. In this example, habitat within the central core of the avian predator's home range, when the center is placed along the powerline, is defined as high risk of being unsuitable, owing to high rates of avian predation on species of concern. Habitats outside the central core, but inside the home range, are characterized as moderate risk. Habitats outside the home range are defined as low risk.

Figure 12. Conceptual example of threat posed by energy development in the sagebrush ecosystem. Levels of risk are based on the distance of each pixel of habitat to the nearest development, defined as the energy site itself and the associated network of roads. Pixels of habitat within the development boundaries are classified as being at high risk of loss or degradation to the point of being unsuitable, owing to habitat conversion to energy sites and roads, to habitat fragmentation, to facilitation of exotic plant invasions, and other human-associated factors of disturbance described by Braun (2002), Noon (2002), and Noss and Wuerthner (2002). In this conceptual example, pixels outside the development boundaries, but within specified distances from the boundaries are defined as moderate or low risk of being lost or degraded to the point of being unsuitable. These distance estimates would vary by the species being evaluated, according to differences in home range, dispersal characteristics, and response to habitat fragmentation and disturbance.

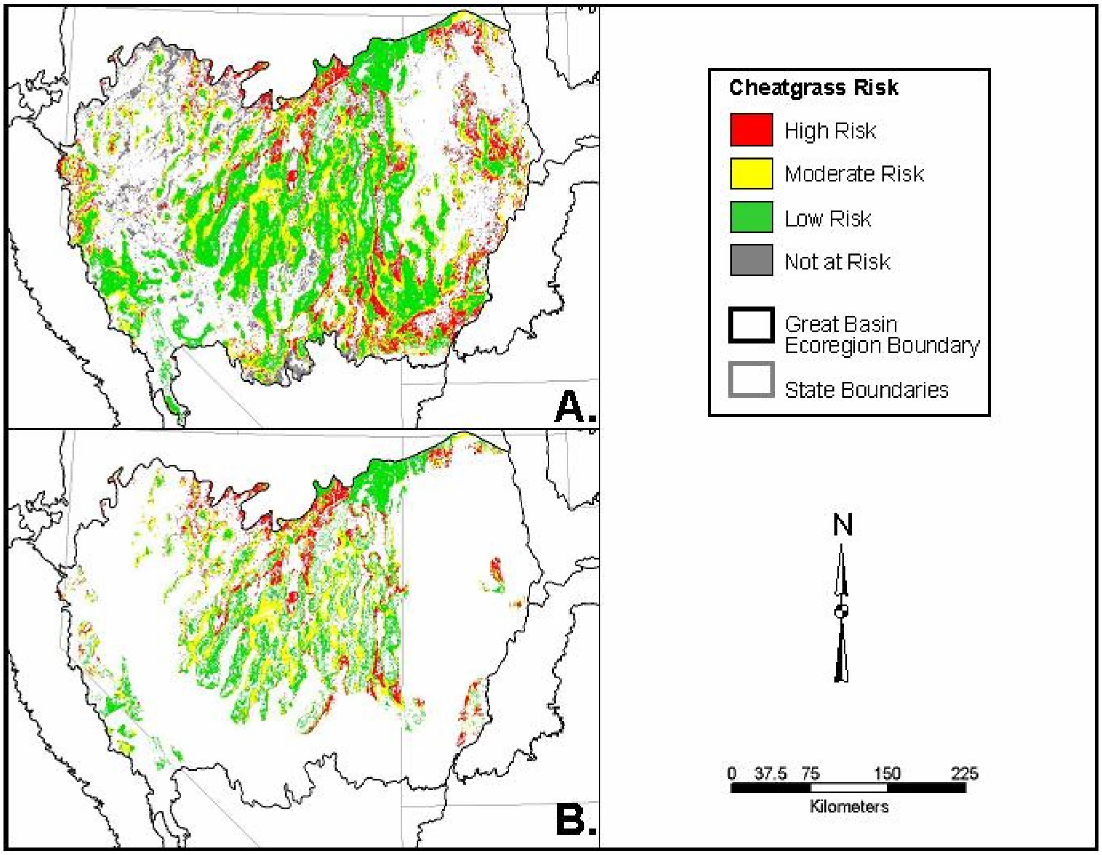

Figure 13. Habitat abundance and risk of habitat loss from cheatgrass, for sagebrush vole (A) and Greater sage-grouse (B), in the Great Basin Ecoregion (Wisdom et al. 2003).

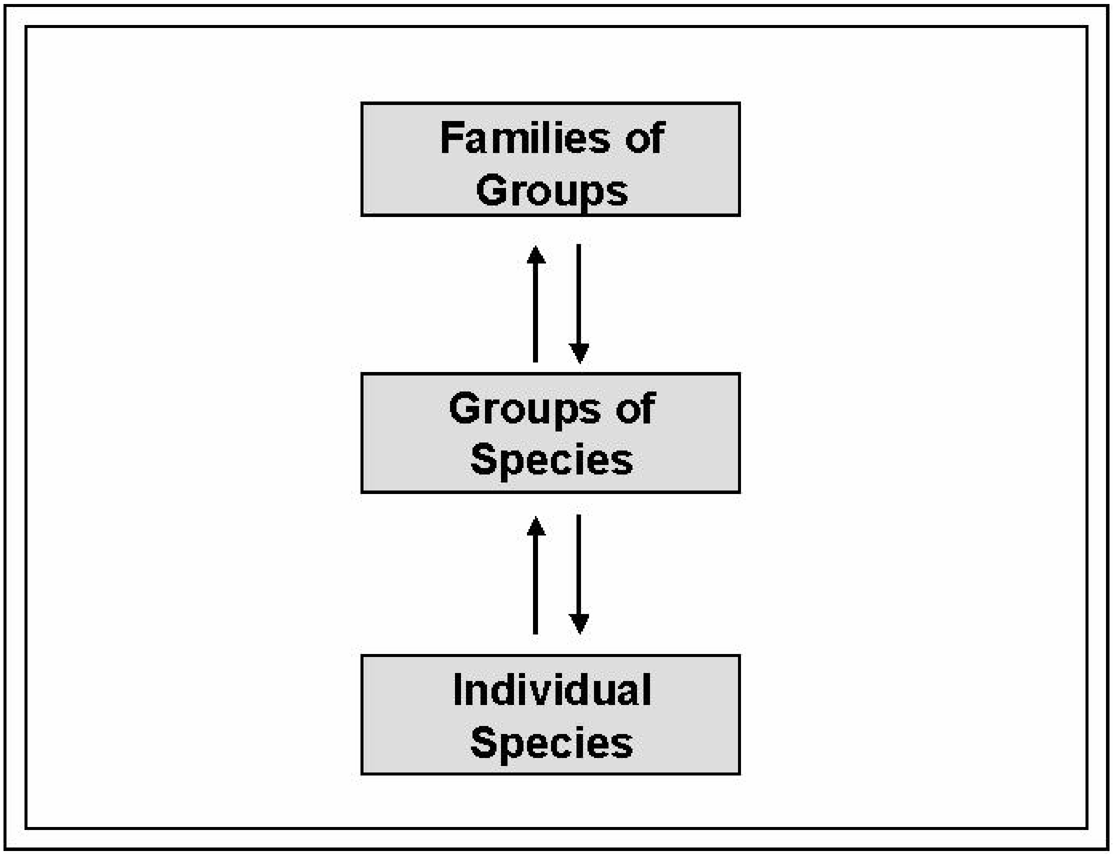

Figure 14. Conceptual framework of using species groups to assess and manage species of conservation concern in an ecoregion (from Wisdom et al. 2000). In this process, information on all individual species of concern is retained and considered for management, but the information is summarized at varying levels (groups of species and "families of groups") for efficient consideration in management. However, any management direction set for groups of species can be checked as to its effect on individual species. Moreover, the needs of individual species, particularly those whose needs are not represented well by groups of species, can also be addressed in management.

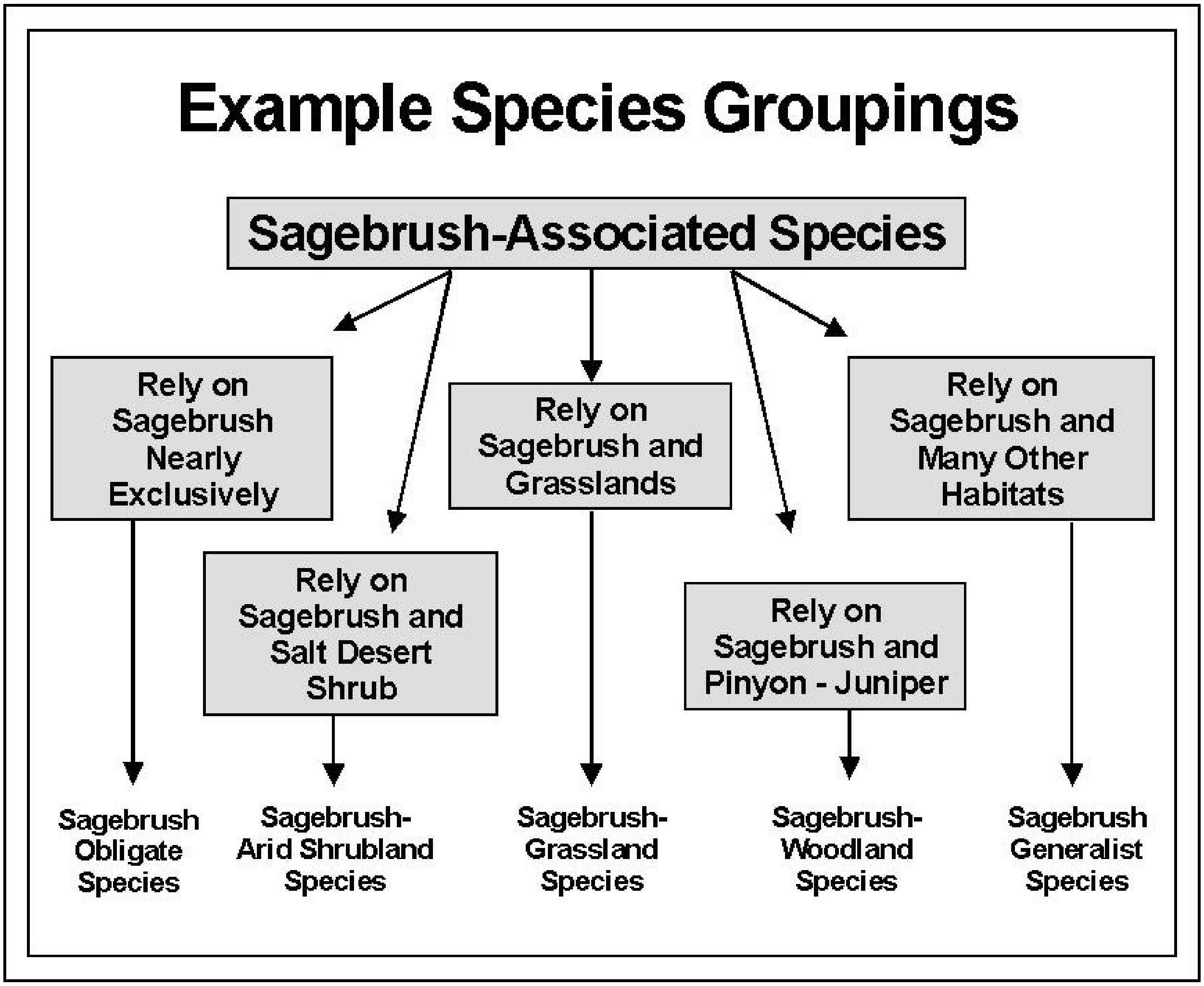

Figure 15. A conceptual approach for grouping species for assessment at the scale of an ecoregion, based on varying combinations of each species' association with sagebrush in relation to other habitats.

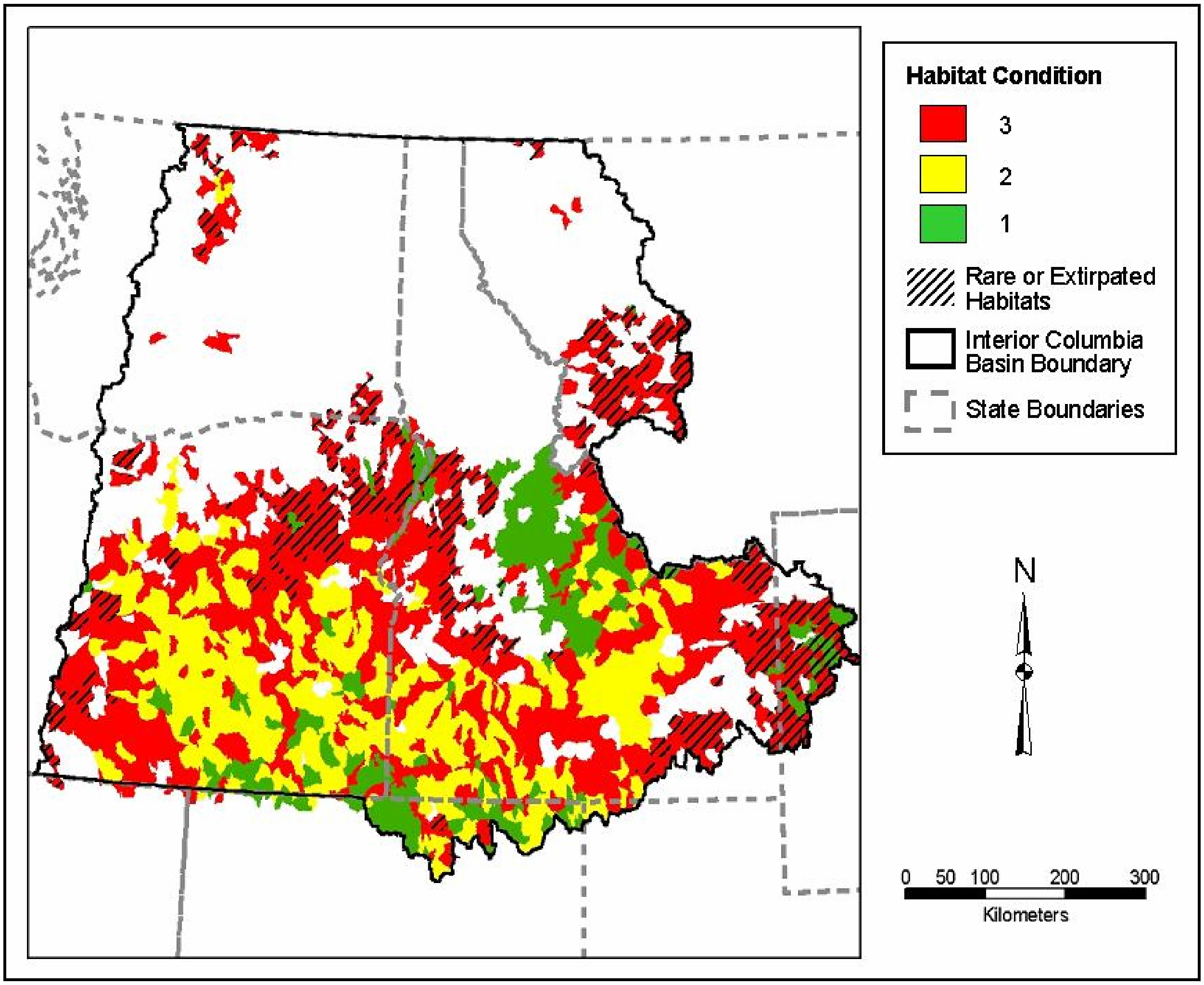

Figure 16. Habitat network characterized for sagebrush-associated species in the Interior Columbia Basin (from Wisdom et al. 2002*c*). Watersheds in Condition 1 contain habitats that have undergone little change since the historical period. Watersheds in Condition 2 are characterized by habitats of moderate resiliency and quality. Watersheds in Condition 3 contain habitats of relatively low abundance or low resiliency and quality. Watersheds with extirpated habitats are defined as those containing habitat historically but no habitat currently. Watersheds with rare habitats are defined as those containing >0% but <1% of habitat area.

APPENDIX 1: GLOSSARY OF TERMS

Abundance—The total number of organisms in an area; contrast with density (Lancia et al. 1994).

Accuracy—(1) The closeness of computations or estimates to the exact or true value (Marriott 1990:2); (2) the magnitude of systematic errors or degree of bias associated with an estimation procedure which affects how well the estimated value represents the true value (not synonymous with precision) (Ministry of Environment, Lands, and Parks 1998).

Accuracy, classification—Upon completion of a landcover map it is vital to check the accuracy of the technique in assigning items to a particular class, which is often done using a confusion matrix. This is a table of actual and predicted classes, which plots the two against each other to allow easy comparison (Association for Geographic Information 1996).

Accuracy, spatial—The degree to which a position (on a map) is measured or depicted, relative to its correct value (on the ground) established by a more accurate process (adapted from Association for Geographic Information 1996).

Alliance—"The alliance is a physiognomically uniform group of plant associations sharing one or more dominant or diagnostic species, which as a rule are found in the uppermost strata of the vegetation…dominant species are often emphasized in the absence of detailed floristic information (such as quantitative plot data), whereas diagnostic species (including characteristic species, dominant differential, and other species groupings based on constancy) are used where detailed floristic data are available" (Reid et al. 2002).

Association—A group of species living in the same place at the same time (Ricklefs 1979:865).

Bias—The mean difference from the real value of a measure by estimators of that measure; a result of systematic error in data collection (Ministry of Environment, Lands, and Parks 1998).

Bottom-up Processes—Ecological patterns and mechanisms unique to local areas and conditions (Peterson and Parker 1998).

Change detection—The sensing of environmental changes that uses two or more remotely sensed images covering the same geographic area acquired over two or more different periods of time (Canada Centre for Remote Sensing 2000).

Classification—In the process of classification, an attempt is made to group data into classes according to some common characteristics thereby reducing the number of data elements. Classification tends to be based upon the attributes or characteristics of data rather than their geometry. In digital image processing, images are usually classified according to the spectral properties of the pixels composing the image. In spatial analysis, a map can be classified according to any attribute value (e.g., soil types, population density). The result of performing classification is a thematic derived map (Association for Geographic Information 1996).

Cluster analysis (hierarchical)—A procedure that places objects into groups or clusters suggested by the data, so that objects in a given cluster tend to be similar to one another, and objects from different clusters tend to be dissimilar. In hierarchical cluster analysis, clusters are arranged such that a cluster may be contained entirely within another cluster; however, no other type of overlap between clusters is allowed (Wisdom et al. 2000).

Coarse-filter—The occurrence, abundance, and location of ecological communities are used to predict individual or multi-species species response. The implication is that if the full range of ecological communities is present in adequate amounts, conservation of species is assured (also see Fine-filter; Roloff et al. 2001).

Condition—Describing the ability of a community or ecosystem to function naturally. Good condition refers to a strong ability for natural function, whereas poor condition refers to dysfunction or unnatural functions. Causes of poor condition include (but are not limited to) invasion by non-native species, losses of native species, and changes in the proportions of native species (Nevada Natural Heritage Program 2002).

Connectivity— The degree to which habitats for a species are continuous or interrupted across a spatial extent, where habitats defined as continuous are within a prescribed distance over which a species can successfully conduct key activities (e.g., effective dispersal distances of seeds or juveniles, mean distances moved for foraging, nesting, and brood-rearing), and habitats defined as interrupted are outside the prescribed distance.

Cover type—A vegetation classification depicting genera, species, group of species, or life form of tree, shrub, grass, or sedge, or a dominant physical feature (for example water or rock) or land use (for example urban or road). When a genus or species name is given to the cover type at a broad scale, it is typically representative of a complex of species or genera with similar characteristics (Wisdom et al. 2000). Cover types used in remote-sensed data typically represent the species of vegetation that dominate the overstory of a given pixel or polygon.

Disjunct—Organisms that are separated into distinct spatial segments, with each segment constituting an interacting population, with little or no interaction between segments.

Dispersal—The movement of organisms away from the place of birth or from centers of population density (Ricklefs 1979:868).

Dispersal, breeding—Movement of individuals that have reproduced between successive breeding sites (Greenwood 1980:1141).

Disturbance regime—Natural pattern of periodic disturbances, such as fire or flood, followed by a period of recovery from the disturbance (e.g., regrowth of a forest after a fire) (Wisdom et al. 2000).

Ecological Province—Large areas defined by similarity in abiotic and biotic conditions, similar to an ecoregion, but typically smaller. Ecological provinces generally encompass millions of hectares, with several provinces fitting within an ecoregion. See West et al. (1998) and Miller et al. (1999) for ecological provinces that occur within or overlap the Great Basin Ecoregion.

Ecological risk assessment—A process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors. Ecological risk assessment may evaluate one or many stressors and ecological components (Risk Assessment Forum 1992:2).

Ecoregion—A large area of similar climate where similar ecosystems occur on similar sites (those having the same landform, slope, parent material, and drainage characteristics); for example, beach ridges throughout the Subartic ecoregion usually support a dense growth of black spruce or jack pine (Bailey 2002). Ecoregions in the United States have been defined and mapped by The Nature Conservancy (Groves et al. 2000; http://gis.tnc.org/data/MapbookWebsite/map_page.php?map_id=9). Bailey (1995) and Omernik (1987) present slightly different ecoregion delineations for North America.

Ecosystem—The totality of components of all kinds that make up a particular environment; the complex of biotic community and its abiotic, physical environment (McNeely et al. 1990:153).

Ecosystem management (ecosystem-based strategy)—". . . management driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem composition, structure, and function" (Ecological Society of America 1996).

Endangered species—Species defined under the Endangered Species Act as those in danger of becoming extinct throughout all or a significant portion of their range because their habitat is threatened with destruction, drastic modification, or severe curtailment, or because of overexploitation, disease, predation, or other factors (Wisdom et al. 2000, Edge 2002)

Endangered Species Act-1973—Act of U.S. Congress, amended several times subsequently, that elevates the goal of conservation of listed species above virtually all other considerations. The Act provides for identifying (listing) endangered and threatened species or distinct segments of species, monitoring candidate species, designating critical habitat, preparing recovery plans, consulting by federal agencies to ensure that their actions do not jeopardize the continued existence of listed species or adversely modify critical habitats, restricting importation and trade in endangered species or products made from them, and restricting the taking of endangered fish and wildlife. The act also provides for cooperation between the federal government and the states (adapted from Rohlf 1989:25-35).

Endemic—Plants or animals that occur naturally in a certain region and whose distribution is limited to a particular locality (Wisdom et al. 2000).

Environment—All the factors that might affect organisms, including abiotic influences (e.g., soils, air temperature, rainfall) and biotic influences (other organisms) (Nevada Natural Heritage Program 2002).

Exotic—Not native; a species that has been introduced into an area, and is thus outside of its native range.

Extent, spatial—(1) The area over which observations are made (e.g., the boundaries of a study area, a species range) (Milne 1997); (2) The geographic extent of a geographic data set specified by the minimum bounding rectangle (i.e., xmin, ymin and xmax, ymax) (Association for Geographic Information 1999).

Extinction—(1) The complete disappearance of a species from the earth (Miller 1991:A5); (2) the total disappearance of a species from an island (this does not preclude later recolonization) (see also Extirpation) (MacArthur and Wilson 1967:187).

Extirpation—The loss or removal of a species from 1 or more specific areas but not from all areas (Johnson and O'Neil 2001).

Fine scale—An area mapped or measured at high resolution, which typically requires a small pixel or polygon size used as mapping units, or which typically require field measurements taken at small plots.

Fine-filter—An assessment of the response of a single species to environmental changes (Roloff et al. 2001).

Flagship species—Species that are used to attract the attention of the public. Such species are generally popular with the public and have experienced habitat or population loss, or both (Caro and O'Doherty 1999).

Focal species—(1) Surrogate measures used in the evaluation of ecological sustainability, including species and ecosystem diversity. 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 (USDA Forest Service 2000); (2) a suite of species whose requirements for persistence define the attributes that must be present if a landscape is to meet the requirements for all species that occur there (Lambeck 1997).

Fragmentation—The breaking up of an organism's habitat into discontinuous portions, particularly for organisms that have difficulty moving from one of those areas to another. Fragmentation can be caused by removal of vegetation over large areas for human development, or even by small roads breaking up the habitat of (for example) amphibians that are resistant to crossing roads or are frequently killed when crossing roads. Power lines can fragment sage-grouse habitat by providing convenient perches for avian predators (Nevada Natural Heritage Program 2002).

Fragmented—The degree to which habitats are subdivided into smaller and more isolated patches, where subdivisions are measured by the relation between the length of habitat edge and the size of habitat patches. Many variations of this basic definition are described by McGarigal and Marks (1995).

Grain—The smallest resolvable unit of study (e.g., 1x1-meter quadrant); generally determines the lower limit of what can be studied (Morrison and Hall 2001).

Grain, spatial—Mapping resolution at which spatial patterns are measured (Wisdom et al. 2000)

Group (of species)—A collection of species in our analysis with similarities in source habitats; groups may be delineated by using hierarchical cluster analysis, and subsequently refined after consultation with species experts (Wisdom et al. 2000).

Habitat fragmentation—The alteration of a large habitat patch to create isolated or tenuously connected patches of the original habitat that are interspersed with an extensive mosaic of other habitat types (Wiens 1989b:201).

Habitat Network—A mapped set of interrelated habitats across a large spatial extent that are defined by different environmental characteristics important to a species or set of species. For example, Wisdom et al. (2002*c*) mapped 3 habitat conditions by watershed within the Interior Columbia Basin, with the 3 conditions making up a network for groups of species of concern.

Habitat patches—Areas distinguished from their surroundings by environmental discontinuities. Patches are organism-defined (i.e., the edges or discontinuities have biological significance to an organism; adapted from Wiens 1976).

Habitat quality—The ability of an area to provide conditions appropriate for individual and population persistence (Hall et al. 1997).

Home range—The area traversed by an animal during its activities during a specified period of time (Morrison and Hall 2001).

Hydrologic unit code (HUC)—A nested delineation of watersheds of similar size and scale, four levels of which were developed by the U.S. Geological Survey. The broadest level is the region, 2nd is the subregion, 3rd is the basin, 4th is the subbasin, 5th is the watershed, and 6th is the subwatershed (Wisdom et al. 2000).

Index—(1) The proportional relation of counts of objects or signs associated with a given species to counts of that species on a given area; (2) counts of individuals (e.g., at a feeding station) reflecting changes in relative abundance on a specified or local area (Ralph 1981:578).

Invasive—A species capable of asserting itself in communities where it did not naturally occur. Usually a species not native to the area (Nevada Natural Heritage Program 2002).

Keystone species—A species whose abundance dramatically alters the structure and dynamics of ecological systems (Brown and Heske 1990).

Landscape—(1) The landforms of a region in the aggregate; the land surface and its associated habitats at scales of hectares to many square kilometers (for most vertebrates) (Turner 1989); (2)

a spatially heterogeneous area; mosaic of habitat types occupying a spatial scale intermediate between an organism's normal home-range size and its regional distribution (Dunning et al. 1992).

Life history—A system of interrelated adaptive traits forming a set of reproductive tactics (Stearns 1976).

Local endemics—Plants or animals that occur naturally in a certain region and whose distribution is limited to a particular locality (Wisdom et al. 2000).

Macro-habitats—Characteristics of habitat that can be estimated accurately with pixel sizes typically used for regional assessments, such as a 90- x 90-m pixel size or larger.

Management indicator species—Those species whose response to environmental conditions is assumed to index like responses of a larger number of species and whose habitats can therefore be managed to benefit a larger set of species; more broadly, species for which a set of management guidelines has been written (Wisdom et al. 2000).

Map unit—A collection of features defined and named the same in terms of their landscape characteristics. Each map unit differs in some respect from all others within a geographic extent (USDA Soil Survey Division Staff 1993).

Measurement bias—A systematic under- or overestimation of the true values due to a difference between the actual measurement and what one intends to measure (adapted from Gilbert 1987:11).

Micro-habitats—Characteristics of habitat that cannot be estimated accurately with pixel sizes typically used for regional assessments, such as a 90- x 90-m pixel size or larger.

Minimum viable population—A threshold number of individuals that will ensure (with some probability level) that a population will persist in a viable state for a given interval of time (adapted from Gilpin and Soule 1986:19).

Model—Any formal representation of the real world. A model may be conceptual, diagrammatic, mathematical, or computational (Morrison and Hall 2001).

Monitoring—(1) Measuring population trends using any of various counting methods (Ralph et al. 1993); (2) A process of collecting information to evaluate whether or not objectives of a project are being realized. In land management, monitoring is used to describe continuous or regular measurement of conditions that can be used to validate assumptions, alter decisions, change implementation, or maintain current management direction (Wisdom et al. 2000).

Moving Window Analysis – A spatial assessment of environmental conditions that is based on an area of fixed size, or "window," with the window incrementally moved across a map and new estimates made of conditions after each incremental move. Results of these estimates are displayed on a new map, and can vary substantially based on the size of the window and the distance of the incremental movement.

Native—Indigenous; living naturally within a given area (Wisdom et al. 2000).

Niche—Multidimensional utilization distribution, giving a population's use of resources ordered along resource axes (Schoener 1989:79).

Patch— A distinct area, such as a polygon or pixel, characterized by a specific habitat type, cover type, or other homogeneous environmental condition.

Patch dynamics—The change in the distribution of habitat patches in a landscape generated by patterns of disturbance and subsequent patterns of vegetative succession (Pickett and Thompson 1978).

Patch Size—The area (hectares) constituting a separate piece of habitat for a species, where the piece is defined as the pixels of habitat adjacent to one another (pixels touching one another on any side or corner), or the piece is defined by some alternative rule set designed specifically for a species.

Pattern—A statement about relationships among several observations of nature. It connotes a particular configuration of properties of the system under investigation (Wiens 1989*a*:18).

Pixel—A contraction of the words "picture element." A data element of a raster matrix or grid map; equivalent to a cell; square or hexagonal in shape, and which represents the smallest mapping unit used to estimate environmental conditions (adapted from Wisdom et al. 2000).

Pixel, size—Size of a grid cell; usually expressed as the length of 1 side in meters, such as 90- x 90-m cell used for regional assessment (Wisdom et al. 2000).

Population—(1) A biologically, geographically, or politically defined group of animals composed of all of the individuals of a species in a particular area (Edge 2002); (2) a group of coexisting (conspecific) individuals that interbreed if they are sexually reproductive (Sinclair 1989).

Population dynamics—The study of changes in the number and composition of individuals in a population, and the factors that influence those changes (Edge 2002).

Population sink—Areas in which mortality rates are such that populations decline in these areas, rather than increase or remain static (Wisdom et al. 2000).

Population viability—The likelihood of continued existence of a well-distributed population or species for a specified time period. For most scientific analyses, the time period is 100 years. For example, high viability is a high likelihood of continued existence of well-distributed populations for a long time period (a century or longer) (Wisdom et al. 2000).

Polygon—Boundaries that enclose an area of interest. A polygon can be of any size and shape, and often are used to define different habitat or cover types for regional assessments.

Population viability analysis (PVA)—Analysis that estimates minimum viable populations (syn. population vulnerability analysis) (Gilpin and Soule 1986:19).

Precision—The closeness to each other of repeated measurements of the same quantity; not synonymous with accuracy (Zar 1984:4).

Regional Assessment—A spatial or temporal analysis of environmental conditions for species of conservation concern that is conducted for areas typically encompassing ≥100,000 hectares (≥250,000 acres), and often encompassing areas >1 million hectares (>2.5 million acres).

Regional Scales—Spatial extents that encompass large areas, such as ecoregion, ecological province, subbasin, or watershed, and which are typically used to evaluate top-down processes.

Resolution—A measure of the ability to detect quantities. High resolution implies a high degree of discrimination but has no implication as to accuracy (Association for Geographic Information 1996).

Resolution, spatial—(1) The smallest area at which we portray discontinuities in biotic and abiotic factors in map form (Hargis et al. 1997); (2) spatial resolution refers to the area on the ground that an imaging system, such as a satellite sensor, can distinguish, such as a 90- x 90-m pixel (Association for Geographic Information 1996).

Restoration—The act returning a resource to some prior condition by re-establishing ecological processes and functions (Edge 2002).

Riparian—A term that refers to the habitat adjacent to streams, lakes, ponds, and wetlands that is influenced by the presence of water (Edge 2002).

Scale—The resolution at which patterns are measured, perceived, or represented. Scale can be broken into several components, including grain and extent (Morrison and Hall 2001).

Scale, temporal—A measure of time, usually in years or groups of years (Wisdom et al. 2000).

Sensitive species—A species not formally listed as threatened or endangered under the Endangered Species Act, but considered to be at risk, as evidenced by a significant current or predicted downward trend in population numbers or density, or a significant current or predicted downward trend in habitat capability that would reduce a species' existing distribution (Johnson and O'Neil 2001).

Shrubsteppe—Habitats characterized in western North America by woody, mid-height shrubs and perennial bunchgrasses; typically arid, with annual precipitation averaging <36 cm (14 inches) over much of the region (Wisdom et al. 2000).

Sink environment—The composite of all environmental conditions occurring in a specified area and time that result in negative population growth (Wisdom et al. 2000).

Sink habitat—A habitat in which reproduction is insufficient to balance local mortality. The population can persist in the habitat only by being a net importer of individuals (adapted from Pulliam 1988).

Sink population—A population that occupies habitat types in which reproductive output is inadequate to maintain local population levels. The population may be replenished by emigrants from source populations (Wiens and Rotenberry 1981:531).

Source environment—The composite of all environmental conditions occurring in a specified area and time that result in stationary or positive population growth (Wisdom et al. 2000).

Source habitat—(1) A habitat that is a net exporter of individuals (Pulliam 1988); (2) those characteristics of macro-vegetation that contribute to stationary or positive population growth. Distinguished from habitats associated with species occurrence; such habitats may or may not contribute to long-term population persistence. Source habitats contribute to source environments (Wisdom et al. 2000).

Source population—A population that occupies habitat suitable for reproduction, in which the output of offspring results in a population that exceeds the carrying capacity of the local habitat, promoting dispersal (adapted from Wiens and Rotenberry 1981:531).

Species at risk—A group of organisms for which loss of viability, including reduction in distribution or abundance, is a concern (USDA Forest Service 2000).

Species of concern—Species with declining or rare habitats or populations, also called species of conservation concern (Wisdom et al. 2002*d*)

Species of conservation concern— Species with declining or rare habitats or populations, also called species of concern (Wisdom et al. 2002*d*).

Subbasin—The 4th delineation within the hydrologic unit code system. Provides a delineation generally of a river, or group of rivers, that flow into a basin (Wisdom et al. 2000)

Subwatershed—The 6th delineation within the hydrologic unit code system. Provides a delineation of a group of streams that flow into a watershed (Wisdom et al. 2000).

Threatened species—A wildlife species officially designated under the Endangered Species Act as having its existence threatened in a localized area, such as a state or smaller area, because its habitat is threatened with destruction, drastic modification, or severe curtailment, or because of overexploitation, disease, predation, or other factors (Wisdom et al. 2000).

Top-down Processes—The dominant spatial and temporal ecological patterns and mechanisms that manifest consistently across large areas (Peterson and Parker 1998).

Umbrella species—A large-bodied (usually), popular species having a large home range and broad requirements for habitats and resources, that can be managed to also provide habitats and resources for other species (Caro and O'Doherty 1999, Wisdom et al. 2000).

Watershed—The 5th delineation within the hydrologic unit code system; provides a delineation of a group of streams that flow into a subbasin (Wisdom et al. 2000).

APPENDIX 2: IDENTIFYING SPECIES OF CONSERVATION CONCERN IN THE SAGEBRUSH ECOSYSTEM

Rich (1999) compiled an initial list of species potentially at risk of local or regional extirpation within the geographic boundaries of the sagebrush ecosystem, based on a variety of information sources. Key sources included species designated as having special status (e.g., sensitive species) by State Offices of the BLM and Regional Offices of the FS. Other sources for terrestrial vertebrates included Saab and Rich (1997), Neel (1999), Idaho Partners in Flight (2000), Wisdom et al. (2000), and Oregon-Washington Partners in Flight (n.d.), the Western Bat Working Group Regional Priority Matrix (Western Bat Working Group 1998), and GAP Analysis (e.g., Washington Department of Fish and Wildlife 1999). Information sources for plants included comprehensive assessments of sensitive plants (e.g. Croft et al. 1997). Aquatic species highly dependent on watersheds within sagebrush ecosystems also were included on Rich's list (1999).

We condensed this initial list for several reasons. First, we dropped fish species because we sought to establish a list of terrestrial species explicitly associated with sagebrush habitats. Second, some of the species inhabit areas within the sagebrush ecosystem, but are not explicitly associated with sagebrush habitats (e.g., wetland- and riparian-associated species imbedded in a larger matrix of sagebrush). And third, some species were not at risk within the boundaries of the sagebrush ecosystem (see sagebrush ecoregions, Figure 1 of main text), based on further examination of their status in relation to their geographic occurrence. Consequently, species remaining on our list, following the exclusion of fish, were screened based on two criteria: 1) degree of association with sagebrush habitats, and 2) degree of population risk for the species within the sagebrush ecosystem (Figures 1 and 2, main text).

To apply the first of these two criteria, habitat associations were assigned to species from the NatureServe database when such information was available (Table 1). Otherwise, habitat associations were determined by consulting recent literature and status reports for individual species (e.g., CalFlora 2000). Based on these information sources, species not specifically associated with sagebrush habitats were dropped.

To apply the second of these two criteria, we used estimates of the degrees of extirpation risk at Global, National, and State levels as described in the NatureServe Explorer database, referred to as conservation status ranks (i.e., G1/S1-critically imperiled, G2/S2-imperiled, G3/S3-vulnerable, G4/S4-apparently secure, and G5/S5-secure) (Table 2). The science staffs of NatureServe and its member programs used a rigorous method consistent across states to assign these ranks of extirpation risk (Master 1991, Stein 2002). Evaluation criteria considered by NatureServe in assigning a rank to each species included the following risk factors: number of populations; the area over which the species occurs; population trend (i.e., whether numbers are increasing, stable, or declining); and known threats.

We considered a species to meet our second criteria if the species was ranked S4 or worse by NatureServe in any of the 11 western states that encompass the sagebrush ecosystem in the United States (i.e., Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming). That is, species were retained if ranked S1, S2, S3, or S4 by NatureServe within any of these 11 western states where sagebrush occurs.

Application of the above criteria resulted in a reduction of species from 735 to 630 when fish were dropped (see Table 3, which includes fish species that were dropped). An additional 267 species were dropped because they were not specifically associated with sagebrush habitats

(98% of the 267), or they were not at risk within the range of sagebrush (2%) (Tables 4 and 5). The remaining 363 species are specifically associated with the sagebrush ecosystem and considered to be of conservation concern (Tables 6, 7, and 8), which we define as species with rare or declining habitats or populations.

The majority of the 363 species of conservation concern are plants (69.7% of all species, Table 6). Although plants and invertebrates have the highest potential vulnerability based on the ranking process, we have the least knowledge about needs of these taxa (e.g. see Bonnet et al. [2002], and Clark and May [2002]).

Table 1. Habitat associations assigned to species by NatureServe (2001), and subsequently used as part of our process of identifying species of conservation concern in the sagebrush ecosystem.[a]

Habitat	Code
Herbaceous vegetation	1
Shrubland	2
Sparse vegetation	3
Non-vascular plants	4
Forest	5
Woodland	6
Dwarf-shrub	7
Cave	8
Aquatic; wetlands	9

[a] "r" was added for riparian habitat designations.

Table 2. Degrees of extirpation risk assigned to species by NatureServe (2001), and subsequently used as part of our process of identifying species of conservation concern in the sagebrush ecosystem.

Global/State rank code	Rank	Definition
GX/SX	Presumed extinct	Believed to be extinct throughout its range. Not located despite intensive searches and virtually no likelihood that it will be rediscovered.
GH/SH	Possibly extinct	Known only from historical occurrences. Still some hope of rediscovery.
G1/S1	Critically imperiled	Critically imperiled because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 5 or fewer occurrences or very few remaining individuals (<1,000).
G2/S2	Imperiled	Imperiled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000).
G3/S3	Vulnerable	Vulnerable either because very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extinction. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals
G4/S4	Apparently secure	Uncommon but not rare, and usually widespread. Possibly cause for long-term concern. Typically more than 100 occurrences globally or more than 10,000 individuals.
G5/S5	Secure	Common, typically widespread and abundant.
G#G#/S#S#	Range rank	A numeric range rank (e.g., G2G3) is used to indicate uncertainty about the exact status of a taxon.

Global/State rank code	Rank	Definition
GU/SU	Unrankable	Currently unrankable due to lack of available information about status or trends.
G?/S?	Unranked	Global (or State) rank not yet assessed.
?	Inexact rank	Denotes inexact numeric rank.
Q	Questionable taxonomy	Taxonomic status is questionable; numeric rank may change with taxonomy.
Z	Moving	Occurs in the area of interest, but as a diffuse, usually moving population; difficult or impossible to map static occurrences.
T	Infraspecific Taxon (trinomial)	The status of infraspecific taxa (subspecies or varieties) is indicated by a "T-rank" following the species' global rank. Rules for assigning T ranks follow the same principles outlined above. For example, the global rank of a critically imperiled subspecies of an otherwise widespread and common species would be G5T1.
B	Breeding	The associated rank refers to breeding occurrences of mobile animals.
N	Non-breeding	The associated rank refers to non-breeding occurrences of mobile animals.

Table 3. Initial list of 735 species at risk within the geographic boundaries of the sagebrush ecosystem, before application of our screening criteria described in the text for Appendix 2.

Taxon	Number of species
Invertebrates	98
Fish	105
Amphibians	3
Reptiles	18
Birds	33
Mammals	48
Vascular plants	430
Total	735

Table 4. Non-fish species included on the initial list of Rich (1999), but subsequently dropped because they did not meet our selection criteria described in the text.

Taxonomic group Species	Scientific name	Habitat association[a]	Drop reason[b]
Invertebrates			
Crescent Dune aegialian scarab	*Aegialia crescenta*	3	1
Hardy's aegialian scarab	*Aegialia hardyi*	3	1
large aegialian scarab	*Aegialia magnifica*	3	1
Roadside skipper	*Amblyscirtes vialis*	1/6	1
Malheur isopod	*Amerigoniscus malheurensis*	8	1
California floater	*Anodonta californiensis*	9	1
Big Dune aphodius scarab	*Aphodius sp*	3	1
Crescent Dune aphodius scarab	*Aphodius sp.*	3	1
Sand Mountain aphodius scarab	*Aphodius sp.*	3	1
Malheur pseudoscorpion	*Apochthonius malheuri*	8	1
Silver bordered bog fritillary	*Boloria selene atrocostalis*	1r	1
Lake Tahoe benthic stonefly	*Capnia lacustra*	9	1
Carson Valley wood nymph	*Cercyonis pegala carsonensis*	1	1
White River wood nymph	*Cercyonis pegala ssp.*	9	1
Idaho dunes tiger beetle	*Cicindela arenicola*	3	1
Mission creek Oregonian	*Cryptomastix magnidentata*	5	1
Disc Oregonian (snail)	*Cryptomastix sp. Nov.*	1	1
Sand Mountain blue	*Euphilotes palliscens ssp.*	3	1
Mono checkerspot	*Euphydryas editha monoensis*	5/6	1
Eastern tailed blue	*Everes comyntas comyntas*	1/2	1
Shortface lanx	*Fisherola nuttalli*	9	1
Columbia pebblesnail	*Fluminicola columbiana*	9	1
Pahranagat pebblesnail	*Fluminicola merriami*	9	1
Malheur pebblesnail	*Fluminicola sp. Nov.*	9	1
Casebeer pebblesnail	*Fluminicola sp. Nov.*	9	1
Turban pebblesnail	*Fluminicola turbiniformis*	9	1
Unnamed ant	*Formica microphthalma*	5	1
Blind cave leiodid beetle	*Glacicavicola bathyscioides*	8	1
Great Basin ramshorn (snail)	*Helisoma newberryi newberryi*	9	1
Railroad Valley skipper	*Hesperia uncas ssp.*	9	1
Spring Mountains icarioides blue	*Icaricia icarioides*	1/5/6	1
Bulb juga (snail)	*Juga bulbosa*	9	1
Purple-lipped juga (snail)	*Juga hemphilli maupinensis*	9	1
A flatworm (planarian)	*Kenkia rhynchida*	8R	1
Banbury springs limpet	*Lanx sp 1*	9	1
Nevada admiral	*Limenitis weidemeyerii nevadae*	5	1
Harney Hot Spring shore bug	*Micranthia fennica*	9	1
Rulien's miloderes weevil	*Miloderes sp.*	3	1

Taxonomic group Species	Scientific name	Habitat association[a]	Drop reason[b]
Unnamed ant	*Myrmecocystus arenarius*	3	1
Deschutes ochrotrichian micro caddisfly	*Ochrotrichia phenosa*	9	1
Malheur Cave springtail	*Oncopodura mala*	8	1
Aquatic moth	*Petrophila confusalis*	9	1
Snake river physa	*Physa natricina*	9	1
Hotspring physa (snail)	*Physella sp. Nov.*	9	1
Montane peaclam	*Pisidium ultramontanum*	9	1
Borax lake ramshorn (snail)	*Planorbella oregonensis*	9	1
Pristine springsnail	*Pristinicola hemphilli*	9	1
Giuliani's dune scarab	*Pseudocotalpa giulianii*	3	1
Bruneau hot springsnail	*Pyrgulopsis bruneauensis*	9	1
Harney Lake springsnail	*Pyrgulopsis hendersoni*	9	1
Idaho springsnail	*Pyrgulopsis idahoensis*	9	1
Crooked creek springsnail	*Pyrgulopsis intermedia*	9	1
Oasis Valley springsnail	*Pyrgulopsis micrococcus*	9	1
Owyhee Hot springsnail	*Pyrgulopsis sp. nov.*	9	1
Xl springsnail	*Pyrgulopsis sp. nov.*	9	1
Lake Abert springsnail	*Pyrgulopsis sp. Nov.*	9	1
Malheur springsnail	*Pyrgulopsis sp. Nov.*	9	1
Formation springsnail	*Pyrgulopsis spp.*	9	1
Wongs springsnail	*Pyrgulopsis wongi*	9	1
Sylvan hairstreak	*Satyrium sylvinus sylvinus*	2	1
Crescent Dune serican scarab	*Serica sp.*	3	1
Sand Mountain serican scarab	*Serica sp.*	3	1
Carson valley silverspot	*Speyeria nokomis ssp*	1r	1
Unnamed ant	*Stenamma wheelerorum*	5	1
Devils Hole warm spring riffle beetle	*Stenelmis calida calida*	9	1
Moapa warm spring riffle beetle	*Stenelmis calida moapa*	9	1
Malheur cave amphipod	*Stygobromus hubbsi*	8/9	1
Bliss rapids snail	*Taylorconcha serpenticola*	9	1
Water mite	*Thermacarus nevadensis*	9	1
Grated tryonia	*Tryonia clathrata*	9	1
Desert valvata	*Valvata utahensis*	9	1
Amphibians			
Tiger salamander	*Ambystoma tigrinum*	allr	1
Northern leopard frog	*Rana pipiens*	1r	1
Reptiles			
Common kingsnake	*Lampropeltis getulus*		1
Common garter snake	*Thamnophis sirtalis*		1

Taxonomic group Species	Scientific name	Habitat association[a]	Drop reason[b]
Birds			
Golden eagle	*Aquila chrysaetos*	1/2/3	1
Rufous Hummingbird	*Selasphorus rufus*	5/6	1
Calliope Hummingbird	*Stellula calliope*	5/6	1
Black-throated Gray Warbler	*Dendroica nigrescens*	2/5/6	1
Grasshopper Sparrow	*Ammodramus savannarum*	1	1
Mammals			
Pygmy shrew	*Sorex hoyi*	1/5	1
Northern water shrew	*Sorex palustris*	r	1
Western red bat	*Lasiurus blossevillii*	5r/6R	1
Big brown bat	*Eptesicus fuscus*	5	1
Allen's big-eared bat	*Idionycteris phyllotis*	5	1
Little brown myotis	*Myotis lucifugus*	6r	1
Long-legged myotis	*Myotis volans*	5/6	1
Swift fox	*Vulpes velox*	1	1
California bighorn sheep	*Ovis canadensis californiana*		1
Least chipmunk	*Tamias minimus*	2/5/6	1
Plants			
Wallowa ricegrass	*Achnatherum wallowaensis*	1	1
Pink agoseris	*Agoseris lackschewitzii*	1r	1
Iodine bush	*Allenrolfea occidentalis*	3	1
Two-stemmed onion	*Allium bisceptrum*	9	1
Tall swamp onion	*Allium validum*	1/5	1
Malheur Valley fiddleneck	*Amsinckia carinata*	2	1
Rough angelica	*Angelica scabrida*	5/6	1
Meadow pussy-toes	*Antennaria corymbosa*	5	1
King snapdragon	*Antirrhinum kingii*	6	1
California bear poppy	*Arctomecon californica*	2	1
White bearpoppy	*Arctomecon merriamii*	2	1
Silverleaf milkvetch	*Astragalus argophyllus var. argophyllus*	1/3	1
King's rattleweed	*Astragalus calycosus*	6	1
Milkvetch	*Astragalus diaphanus diaphanus*	1	1
Mesic milkvetch	*Astragalus diversifolius*	1	1
Needle Mountains milkvetch	*Astragalus eurylobus*	1/2	1
Threecorner milkvetch	*Astragalus geyeri var. triquetrus*	3	1
Plains milkvetch	*Astragalus gilviflorus*	1	1
Dubois Milkvetch	*Astragalus gilviflorus var. purpureous*	1/3	1
Hyattville Milkvetch	*Astragalus jejunus var. articulatus*	3	1

Taxonomic group Species	Scientific name	Habitat association[a]	Drop reason[b]
Sodaville milkvetch	*Astragalus lentiginosus var. sesquimentralis*	9	1
Park milkvetch	*Astragalus leptaleus*	5	1
Least bladdery milkvetch	*Astragalus microcystis*	1	1
Half-ring pod milkvetch	*Astragalus mohavensis var. hemigyrus*	2/6	1
Mokiak milkvetch	*Astragalus mokiacensis*	2	1
Naturita milkvetch	*Astragalus naturitensis*	6	1
Nelson milkvetch	*Astragalus nelsonianus*	1/3	1
Clokey eggvetch	*Astragalus oophorus var. clokeyanus*	6	1
Payson's milkvetch	*Astragalus paysonii*	1	1
Ash Meadows milkvetch	*Astragalus phoenix*	3	1
Precocious Milkvetch	*Astragalus proimanthus*	1	1
Lamoille Canyon milkvetch	*Astragalus robbinsii var. occidentalis*	9	1
Tiehm milkvetch	*Astragalus tiehmii*	2	1
Tygh Valley milkvetch	*Astragalus tyghensis*	1	1
Texas bergia	*Bergia texana*	9	1
King's desertgrass	*Blepharidachne kingii*	6	1
Dainty moonwort	*Botrychium crenulatum*	1/9	1
Long-bearded sego lily	*Calochortus longebarbatus*	1	1
Green-band mariposa lily	*Calochortus macrocarpus var. maculosus*	1	1
Broad-fruit mariposa lily	*Calochortus nitidus*	1	1
Alkali mariposa lily	*Calochortus striatus*	9	1
Cusick's camas	*Camassia cusickii*	9	1
Porcupine sedge	*Carex hystericina*	9	1
Inverted pale paintbrush	*Castilleja pallescens inverta*	1	1
Monte Neva paintbrush	*Castilleja salsuginosa*	9	1
Spring-loving centaury	*Centaurium namophilum*	9	1
Cusick's false yarrow	*Chaenactis cusickii*	1	1
Centennial rabbitbrush	*Chrysothamnus parryi montanus*	3	1
Bulb-bearing waterhemlock	*Cicuta bulbifera*	9	1
Cedar Rim Thistle	*Cirsium aridum*	3	1
Rocky Mountain thistle	*Cirsium perplexans*	3	1
Many-stemmed Spider-flower	*Cleome multicaulis*	1	1
Flat-seeded cleomella	*Cleomella plocasperma*	2	1
Tecopa birdsbeak	*Cordylanthus tecopensis*	2/3/9	1
Idaho hawksbeard	*Crepis bakeri ssp. idahoensis*	1	1
Unusual catseye	*Cryptantha insolita*	2	1
Beaked cryptantha	*Cryptantha rostellata*	1/6	1
Owl Creek Miner's Candle	*Cryptantha subcapitata*	1/3	1
Goodrich biscuitroot	*Cymopterus goodrichii*	1/6	1
Blue Mountain prairieclover	*Dalea ornata*	6	1

Taxonomic group Species	Scientific name	Habitat association[a]	Drop reason[b]
Wenatchee larkspur	*Delphinium viridescens*	9	1
Wyoming Tansymustard	*Descurainia torulosa*	3	1
Gold Butte moss	*Didymodon nevadensis*	3	1
Doublet	*Dimeresia howellii*	6	1
Bacigalupi's downingia	*Downingia bacigalupii*	9	1
Silver leaf sunray	*Enceliopsis argophylla*	3	1
Ash Meadows sunray	*Enceliopsis nudicaulis var. corrugata*	3	1
Swamp willow-weed	*Epilobium palustre*	9	1
Giant helleborine	*Epipactis gigantea*	9	1
Sheep fleabane	*Erigeron ovinus*	5/6	1
Sulphur Springs buckwheat	*Eriogonum argophyllum*	9	1
Pahrump Valley buckwheat	*Eriogonum bifurcatum*	3	1
Golden buckwheat	*Eriogonum chrysops*	3	1
Comb Wash buckwheat	*Eriogonum clavellatum*	2	1
Umtanum desert buckwheat	*Eriogonum codium*	2	1
Colorado wild buckwheat	*Eriogonum coloradense*	1/6	1
Desert buckwheat	*Eriogonum desertorum*	3	1
Ochre-flowered buckwheat	*Eriogonum ochrocephalum calcareum*	2	1
Tiehm buckwheat	*Eriogonum tiehmii*	2	1
Sticky buckwheat	*Eriogonum viscidulum*	2	1
Duchesne buckwheat	*Eriogonum X duchesnense*	2	2
Cushion cactus	*Escobaria vivipara*	2/6	1
Kingston bedstraw	*Galium hilendiae kingstonense*	6	1
Intermountain bedstraw	*Galium serpenticum*	5	1
Colorado Butterfly Plant	*Gaura neomexicana coloradensis*	1/9	1
Smooth dwarf greasebush	*Glossopetalon pungens var. glabra*	2/6	1
Bogg's Lake hedgehyssop	*Gratiola heterosepala*	9	1
Ash Meadows gumplant	*Grindelia fraxinopratensis*	9	1
Howell's gumweed	*Grindelia howellii*	9	1
Sagebrush stickseed	*Hackelia diffusa var. arida*	5	2
Three forks stickseed	*Hackelia ophiobia*	3	1
Lone Mountain tonestus	*Haplopappus graniticus*	3	1
Palouse goldenweed	*Haplopappus liatriformis*	1	1
Ward's Goldenweed	*Haplopappus wardii*	3	1
Salt heliotrope	*Heliotropium curassavicum*	1/2/6/7	1/2
Water howellia	*Howellia aquatilis*	9	1
Large Canadian St. John's-wort	*Hypericum majus*	9	1
Red Rock Canyon aster	*Ionactis caelestis*	5/6	1
Nuttall's guillwort	*Isoetes nuttallii*	9	1
Sierra Valley mousetail	*Ivesia aperta var. canina*	1/5	1
Rock purpusia	*Ivesia arizonica var. saxosa*	3	1

Taxonomic group Species	Scientific name	Habitat association[a]	Drop reason[b]
Jaeger ivesia	*Ivesia jaegeri*	5/6	1
Ash Meadows ivesia	*Ivesia kingii var. eremica*	9	1
Shelly's ivesia	*Ivesia rhypara shellyi*	3	1
Shockley's ivesia	*Ivesia shockleyi*	5/6	1
Waxflower	*Jamesia tetrapetala*	3	1
Great basin langloisia	*Langloisia setosissima punctata*	2/6	1
Garnet bladderpod	*Lesquerella carinata var. languida*	1	1
Large-fruited Bladderpod	*Lesquerella macrocarpa*	1	1
Payson's bladderpod	*Lesquerella paysonii*	1	1
Southern mudwort	*Limosella acaulis*	9	1
False pimpernel	*Lindernia dubia var. anagellidea*	9	1
Kalm's lobelia	*Lobelia kalmii*	9	1
Clark parsley	*Lomatium graveolens var. clarkii*	6	1
Salmon-flower desert parsley	*Lomatium salmoniflorum*	5	1
Marsh felwort	*Lomatogonium rotatum*	1/9	1
Holmgren lupine	*Lupinus holmgrenanus*	6	1
Rush-like skeletonweed	*Lygodesmia juncea*	1	1
Smooth malacothrix	*Malacothrix glabrata*	2/6	1
Ash Meadows blazingstar	*Mentzelia leucophylla*	9	1
Manystem blazingstar	*Mentzelia multicaulis var. librina*	2	1
Packard's mentzelia	*Mentzelia packardiae*	3	1
Macfarlane's four o'clock	*Mirabilis macfarlanei*	1	1
Amargosa niterwort	*Nitrophila mohavensis*	3	1
Desert evening-primrose	*Oenothera primiveris*	2/6	1
Oryctes	*Oryctes nevadensis*	3	1
Little ricegrass	*Oryzopsis exigua*	1/6	1
White locoweed	*Oxytropis deflexa var. sericea*	1/5	1
Absaroka Beardtongue	*Penstemon absarokensis*	3	1
White-margined beardtongue	*Penstemon albomarginatus*	2/3	1
Nevada dune beardtongue	*Penstemon arenarius*	1/2	1
Yellow twotone beardtongue	*Penstemon bicolor ssp. bicolor*	3	1
Degener beardtongue	*Penstemon degeneri*	1/6	1
Hot-rock beardtongue	*Penstemon deustus variabilis*	1	1
Death Valley beardtongue	*Penstemon fruticiformis amargosae*	2	1
Spine-noded milkvetch	*Peteria thompsoniae*	2/3	1
Mackenzie's phacelia	*Phacelia lutea mackenzieorum*	3	1
Least phacelia	*Phacelia minutissima*	9	1
Nine Mile Canyon phacelia	*Phacelia novenmillensis*	5/6	1
Parish phacelia	*Phacelia parishii*	1r	1
Kelsey's phlox	*Phlox kelseyi*	1	1
Beaver Rim Phlox	*Phlox pungens*	3	1
Dorn's Twinpod	*Physaria dornii*	2	1

Taxonomic group Species	Scientific name	Habitat association[a]	Drop reason[b]
Mesamint	*Pogogyne floribunda*	9	1
Silvies valley desert combleaf	*Polyctenium fremontii bisulcatum*		2
Narrowleaved cottonwood	*Populus angustifolia*	5r/9	1
Soldier Meadow cinquefoil	*Potentilla basaltica*	1	1
Cottam cinquefoil	*Potentilla cottamii*	6	1
Ruby Mountain primrose	*Primula capillaris*	1	1
Slender wooly-heads	*Psilocarphus tenellus*		2
Sticky goldenweed	*Pyrrocoma lucida*	5	1
Persistentsepal yellowcress	*Rorippa calycina*	1r	1
Bartonberry	*Rubus bartonianus*	2r	1
Hoary willow	*Salix candida*	9	1
Sierra sanicle	*Sanicula graveolens*	5	1
Schlesser pincushion	*Sclerocactus schlesseri*	2	1
Verrucose sea-purslane	*Sesuvium verrucosum*	3r	1
Shoshonea	*Shoshonea pulvinata*	3	1
Oregon checker-mallow	*Sidalcea oregana var. calva*	9	1
Spalding's silene	*Silene spaldingii*	1/6	1
Cinquefoil tansy	*Sphaeromeria potentilloides*	9	1
Laramie False Sagebrush	*Sphaeromeria simplex*	1	1
Ute Ladies'-Tresses	*Spiranthes diluvialis*	1r	1
Tall dropseed	*Sporobolus asper*	1/2/6	1
Woodsage	*Teucrium canadense viscidum*	9	1
Rock Springs Greenthread	*Thelesperma caespitosum*	1	1
Uinta Greenthread	*Thelesperma pubescens*	3	1
Arrow-leaf thelypody	*Thelypodium eucosmum*	6	1
Howell's spectacular thelypody	*Thelypodium howellii spectabilis*	9	1
**	*Thelypodium paniculatum*	1r	1
wavy-leaf thelypody	*Thelypodium repandum*	2	1
Cedar Mtn. Easter Daisy	*Townsendia microcephala*	3	1
Barneby's Clover	*Trifolium barnebyi*	3	1
**	*Trifolium douglasii*	1r	1
Leiberg's clover	*Trifolium leibergii*	3	1
**	*Trifolium thompsonii*	1	1
Rock violet	*Viola lithion*	5	1

[a] Habitat associations are: 1 - herbaceous vegetation; 2 - shrubland; 3 - sparse vegetation; 4 - non-vascular plants; 5 - forest; 6 - woodland; 7 - dwarf-shrub; 8 - cave; and 9 - aquatic/wetlands.
[b] 1 - species is not specifically associated with sagebrush habitats; 2 - species is not at risk within the range of sagebrush.

Table 5. Status and occurrence of species on the initial list of Rich (1999), but subsequently dropped because they did not meet our selection criteria described in the text. See Table 4 for scientific names of species and reason for dropping species from further consideration.

Taxonomic group	Global	State Natural Heritage Program rank and occurrence										
Species	rank	AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Invertebrates												
Crescent Dune aegialian scarab	G1						S1					
Hardy's aegialian scarab	G1						S1					
large aegialian scarab	G1						S1					
Roadside skipper	G5	S?	S3		S?	S5		S?	S?	S?	S4	S?
Malheur isopod	G1								S1			
California floater	G3	S1S2	S2?		S?		S1?		S1?	S1	S1S2	S?
Big Dune aphodius scarab	GUQ						SU					
Crescent Dune aphodius scarab	GUQ						SU					
Sand Mountain aphodius scarab	GUQ						SU					
Malheur pseudoscorpion	G1								S1			
Silver bordered bog fritillary												
Lake Tahoe benthic stonefly	G1		S1				S1					
Carson Valley wood nymph	T2		S?				S2					
White River wood nymph	G5T2						S2					
Idaho dunes tiger beetle	G2				S1							
Mission creek oregonian	G?				SU							
Disc Oregonian (snail)	G2				S?				S1			
Sand Mountain blue	G3G4T1						S1					
Mono checkerspot	G5T3?		S1S3				S2					
Eastern tailed blue	G5	S?	S3	S5	S?		S?	S?	S?		S2	S?
Shortface lanx	G2				S1	S1S3			S2		S2	

Taxonomic group Species	Global rank	State Natural Heritage Program rank and occurrence										
		AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Columbia pebblesnail												
Pahranagat pebblesnail	G1						S1					
Malheur pebblesnail												
Casebeer pebblesnail	G1								S1			
Turban pebblesnail	G3G4		S?				S?		S1			
Unnamed ant	G2?						S1					
Blind cave leiodid beetle	G2				S1S3							S?
Great Basin ramshorn (snail)	G1T?								S1			
Railroad Valley skipper	G5T1T2						S?					
Spring Mountains icarioides blue	G5T2		S?				S3					
Bulb juga (snail)	G1								S2			
Purple-lipped juga (snail)	T1								S2			
A flatworm (planarian)	G1								S2?			
Banbury springs limpet	G1				S1							
Nevada admiral	G5T2						S3					
Harney Hot Spring shore bug	G1								S1			
Rulien's miloderes weevil	G1						S1					
Unnamed ant	G2?						S3					
Deschutes ochrotrichian micro caddisfly	G2		S1S3						SH			
Malheur Cave springtail	G3G4		S?						S1			
Aquatic moth	G?						S1					
Snake river physa	G1				S1							
Hotspring physa (snail)	G1								S1			
Montane peaclam	G1		S?						S1			
Borax lake ramshorn (snail)	G1								S1	S1S2		
Pristine springsnail	G3		S?		S?				S2?		S?	

Species	Taxonomic group	Global rank	State Natural Heritage Program rank and occurrence										
			AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Giuliani's dune scarab		G1						S1					
Bruneau hot springsnail		G1				S1							
Harney Lake springsnail		G1								S1			
Idaho springsnail		G1				S1							
Crooked creek springsnail		G2		S1						S1			
Oasis Valley springsnail		G3		S?				S2					
Owyhee Hot springsnail		G1								S1			
Xl springsnail		G2								S1			
Lake Abert springsnail		G1								S1			
Malheur springsnail		G1								S1			
Formation springsnail		G?											
Wongs springsnail		G3		S1S2				S1					
Sylvan hairstreak				OCC						OCC			
Crescent Dune serican scarab		G1						S1					
Sand Mountain serican scarab		G1						S1					
Carson valley silverspot													
Unnamed ant		G1?						S1					
Devils Hole warm spring riffle beetle		T1						S1					
Moapa warm spring riffle beetle													
Malheur cave amphipod		G1								S1			
Bliss rapids snail		G1				S1							
Water mite		GH						SH					
Grated tryonia		G2						S2					
Desert valvata		G1				S1					SX		
	Amphibians												

Species	Taxonomic group	Global rank	State Natural Heritage Program rank and occurrence										
			AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Tiger salamander		G5	S5	S?	S5	S5	S5	SE	S5	SU	S5	S3	S3S4
Northern leopard frog		G5	S2	S2	S3	S3	S3S4	S3	S4	S2?	S4S5	S1	S3
	Reptiles												
Common kingsnake		G5	S5	S5	S1			S5	S5	S2	S3		
Common garter snake		G5		S4	S3	S5	S4	S3	S4	S5	S3S4	S5	S5
	Birds												
Golden Eagle		G5	S4	S3	S3S4B,S4N	S4B,S4N	S4B,SZN	S4	S4B,S4N	S4?	S4	S3B,S3N	S3?B,S3N
Rufous Hummingbird		G5	SN	S3S4	SZN	S5B,SZN	S5B,SZN	S3?B	S5N	S4	SZN	S5B,SZN	S2B,SZN
Calliope Hummingbird		G5	SN	S4	SZN	S5B,SZN	S5B,SZN	S4B	S4N	S4?	S3S4B	S4S5B,SZN	S2B,SZN
Black-throated Gray Warbler		G5	S5	S?	S5B,SZN	S3?B,SZN		S5B	S4B,S4N		S4S5B		S2B,SZN
Grasshopper Sparrow		G5	S3	S2	S3S4B,SZN	S3B,SZN	S4B,SZN	S3B	S3B,S4N	S2?B	S1B	S3B,SZN	S3B,SZN
	Mammals												
Pygmy shrew		G5			S2	S2	S4					S4	S1
Northern water shrew		G5	S1	S4S5	S4	S4?	S5	S3	S3	S4	S4	S5	S4
Western red bat		G5	S2	S?				S?	S2	S?	S1		
Big brown bat		G5	S4S5	S5	S5	S4?	S4	S5	S5	S4	S4	S5	S5
Allen's big-eared bat		G3	S2S3	S1				S1	S1		S1		
Little brown myotis		G5	S3	S4	S5	S5	S5	S2	S5	S4	S4	S5	S5

Taxonomic group Species	Global rank	State Natural Heritage Program rank and occurrence										
		AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Long-legged myotis	G5	S3S4	S5	S5	S3?	S4	S4B	S5	S3	S4	S3	S3B,SZN
Swift fox	G3		S?	S3		S1		S2				S2S3
California bighorn sheep	G4G5T1		S1				S4			SE		
Least chipmunk	G5	S4	S4	S5	S5	S5	S5	S4	S4	S5	S4	S5
Plants												
Wallowa ricegrass	G2G3											
Pink agoseris	G4				S2	S3						S3
Iodine bush	G4	SR	S?		S1		SR	SR	S2	SR		
Two-stemmed onion	G4G5	SR	SR		SR		SR	SR	S4	SR		
Tall swamp onion	G4		SR		S3		SR		SR		SR	
Malheur Valley fiddleneck	G2								S2			
Rough angelica	G2						S2					
Meadow pussy-toes	G5		SR	SR	SR	SR	SR		SR	SR	S1	S3
King snapdragon	G4	S3	SR		SR		SR		SU	SR		
California bear poppy	G3	S2					S3			SE?		
White bearpoppy	G3		S2				S3					
Silverleaf milkvetch	G5T4		S1		SR	S3	SR			SR		S2S3
King's rattleweed	G5	SR	S?	SR	SR		S5	S5	S1	S4		S1S2
Milkvetch	G3G4								S4		SX	
Mesic milkvetch	G3				S2		S1					SH
Needle Mountains milkvetch	G2	SR					S2					
Threecorner milkvetch	G4?T2T3	S1					S2S3					
Plains milkvetch	G5			S1		SR				S1		S3
Dubois Milkvetch	G5T2											S2

Taxonomic group Species	Global rank	State Natural Heritage Program rank and occurrence										
		AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Hyattville Milkvetch	G3T1											S1
Sodaville milkvetch	G5T1		S1				S1					
Park milkvetch	G4			SR	S3	S3						S1
Least bladdery milkvetch	G5				SH	SR					S2	SR
Half-ring pod milkvetch	G3T2		SH				S2					
Mokiak milkvetch	G2G3	SR					S1S2					
Naturita milkvetch	G2G3			S2S3				S2		S1		
Nelson milkvetch	G2			S1						S1		S2
Clokey eggvetch	G4T2						S2					
Payson's milkvetch	G3				S3							S2
Ash Meadows milkvetch	G2						S2					
Precocious Milkvetch	G1											S1
Lamoille Canyon milkvetch	G5T2T3						S2S3					
Tiehm milkvetch	G3						S3					
Tygh Valley milkvetch	G2								S2			
Texas bergia	G5		SR	SR			SR	SR	SR	S1		SR
King's desertgrass	G4		S1		S1		SR			SR		
Dainty moonwort	G3	SH	S1		S1	S2	S1?		S2	S1	S3	S1
Long-bearded sego lily	G4		S3						S3		S2S3	
Green-band mariposa lily	G5T2				S2				S2		S1	
Broad-fruit mariposa lily	G3				S3				S1		S1	
Alkali mariposa lily	G2		S2				S1					
Cusick's camas	G4				S2				S4			
Porcupine sedge	G5	SR	S1?	SR	SR	SR		SR	S2	SR	S2	S2
Inverted pale paintbrush	G4T?				SR		SR		SR			
Monte Neva paintbrush	G1Q						S1					

Taxonomic group Species	Global rank	State Natural Heritage Program rank and occurrence										
		AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Spring-loving centaury	G2Q		S1				S2					
Cusick's false yarrow	G2G3				S2				S2			
Centennial rabbitbrush	G5T1				S1	S1						
Bulb-bearing waterhemlock	G5				S2	S3S4			SH		S2	S1
Cedar Rim Thistle	G2Q											S2
Rocky Mountain thistle	G2			S2								
Many-stemmed Spider-flower	G2G3	S1		S2S3				SH				S1
Flat-seeded cleomella	G4	SU	S?		SH		SR		SR	S1		
Tecopa birdsbeak	G2		S1				S2					
Idaho hawksbeard	G4T2				S2							
Unusual catseye	GHQ						SH					
Beaked cryptantha	G4		SR						S1		S1	
Owl Creek Miner's Candle	G1											S1
Goodrich biscuitroot	G1						S1					
Blue Mountain prairieclover	G4G5		S1		SR		SR		SR		SR	
Wenatchee larkspur	G2										S2	
Wyoming Tansymustard	G1											S1
Gold Butte moss	G2G3			OCC			S1	OCC		OCC		
Doublet	G4		S3		S2		S4		SR			
Bacigalupi's downingia	G4		S?		S2		SR		S4			
Silver leaf sunray	G2G3	S2					S1?			S1		
Ash Meadows sunray	G5T2		S?				S2					
Swamp willow-weed	G5		SR	SR	S3	S3S4	SR		SR		SR	S2
Giant helleborine	G3	SR	SR	S2	S3	S2	SR	S2?	SR	S2S3	S3	S1
Sheep fleabane	G2						S2					
Sulphur Springs buckwheat	G1						S1					

Taxonomic group	Global	State Natural Heritage Program rank and occurrence										
Species	rank	AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Pahrump Valley buckwheat	G1		S1				S1					
Golden buckwheat	G1								S1			
Comb Wash buckwheat	G2			S1						S1S2		
Umtanum desert buckwheat	G1										S1	
Colorado wild buckwheat	G2			S2								
Desert buckwheat	G3?				S1		SR			S1		
Ochre-flowered buckwheat	G4T3				S1				S3			
Tiehm buckwheat	G1						S1					
Sticky buckwheat	G2	S1					S2					
Duchesne buckwheat	HYB									SR		SR
Cushion cactus	G5	S5	S?	SR	S2	SR	S4	SR	SU	SR		S3
Kingston bedstraw	G4T2		S1				S1					
Intermountain bedstraw	G4G5		S?		SR		SR				SR	
Colorado Butterfly Plant	G3T2			S1								S2
Smooth dwarf greasebush	G2G3		S1				S2S3					
Bogg's Lake hedgehyssop	G3		S3						S1			
Ash Meadows gumplant	G2		S1				S2					
Howell's gumweed	G3				S1	S2S3						
Sagebrush stickseed	G4T?				SR						SR	
Three forks stickseed	G3				S2		S2		S1			
Lone Mountain tonestus	G1						S1					
Palouse goldenweed	G2				S2						S2	
Ward's Goldenweed	G2											S2
Salt heliotrope	G5	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
Water howellia	G2		S1		S1	S2			SH		S2	
Large Canadian St. John's-wort	G5			SR	S3	SR					S1?	

Taxonomic group Species	Global rank	State Natural Heritage Program rank and occurrence AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Red Rock Canyon aster	G1						S1					
Nuttall's guillwort	G4?		SR			SU			SU		S1	
Sierra Valley mousetail	G2T1		S1									
Rock purpusia	G3G4T1						S1					
Jaeger ivesia	G2G3		S1				S2S3					
Ash Meadows ivesia	G3T1T2Q						S1S2					
Shelly's ivesia	G2T1								S1			
Shockley's ivesia	G3G4		SR				SR		S1	S1		
Waxflower	G2						S2			S1		
Great basin langloisia	G4T?		SR		SR		SR		SU			
Garnet bladderpod	G3G4T1					S1						
Large-fruited Bladderpod	G2											S2
Payson's bladderpod	G3				S2	S1						S3
Southern mudwort	G5	SR	SR		S1		SR	SR			S2	
False pimpernel	G5T4	S1	SR	SR	SR			SR	SU		S3?	
Kalm's lobelia	G5				SU	SU					S1	
Clark parsley	G3T1Q				SR		S1			S4		S2
Salmon-flower desert parsley	G3				S2				SH		SR	
Marsh felwort	G5			SR	S1	S1				S1S2		S2
Holmgren lupine	G3?Q		S2S3				S2					
Rush-like skeletonweed	G5	SR		SR	SR	SR	SR	SR	SR	S1	SR	S4S5
Smooth malacothrix	G5	SR	SR		S3		SR	SR	S4	SR		
Ash Meadows blazingstar	G1						S1					
Manystem blazingstar	G3T1									S1		
Packard's mentzelia	G1Q						S1		S1			
Macfarlane's four o'clock	G2				S2				S1			

Taxonomic group	Global	State Natural Heritage Program rank and occurrence										
Species	rank	AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Amargosa niterwort												
Desert evening-primrose	G5	SR	SR				SR	SR		SR		
Oryctes	G2G3		S1				S2S3					
Little ricegrass	G5		SR	SR	SR	SR	SR		SR	SR	SR	S3
White locoweed	G5T5		S1	SR	SR	SR		SR	SR	SR	SR	S3S4
Absaroka Beardtongue	G2											S2
White-margined beardtongue	G2	S2	S1				S2					
Nevada dune beardtongue	G2G3						S2S3					
Yellow twotone beardtongue	G3T2Q					S2						
Degener beardtongue	G2			S2								
Hot-rock beardtongue	G5T1T2								SU		S1S2	
Death Valley beardtongue	G4T3		S3				S2					
Spine-noded milkvetch	G4	S2S3	S1?		S2		S2			S2		
Mackenzie's phacelia	G4T3								S3			
Least phacelia	G3				S2		S2		S1		S1?	
Nine Mile Canyon phacelia	G2		S2									
Parish phacelia	G2G3	S1	S1				S2S3					
Kelsey's phlox	G4			SR	S?	SR	SR					S2
Beaver Rim Phlox	G2											G2
Dorn's Twinpod	G1											S1
Mesamint	G3		S3						S1			
Silvies valley desert combleaf	G4TH								SR			
Narrowleaved cottonwood	G5	SR	S2S3	SR	SR	SR	SR	SR	S4	SR		S4S5
Soldier Meadow cinquefoil	G1		S1				S1					
Cottam cinquefoil	G1						S1			S1		
Ruby Mountain primrose	G1						S1					

Taxonomic group Species	Global rank	State Natural Heritage Program rank and occurrence										
		AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Slender wooly-heads	G4		S?		SH				SR		SR	
Sticky goldenweed	G1	S1										
Persistentsepal yellowcress	G3				SR	S1						S2S3
Bartonberry	G2				S2				S2			
Hoary willow	G5			S2	S2						S1S2	S2
Sierra sanicle	G4		SR		S1	SR	SR		SR		SR	S1
Schlesser pincushion	G1Q						S1					
Verrucose sea-purslane	G5	SR	SR	SE			SR	SR	S2	SR		S1
Shoshonea	G2					S1						S2
Oregon checker-mallow	G5T1										S1	
Spalding's silene	G2				S1	S1			S1		S2	
Cinquefoil tansy	G5		SR		S1		SR		SR			
Laramie False Sagebrush	G2											S2
Ute Ladies'-Tresses	G2			S2	S1	S2	SH			S1	S1	S1
Tall dropseed	G5	OCC		OCC	S1	SH		OCC	OCC	OCC	OCC	OCC
Woodsage	G5T5?	SR	S?	SR	S2	SR	SR	SR	SR	S1	SU	S1S2
Rock Springs Greenthread	G1									S1		S1
Uinta Greenthread	G1									S1		S1
Arrow-leaf thelypody	G2								S2			
Howell's spectacular thelypody	G2T1								S1			
**	G2			S1	S1	SH						S2
wavy-leaf thelypody	G3				S3							
Cedar Mtn. Easter Daisy	G1											S1
Barneby's Clover	G4T1											S1
**	G3G4				S2	S1			S1		S1?	
Leiberg's clover												

Species	Taxonomic group	Global rank	State Natural Heritage Program rank and occurrence										
			AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
**		G2										S2	
Rock violet		G1						S1			S1		

Key to rank designations

G = Global rank indicator, based on worldwide distribution at the species level
T = Global trinomial rank indicator, based on worldwide distribution at the infraspecific level
S = State rank indicator, based on distribution within the state at the lowest taxonomic level
1 = Critically imperiled due to extreme rarity, imminent threats, or and/or biological factors
2 = Imperiled due to rarity and/or other demonstrable factors
3 = Rare and local throughout its range, or with very restricted range, or otherwise vulnerable to extinction
4 = Apparently secure, though frequently quite rare in parts of its range, especially at its periphery
5 = Demonstrably secure, though frequently quite rare in parts of its range, especially at its periphery
_#_# = Range of uncertainty in a numeric rank (for example, G2G4 or S1S2)
H = Historical occurrence(s) only, presumed still extant and could be rediscovered
R = Reported from the state, awaiting firm documentation
U = Unrankable; present and possibly in peril, but not enough data yet to estimate rank
X = Extirpated from the state (SX) or extinct (GX or TX)
? = Not yet ranked at the scale indicated (G, T, or S)
B = Breeding status within the state; rank for breeding occurrences only
N = Non-breeding status within the state; rank for non-breeding occurrences only
Q = Taxonomic status Questionable or uncertain
OCC = Occurrence verified through source other than the Natural Heritage Program

Table 6. Taxon and associated number of species identified as being of conservation concern in the sagebrush ecosystem, resulting from application of our selection criteria described in the text.

Taxonomic group	Number of species	Percentage
Invertebrates	27	7.4
Amphibians	1	0.3
Reptiles	16	4.4
Birds	28	7.7
Mammals	38	10.5
Vascular plants	253	69.7
Total	363	100.0

Table 7. Final list of 363 species that we identified as being of conservation concern in the sagebrush ecosystem and their federal status and habitat associations (see Table 1 for habitat association codes), based on application of our selection criteria described in the text.

Taxonomic group Species	Scientific name	Federal status	Habitat associations
Invertebrates			
Spring Mountains acastus checkerspot	*Chlosyne acastus*	BLM	2/5/6
Salmon Oregonian	*Cryptomastix harfordiana*		1/2
Hells Canyon land snail	*Cryptomastix populi*	BLM	1/2
Baking Powder Flat blue	*Euphilotes battoides ssp.*	BLM	2
Spring Mountains dark blue	*Euphilotes enoptes ssp.*	BLM	2
Mattoni's blue	*Euphilotes rita mattonii*	BLM	2
Spring Mountains comma skipper	*Hesperia comma ssp.*	BLM	2/5/6
MacNeill's saltbush sootywing	*Hesperopsis gracielae*	BLM, FS	2
Nevada viceroy	*Limenitis archippus lahontani*	BLM	1/2/6
Deschutes sideband	*Monadenia fedelis ssp. 1*	BLM	1/2
Oregon snail (dalles sideband)	*Monadenia fidelis minor*	BLM	1/2
Keeled mountainsnail	*Oreohelix carinifera*		2
Enigmatic mountainsnail	*Oreohelix haydeni perplexa*		2
Costate mountainsnail	*Oreohelix idahoensis idahoensis*		2
Deep slide mountainsnail	*Oreohelix intersum*		1/2
Limestone Point mountainsnail	*Oreohelix n. sp. 18*		2
Hells Canyon mountainsnail	*Oreohelix sp. 29*		2
Pittsburg Landing mountainsnail	*Oreohelix sp. 30*		2
Big snowy mountainsnail	*Oreohelix strigosa berryi*		2
Dalles mountain snail	*Oreohelix variabilis*	BLM	2
Lava rock mountain snail	*Oreohelix waltoni*		2
Pahranagat naucorid bug	*Pelecoris shoshone shoshone*	BLM	
Steptoe Valley crescentspot	*Phyciodes pascoensis ssp.*	BLM	
Bleached sandhill skipper	*Polites sabuleti sinemaculata*	BLM	2
Atlantis fritillary	*Speyeria atlantis elko*		2/6
Grey's silverspot	*Speyeria atlantis greyi*	BLM	
Northwest hesperian	*Vespericola columbianus*	BLM	2
Amphibians			
Great Basin spadefoot	*Scaphiopus intermountanus*	BLM	2/5/6
Reptiles			
Desert collared lizard	*Crotaphytus insularis*		2
Mojave black-collared lizard	*Crotaphytus bicinctores*	BLM	2/3
Longnose leopard lizard	*Gambelia wislizenii*	BLM	2
Texas horned lizard	*Phrynosoma cornutum*	BLM, FS	1/2

Taxonomic group Species	Scientific name	Federal status	Habitat associations
Short-horned lizard	*Phrynosoma douglasi*		2/6
Desert horned lizard	*Phrynosoma platyrhinos*		2
Sagebrush lizard	*Sceloporus graciosus*	BLM	2/6
Desert spiny lizard	*Sceloporus magister*	BLM	2
Side-blotched lizard	*Uta stansburiana*	BLM	2
Night snake	*Hypsiglena torquata*	BLM	1/2/3/6
Utah milk snake	*Lampropeltis triangulum taylori*	BLM	1/2/3
Striped whipsnake	*Masticophis taeniatus*	FS	1/2/6
Longnose snake	*Rhinocheilus lecontei*	BLM	1/2
Ground snake	*Sonora semiannulata*	BLM	1/2/6
Midget faded rattlesnake	*Crotalus viridis concolor*	BLM	1/2
Massasauga	*Sistrurus catenatus*	BLM, FS	1/2
Birds			
Ferruginous Hawk	*Buteo regalis*	BLM, FS	1/2
Swainson's Hawk	*Buteo swainsoni*	BLM, FS	1/2/5/6
Prairie Falcon	*Falco mexicanus*	BLM	1/2
Sage Grouse	*Centrocercus urophasianus*	BLM, FS	2
Sage Grouse - western	*Centrocercus urophasianus*	BLM, FS	2
Gunnison Sage-Grouse	*Centrocercus minimus*	BLM, C	2
Sharp-tailed Grouse	*Tympanuchus phasianellus*	BLM, FS	1/2
Scaled Quail	*Callipepla squamata*		2
Long-billed Curlew	*Numenius americanus*	BLM	1/2
Short-eared Owl	*Asio flammeus*		1/2
Western Burrowing Owl	*Speotyto cunicularia*		1/2
Gray Flycatcher	*Empidonax wrightii*	FS	2/6
Rock Wren	*Salpinctes obsoletus*		1/2
Sage Thrasher	*Oreoscoptes montanus*	BLM	2
Loggerhead Shrike	*Lanius ludovicianus*	BLM, FS	2/6
MacGillivray's Warbler	*Oporornis tolmiei*		2
Virginia's Warbler	*Vermivora virginiae*	BLM	2/6
Grasshopper Sparrow	*Ammodramus savannarum*	BLM	1/2
Sage Sparrow	*Amphispiza belli*	BLM	2
Black-throated Sparrow	*Amphispiza bilineata*	BLM	2/3
Lark Bunting	*Calamospiza melanocorys*		2
Lark Sparrow	*Chondestes grammacus*		1/2/6
Green-tailed Towhee	*Pipilo chlorurus*	BLM, FS	2/6
Vesper Sparrow	*Pooecetes gramineus*	BLM	1/2
Brewer's Sparrow	*Spizella breweri*	BLM	1/2
Clay-colored Sparrow	*Spizella pallida*		1/2
Brewer's Blackbird	*Euphagus carolinus*		1r/2r/6r
Western Meadowlark	*Sturnella neglecta*	BLM	1/2/6

Taxonomic group Species	Scientific name	Federal status	Habitat associations
Mammals			
Merriam's shrew	*Sorex merriami*	BLM	1/2/6
Preble's shrew	*Sorex preblei*	BLM	1/2
California leaf-nosed bat	*Macrotus californicus*	BLM, FS	2
Pallid bat	*Antrozous pallidus*	BLM, FS	1/2/6
Spotted bat	*Euderma maculatum*	BLM, FS	2/6
Western small-footed myotis	*Myotis ciliolabrum*	BLM	1/2/6
Long-eared myotis	*Myotis evotis*	BLM	2/5/6
Fringed myotis	*Myotis thysanodes*	BLM, FS	1/2/6
Cave myotis	*Myotis velifer*	BLM	1/2
Yuma myotis	*Myotis yumanensis*	BLM	1r/2r/5r/6r
Townsend's big-eared bat	*Corynorhinus townsendii*	BLM, FS	2/5/6
California mastiff bat	*Eumops perotis californicus*	BLM	2/6
Big free-tailed bat	*Nyctinomops macrotis*	BLM	2/5/6
Kit fox	*Vulpes macrotis*	BLM	1/2
Pronghorn	*Antilocapra americana*		1/2
White-tailed antelope squirrel	*Ammospermophilus leucurus*	FS	2
Uinta ground squirrel	*Spermophilus armatus*		1/2
Southern Idaho ground squirrel	*Spermophilus brunneus endemicus*	BLM, FS	1/2
Wyoming ground squirrel	*Spermophilus elegans*		1/2
Townsend's ground squirrel	*Spermophilus townsendii*		2
Rock squirrel	*Spermophilus variegatus*	BLM	2/6
Washington ground squirrel	*Spermophilus washingtoni*	C	1/2
Cliff chipmunk	*Tamias dorsalis*	BLM	2/6
Fish Spring pocket gopher	*Thomomys bottae abstrusus*	BLM	2
San Antonio pocket gopher	*Thomomys bottae curtatus*	BLM	2
Cebolleta southern pocket gopher	*Thomomys bottae paquatae*	BLM	2/6
Merriam's kangaroo rat	*Dipodomys merriami*	BLM	1/2
Chisel-toothed kangaroo rat	*Dipodomys microps*	BLM	2
Ord's kangaroo rat	*Dipodomys ordii*		1/2
Dark kangaroo mouse	*Microdipodops megacephalus*	BLM	2
Little pocket mouse	*Perognathus longimembris*	BLM	2
Northern grasshopper mouse	*Onychomys leucogaster*		1/2
Canyon mouse	*Peromyscus crinitus*		1/2/3
Pinyon mouse	*Peromyscus truei*		2/5/6
Sagebrush vole	*Lemmiscus curtatus*		2
Black-tailed jackrabbit	*Lepus californicus*		1/2
White-tailed jackrabbit	*Lepus townsendii*		1/2
Pygmy rabbit	*Brachylagus idahoensis*	BLM, FS	2
Plants			

Taxonomic group Species	Scientific name	Federal status	Habitat associations
Henderson's ricegrass	*Achnatherum hendersonii*	BLM, FS	2
Desert needlegrass	*Achnatherum speciosum*		2/6
Cusick's giant-hyssop	*Agastache cusickii*	BLM, FS	2/6
Aase's onion	*Allium aaseae*		2
Two-headed onion	*Allium anceps*		2
Constricted Douglas' onion	*Allium constrictum*		2
Tolmie's onion	*Allium tolmiei persimile*	FS	2
Meadow pussytoes	*Antennaria arcuata*	BLM, FS	1/2
Bodie Hills rockcress	*Arabis bodiensis*	BLM, FS	2/6
Grouse Creek rockcress	*Arabis falcatoria*	BLM, FS	2
Elko rockcress	*Arabis falcifructa*	BLM	2
Mount Sapphire rockcress	*Arabis fecunda*	BLM, FS	2/6
Ophir rockcress	*Arabis ophira*	BLM, FS	2
Small Rock Cress	*Arabis pusilla*	BLM	2
Prickly-poppy	*Argemone munita rotundata*		2/6
Mystery wormwood	*Artemisia biennis var. diffusa*	BLM	2
Estes' artemisia	*Artemisia ludoviciana estesii*	BLM, FS	2
Packard's artemisia	*Artemisia packardiae*		2
Fuzzy sagebrush	*Artemisia papposa*		2
Porter's sagebrush	*Artemisia porteri*	BLM	2
Eastwood milkweed	*Asclepias eastwoodiana*	BLM, FS	2/6
Coral lichen	*Aspicilia fruticulosa*		2
Clokey milkvetch	*Astragalus aequalis*	BLM, FS	2/6
Purple milkvetch	*Astragalus agrestis*	BLM	2
Alvord milkvetch	*Astragalus alvordensis*		2
Challis milkvetch	*Astragalus amblytropis*		2
Sheep Mountain milkvetch	*Astragalus amphioxys var. musimonum*	BLM	2/6
Gunnison milkvetch	*Astragalus anisus*		2
Goose Creek milkvetch	*Astragalus anserinus*	BLM, FS	2/6
Astragalus anxius	*Astragalus anxius*	BLM	2/6
Lemhi milkvetch	*Astragalus aquilonius*	FS	2
Palouse milkvetch	*Astragalus arrectus*	FS	1/2
Mourning milkvetch	*Astragalus atratus inseptus*		2
Owyhee milkvetch	*Astragalus atratus owyheensis*		2
Barr's milkvetch	*Astragalus barrii*	FS	1/2/3
Beatley milkvetch	*Astragalus beatleyae*		2
Brandegee milkvetch	*Astragalus brandegei*		2/6
Cronquist milkvetch	*Astragalus cronquistii*	BLM	2
Barren milkvetch	*Astragalus cusickii var. sterilis*		2
Debeque milkvetch	*Astragalus debequaeus*	BLM	
Debris milkvetch	*Astragalus detritalis*	BLM	2/6
South Fork John Day milkvetch	*Astragalus diaphanus diurnus*	FS	2/6

Taxonomic group Species	Scientific name	Federal status	Habitat associations
Duchesne milkvetch	*Astragalus duchesnensis*	BLM	2/6
Horseshoe milkvetch	*Astragalus equisolensis*	BLM	2
Geyer's milkvetch	*Astragalus geyeri var. geyeri*	BLM	1/2
Gilman milkvetch	*Astragalus gilmanii*	BLM	2/6
Inyo milkvetch	*Astragalus inyoensis*	BLM	2/6
Starveling milkvetch	*Astragalus jejunus var. jejunus*	BLM, FS	2
Grand Junction milkvetch	*Astragalus linifolius*	BLM	2/6
Skiff milkvetch	*Astragalus microcymbus*	BLM	2/6
Pauper milkvetch	*Astragalus misellus var. pauper*		2
Mulford's milkvetch	*Astragalus mulfordiae*		2
Ferron milkvetch	*Astragalus musiniensis*	BLM	2/6
Newberry's milkvetch	*Astragalus newberryi*		2/6
Picabo milkvetch	*Astragalus oniciformis*		2
Egg milkvetch	*Astragalus oophorus*		2/6
Lavin eggvetch	*Astragalus oophorus var. lavinii*	BLM, FS	2/6
Long-calyx eggvetch	*Astragalus oophorus var. lonchocalyx*	BLM	2
Peck's milkvetch	*Astragalus peckii*	FS	1/2/3/5
Fisher Tower's milkvetch	*Astragalus piscator*	BLM	2
Ame's milkvetch	*Astragalus pulsiferae var. suksdorfii*	BLM	2
Snake River milkvetch	*Astragalus purshii var. ophiogenes*		2
San Rafael milkvetch	*Astragalus rafaelensis*	BLM	2'5/6
Spring Mountain milkvetch	*Astragalus remotus*	BLM, FS	2
Ripley's milkvetch	*Astragalus ripleyi*	BLM, FS	2/5/6
Trout Creek milkvetch	*Astragalus salmonis*		2
Bitterroot milkvetch	*Astragalus scaphoides*	BLM, FS	1/2
Sandstone milkvetch	*Astragalus sesquiflorus*	BLM	2/5/6
Whited's milkvetch	*Astragalus sinuatus*	BLM	2
Lonesome milkvetch	*Astragalus solitarius*	BLM	2
Sterile milkvetch	*Astragalus sterilis*		2
Bastard kentrophyta	*Astragalus tegetarioides*	BLM, FS	2/5/6
Four-wing milkvetch	*Astragalus tetrapterus*		2
Toquima milkvetch	*Astragalus toquimanus*	BLM, FS	2
Currant milkvetch	*Astragalus uncialis*	BLM, FS	2
Mud flat milk-vetch	*Astragalus yoder williamsii*	FS	2
Blue gramma	*Bouteloua gracilis*		1/2/6
Cane Spring evening-primrose	*Camissonia megalantha*	BLM	2
Palmer's evening primrose	*Camissonia palmeri*		2
Winged-seed evening primrose	*Camissonia pterosperma*		2/6
Green-tinged Indian paintbrush	*Castilleja chlorotica*	BLM, FS	2
Steens Mountain Paintbrush	*Castilleja pilosa steenensis*	BLM	2
Thick-stemmed wild cabbage	*Caulanthus crassicaulis*		2/6
Wild cabbage	*Caulanthus major nevadensis*	BLM	2/6

Taxonomic group Species	Scientific name	Federal status	Habitat associations
Hairy wild cabbage	*Caulanthus pilosus*		2/6
Large-flowered chaenactis	*Chaenactis macrantha*		2/6
Broad-flowered pincushion	*Chaenactis stevioides*		2
Desert chaenactis	*Chaenactis xantiana*		2/6
Remote rabbitbrush	*Chrysothamnus eremobius*	BLM	2/6
Dwarf gray rabbitbrush	*Chrysothamnus nauseosus nanus*		2
Ownbey's thistle	*Cirsium ownbeyi*	BLM	2/6
Bristle-flowered collomia	*Collomia macrocalyx*		2
Barren Valley collomia	*Collomia renacta*	BLM	2
Low hawkseed	*Crepis modocensis modocensis*		2/5/6
Low cryptantha	*Cryptantha humilis*		
Tufted cryptantha	*Cryptantha caespitosa*		2/6
Gray cryptantha	*Cryptantha leucophaea*		2
Malheur cryptantha	*Cryptantha propria*		2
Schoolcraft's catseye	*Cryptantha schoolcraftii*	BLM	2
Snake river cryptantha	*Cryptantha spiculifera*		2
White River catseye	*Cryptantha welshii*	BLM	2/6
Sepal-tooth dodder	*Cuscuta denticulata*		2
Bodie Hills draba	*Cusickiella quadricostata*	BLM, FS	2/6
Greeley's cymopterus	*Cymopterus acaulis greeleyorum*	BLM	2/6
Ibapah spring-parsley	*Cymopterus ibapensis*		2
Sanicle biscuitroot	*Cymopterus ripleyi var. saniculoides*	BLM	2/6
Dermatocarpon	*Dermatocarpon lorenzianum*		
Gold Butte moss	*Didymodon nevadensis*	BLM	
Yellowstone draba	*Draba incerta*		2
White eatonella	*Eatonella nivea*	BLM	2/6
Nevada willowherb	*Epilobium nevadense*	BLM, FS	2/6
Bisti fleabane	*Erigeron bistiensis*		1/2
Broad fleabane	*Erigeron latus*	BLM	2
Piper's daisy	*Erigeron piperianus*		2
Windloving buckwheat	*Eriogonum anemophilum*	BLM	2
Brandegee wild buckwheat	*Eriogonum brandegei*	BLM, FS	2/6
Welsh's buckwheat	*Eriogonum capistratum var. welshii*	FS	
Grand buckwheat	*Eriogonum contortum*	BLM	2
Crosby's buckwheat	*Eriogonum crosbyae*	BLM	2
Cusick's buckwheat	*Eriogonum cusickii*	BLM	2/6
Ephedra buckwheat	*Eriogonum ephedroides*	BLM	2
Clokey buckwheat	*Eriogonum heermannii var. clokeyi*	BLM, FS	2
Rabbit wild buckwheat	*Eriogonum lagopus*		2/6
Lewis buckwheat	*Eriogonum lewisii*	BLM, FS	2/3
Steamboat buckwheat	*Eriogonum ovalifolium var. williamsiae*	E	2
Prostrate buckwheat	*Eriogonum prociduum*	BLM, FS	2/5/6

Taxonomic group Species	Scientific name	Federal status	Habitat associations
Altered andesite buckwheat	*Eriogonum robustum*	BLM	2/6
Playa buckwheat	*Eriogonum salicornioides*	BLM	2
Packard's cowpie buckwheat	*Eriogonum shockleyi packardiae*		2
Matted cowpie buckwheat	*Eriogonum shockleyi shockleyi*		2
Frisco buckwheat	*Eriogonum soredium*	BLM	2/6
Woodside buckwheat	*Eriogonum tumulosum*	BLM	2/6
Sunnyside green gentian	*Frasera gypsicola*		2
Pahute green gentian	*Frasera pahutensis*	BLM	2/6
Castle Lake bedstraw	*Galium glabrescens*		2
Aztec gilia	*GilIa formosa*		2
Dwarf greasebush	*Glossopetalon pungens var. pungens*	BLM	2/6
White-margined wax plant	*Glyptopleura marginata*		2/3
Cronquist's stickseed	*Hackelia cronquistii*		2
Bugleg goldenweed	*Haplopappus insecticruris*	FS	2
Radiate goldenweed	*Haplopappus radiatus*	FS	2
Western sweetvetch	*Hedysarum occidentale*	FS	2/6
Cooper's hymenoxys	*Hymenoxys cooperi canescens*		2/6
**	*Hymenoxys acaulis var. nana*	BLM	2/6
Richardson's bitterweed	*Hymenoxys richardsonii*		2/6
Longsepal globemallow	*Iliamna longisepala*	FS	2
Spreading gilia	*Ipomopsis polycladon*		2/6
Sierra Valley ivesia	*Ivesia aperta var. aperta*	BLM, FS	1/2/5/6
Ash Creek mousetail	*Ivesia paniculata*	BLM	2/6
Grimy mousetail	*Ivesia rhypara*		2
Grimy ivesia	*Ivesia rhypara rhypara*	BLM	2
Plumas mousetail	*Ivesia sericoleuca*	BLM, FS	1/2/6
Webber ivesia	*Ivesia webberi*	FS	2/6
Grimes vetchling	*Lathyrus grimesii*	BLM, FS	2
Davis' peppergrass	*Lepidium davisii*		2
Slick-spot peppergrass	*Lepidium papilliferum*	FS	2
Bruneau River prickly phlox	*Leptodactylon glabrum*	BLM	2
Hazel's prickly-phlox	*Leptodactylon pungens hazeliae*	FS	2/5/6
Sidesaddle bladderpod	*Lesquerella arenosa var. argillosa*	BLM	
Fremont bladderpod	*Lesquerella fremontii*	BLM, FS	2/6
Western bladderpod	*Lesquerella occidentalis*		2
Prostrate bladderpod	*Lesquerella prostrata*	BLM	1/2/6
Spreading pygmyleaf	*Loeflingia squarrosa var. squarrosa*	BLM	2
Colorado desert parsley	*Lomatium concinnum*	BLM	2
Wideleaf bisquitroot	*Lomatium latilobum*	BLM, FS	2/6
Ochoco lomatium	*Lomatium ochocense*	BLM, FS	2
Packard's lomatium	*Lomatium packardiae*		2
Rose's lomatium	*Lomatium roseanum*		2

Taxonomic group Species	Scientific name	Federal status	Habitat associations
Biddle's lupine	*Lupinus biddlei*		2/6
Cusick's lupine	*Lupinus cusickii*		
Inch-high lupine	*Lupinus uncialis*		2
Dolores River skeletonplant	*Lygodesmia doloresensis*	BLM	2/6
Fringed waterplantain	*Machaerocarpus californicus*		1/2/6
Torrey's malacothrix	*Malacothrix torreyi*	BLM	2
Nodding melic	*Melica stricta*		2/5/6
Smooth mentzelia	*Mentzelia mollis*	BLM	2
Bank monkey flower	*Mimulus clivicola*	FS	2/5
Egg Lake monkey flower	*Mimulus pygmaeus*	BLM	2/6
Suksdorf's monkey-flower	*Mimulus suksdorfii*	FS	2/6
Bigelow's four-o'clock	*Mirabilis bigelovii retrorsa*		1/2
Annual dropseed	*Muhlenbergia minutissima*		2/5/6
Green needlegrass	*Nassella viridula*		1/2/5/6
Rigid threadstem	*Nemacladus rigidus*		2/6
Coyote tobacco	*Nicotiana attenuata*	FS	1/2/5/6
Challis crazyweed	*Oxytropis besseyi salmonensis*	FS	2
Bristly combseed	*Pectocarya setosa*		1/2/6
Dwarf louse wort	*Pedicularis centranthera*	BLM	2
Simpson's hedgehog cactus	*Pediocactus simpsonii robustior*		2
Absaroka Beardtongue	*Penstemon absarokensis*	BLM	
Stemless beardtongue	*Penstemon acaulis*	BLM	2/6
Broadbeard beardtongue	*Penstemon angustifolius*	BLM	1/2/6
Yellow twotone beardtongue	*Penstemon bicolor ssp. bicolor*	BLM, FS	
Cary's beardtongue	*Penstemon caryi*	BLM, FS	2/6
Tunnel Springs beardtongue	*Penstemon concinnus*	BLM, FS	2/6
Cordelia beardtongue	*Penstemon floribundus*	BLM	2/6
Gibben's Beardtongue	*Penstemon gibbensii*	BLM	1/2/6
Blue-leaf beardtongue	*Penstemon glaucinus*	BLM, FS	
Harrington beardtongue	*Penstemon harringtonii*	BLM, FS	2/6
Idaho penstemon	*Penstemon idahoensis*	BLM, FS	2/6
Antelope valley beardtongue	*Penstemon janishiae*		2/6
King's beardtongue	*Penstemon kingii*		
Lemhi beardtongue	*Penstemon lemhiensis*	BLM, FS	2/3
Pahute Mesa beardtongue	*Penstemon pahutensis*	BLM	
Aquarius Plateau beardtongue	*Penstemon parvus*	FS	1/2
Minidoka beardtongue	*Penstemon perpulcher*		2
Bashful beardtongue	*Penstemon pudicus*	BLM	2/6
Short-lobe penstemon	*Penstemon seorsus*		2
Ward's beardtongue	*Penstemon wardii*	BLM, FS	2/6
Squaw apple	*Peraphyllum ramosissimum*		2/5/6
Beatley scorpion plant	*Phacelia beatleyae*	BLM	2

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Naked-stemmed phacelia	*Phacelia gymnoclada*		2
Obscure scorpion plant	*Phacelia inconspicua*	FS	2
Playa phacelia	*Phacelia inundata*		2/6
Mono phacelia	*Phacelia monoensis*	BLM	2/6
Chambers' twinpod	*Physaria chambersii*		2
Small-flowered ricegrass	*Piptatherum micranthum*		1/2/5/6
Hairy-foot plantain	*Plantago eriopoda*		1/2
Washington polemonium	*Polemonium pectinatum*	BLM	2
Desert combleaf	*Polyctenium fremontii var. confertum*	BLM	2
Williams combleaf	*Polyctenium williamsiae*	FS	2
Austin's knotweed	*Polygonum austiniae*		2
Modoc County knotweed	*Polygonum polygaloides esotericum*	BLM	2/6
Pygmy poreleaf	*Porophyllum pygmaeum*	BLM	2/6
Alkali primrose	*Primula alcalina*	FS	9
Snake River goldenweed	*Pyrrocoma radiata*		2
California chicory	*Rafinesquia californica*		2/6
Columbian yellowcress	*Rorippa columbiae*	BLM, FS	1/2
Clokey Mountain sage	*Salvia dorrii var. clokeyi*	BLM, FS	2
Blaine pincushion	*Sclerocactus blainei*	BLM	1/2
Mesa Verde cactus	*Sclerocactus mesae-verdae*		2
Nye pincushion	*Sclerocactus nyensis*	BLM	2
Homgren's skullcap	*Scutellaria holmgreniorum*	BLM	2/6
Dwarf skullcap	*Scutellaria nana*		2/5/6
Ertter's ragwort	*Senecio ertterae*		2
Jan's catchfly	*Silene nachlingerae*	BLM, FS	2/6
Jones globemallow	*Sphaeralcea caespitosa*	BLM, FS	2
Biennial prince-plume	*Stanleya confertiflora*	BLM	2
Wooly mock goldenweed	*Stenotus lanuginosus*	BLM	2/6
Malheur wire-lettuce	*Stephanomeria malheurensis*	E	2
Tiehm stroganowia	*Stroganowia tiehmii*	BLM	2
Stylocline	*Stylocline filaginea*		2
Malheur stylocline	*Stylocline psilocarphoides*		2
Long-flowered snowberry	*Symphoricarpos longiflorus*		2/6
Wovenspore lichen	*Texosporium sancti-jacobi*		2
Howell's thelypody	*Thelypodium howellii howelli*	FS	2
Purple thick-leaved thelypody	*Thelypodium laciniatum streptanthoides*		2
**	*Tortula bartramii*		2
Gypsum Townsend's aster	*Townsendia gypsophila*		2
Charleston grounddaisy	*Townsendia jonesii var. tumulosa*	BLM, FS	2
Scapose townsendia	*Townsendia scapigera*		2/5/6
Currant Summit clover	*Trifolium andinum var. podocephalum*	BLM, FS	2/6
Owyhee clover	*Trifolium owyheense*		2

Taxonomic group Species	Scientific name	Federal status	Habitat associations
Desert yellowhead	*Yermo xanthocephalus*	PT	2

[a] Federal status is as follows: BLM - designated as sensitive by the Bureau of Land Management; FS - designated as sensitive by the USDA Forest Service; E - listed as endangered by the U.S. Fish and Wildlife Service; and PT - proposed for listing as threatened under the Endangered Species Act.

Table 8. Status and occurrence by state of the 363 species that we identified as being of conservation concern in association with the sagebrush ecosystem.

Taxonomic group Species	Global rank	State Natural Heritage Program rank and occurrence										
		AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Invertebrates												
Spring Mountains acastus checkerspot	G4G5T1						S3					
Salmon oregonian	G?				S?							
Hells Canyon land snail	G2				S?				S1			
Baking Powder Flat blue	G5T1						S1					
Spring Mountains dark blue	G1						S1					
Mattoni's blue	G3G4T1						S1					
Spring Mountains comma skipper	G5T1						S1					
MacNeill's saltbush sootywing	G2	S?	S3				S1			S1		
Nevada viceroy	G5T2T3						S2					
Deschutes sideband	G?T1								S1			
Oregon snail (dalles sideband)	G?T2		S?						S2		S2?	
Keeled mountainsnail	G1					S1						
Enigmatic mountainsnail	G2G3T?				S?							
Costate mountainsnail	G1G3T1T3				SU							
Deep slide mountainsnail	G?				S?							
Limestone Point mountainsnail	G?				S?							
Hells Canyon mountainsnail	G?				S?				S1?			
Pittsburg Landing mountainsnail	G?				S?							
Big snowy mountainsnail	G5T2					S1S2						S?
Dalles mountain snail	F2								S2			
Lava rock mountain snail	G1G3				SU							
Pahranagat naucorid bug	G1						S1					
Steptoe Valley crescentspot	G5T1						S1					

Taxonomic group Species	Global rank	State Natural Heritage Program rank and occurrence AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Bleached sandhill skipper	G5T1						S1					
Atlantis fritillary	GRT2						S2					
Grey's silverspot	GRT1T2						S1S2					
Northwest hesperian	G?								S?		S?	
Amphibians												
Great Basin spadefoot	G5	S2	S5	S3	S4	SR	S4		S5	S4	S5	S4
Reptiles												
Desert collared lizard	G5	S3?	S?		S2		S4		S2	S4		
Mojave black-collared lizard	G5	S3?	S?		S2		S4		S2	S4		
Longnose leopard lizard	G5	S5	S5	S1	S5		S4	S5	S4	S4		
Texas horned lizard	G4G5	S3S4		S3				S4				
Short-horned lizard	G5		S4		S5		S?		S4?		S5	
Desert horned lizard	G5	S5	S5		S4		S4		S3	S4		
Sagebrush lizard	G5	S3S4	S5	S5	S5	S3S4	S4	S4	S5	S5	S5	S5
Desert spiny lizard	G5	S5	S5	S2			S5	S5		S3S4		
Side-blotched lizard	G5	S5	S5	S4	S5		S5	S5	S5	S5	S5	
Night snake	G5	S5	S5	S3	S3		S5	S5	S3	S4	S4	
Utah milk snake	G5T4Q	S2		S2?						OCC		
Striped whipsnake	G5	S4	S4	S4	S4		S5	S5	S4	S5	S1	
Longnose snake	G5	S5	S5	S1?	S3		S5	S5		S3		
Ground snake	G5	S5	S4	S3	S3		S5	S5	S2	S2		
Midget faded rattlesnake	G5T4			S3?								S1S2
Massasauga	G3G4	S2		S2				S3S4				
Birds												
Ferruginous Hawk	G4TU	S2B,S4N	S3S4	S3B,S4N	S3B,SZN	S3B,SZN	S3	S2B,S4N	S3B	S2N,S2S3B	S2B,SZN	S3B,S3N
Swainson's Hawk	G5	S3	S2	S5B	S4B,SZN	S4B,SZN	S2B	S4B,S4N	S3B	S3B,SRN	S3B,SZN	S4B,SZN

Taxonomic group Species	Global rank	AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
		State Natural Heritage Program rank and occurrence										
Prairie Falcon	G5	S4	S3	S4B,S4N	S5B,S3N	S4	S4	S4B,S4N	S4	S4	S3B,S3N	S4B,S4N
Sage Grouse	G4	SR	S3	S4	S4	S4	S4	SHB,SHN	S3	S2	S3	S3
Sage Grouse - western	G4T3Q								S3		S3	
Gunnison Sage-Grouse	G1			S1						S1		
Sharp-tailed Grouse	G4	S4	SX	S2	S3	S4	SX	SHB,SHN	SX	S1S2	S2	S4
Scaled Quail	G5	S5		S4			SE	S5B,S5N		SE	SE	
Long-billed Curlew	G5	S1B,S3S4N	S2	S2B,SZN	S3B,SZN	S4B,SZN	S3?B	S4B	S3S4	S3B	S2B,S2N	S3B,SZN
Short-eared Owl	G5	SN	S3	S2B,SZN	S5	S4	S4	S2N	S4?	S2S3	S4B,S4N	S2S3
Western Burrowing Owl	G4TU	S3	S2		S3S4		S3B	S4B,S4N	S2?B			S?
Gray Flycatcher	G5	S5	S5	S5B	S2B,S2N		S4B	S4B,S4N	S4?	S4S5B	S2B,SZN	S4B,S4N
Rock Wren	G5	S5	S5	S4	S5B,SZN	S5B,SZN	S5	S5B,S5N	S5	S3N,S4S5B	S5B,SZN	S5B,S5N
Sage Thrasher	G5	S5	S5	S5	S5B,SZN	S5B,SZN	S5B	S4B,S5N	S4	S4S5B,SAN	S3B,SZN	S3B,SZN
Loggerhead Shrike	G4	S4	S4	S3S4B,SZN	S3	S4B,SZN	S3	S4B,S4N	S4B,S2N	S3S4N,S4B	S3B,SZN	S4B,SZN
MacGillivray's Warbler	G5	S4	S?	S4B,SZN	S5B,SZN	S5B,SZN	S4B	S5B,S5N	S4	S4S5B	S5B,SZN	S5B,S5N
Virginia's Warbler	G5	S5	S2S3	S5	S2B,SZN	SR	S4?B	S4B,S4N		S4S5B		S2B,SZN
Grasshopper Sparrow	G5	S3	S2	S3S4B,SZN	S3B,SZN	S4B,SZN	S3B	S3B,S4N	S2?B	S1B	S3B,SZN	S3B,SZN
Sage Sparrow	G5	S4	S?	S3B,SZN	S4B,SZN	S1B,SZN	S4B,S4N	S4B,S4N	S4	S3S4	S3B,SZN	S3B,SXN
Black-throated Sparrow	G5	S5	S?	S3B,SZN	S2B,SZN		S5B	S5B,S5N		S2N,S5B	SZN	SAB,SZN
Lark Bunting	G5	S1B,S5N	S?	S4	S1?B,SZN	S4B,SZN		S4B,S5N		S2S3B	SZN	S4B,SZN
Lark Sparrow	G5	S5	S?	S4	S5B,SZN	S5B,SZN	S4B	S5B,S4N	S4?	S2N,S5B	S4B,SZN	S5B,S5N
Green-tailed Towhee	G5	S3B,S4N	S?	S5	S5B,SZN	S4B,SZN	S5B	S4B,S4N	S4?	S4B	S1B	S5B,S5N
Vesper Sparrow	G5	S5	S?	S5	S4B,SZN	S5B,SZN	S4B	S5B,S4N	S4B	S2N,S5B	S4B,SZN	S5B,S5N
Brewer's Sparrow	G5	S5	S?	S4B,SZN	S4B,SZN	S4B,SZN	S4?B	S3B,S4N		S4S5B	S4B,SZN	S3B,SZN
Clay-colored Sparrow	G5	S1N				S4B,SZN		S4N	SZN		SZN	S3B,SZN
Brewer's Blackbird	G5	S5	S?	S5B,S4N	S5B,S5N	S5B,SZN	S5B	S5B,S5N		S4S5	S5	S5B,S5N
Western Meadowlark	G5	SZN	S?	S5	S5B,S3N	S5B,SZN	S5	S5B,S5N	S5	S5	S5B,S5N	S5B,S5N

Taxonomic group Species	Global rank	State Natural Heritage Program rank and occurrence										
		AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Mammals												
Merriam's shrew	G5	S3	S3	S3	S2?	S3	S3	S2	S3	S2?	S3	S3S4
Preble's shrew	G4		S?	S1		S3	S2	S1	S3	S1	SR	S1S2
California leaf-nosed bat	G4	S3S4	S2S3				S2					
Pallid bat	G5	S4S5	S3	S4	S1?	S1	S3B	S5	S3	S3	S3	S1B,SXN
Spotted bat	G4	S1S2	S2S3	S2	S2	S1	S1S2	S3	S1	S2	S3	S1B,SZN
Western small-footed myotis	G5	S3	S?	S4	S4?	S4	S3B	S5	S3	S2	S4	S3B,S3N
Long-eared myotis	G5	S3S4	S4?	S4	S3?	S4	S4B	S4	S3	S4B,SZN	S3	S1B,S1?N
Fringed myotis	G4G5	S3S4	S4	S3	S1?	S3	S2B	S5	S3	S2B,SZN?	S3?	S1B,S1N
Cave myotis	G5	S4	S1				SR	S4				
Yuma myotis	G5	S3S4	S5	S3	S3?	S3	S4B	S5	S3	S3	S5	S1/B,SZ?N
Townsend's big-eared bat	G4	S3	S3S4	S2	S2?	S2S3	S3B	S3	S4	S2	S1	S1B,S2N
California mastiff bat	G5T4	S1S2	S?				S1					
Big free-tailed bat	G5	S2S3	S2	S1?			S1N	S2		S2B		
Kit fox	G4	S4	S3S4	S1	S1		S4	S4	S?	S3		
Pronghorn	G5	S5	S4	S4	S5	S5	S5	S5	S4	S4	SE	S5
White-tailed antelope squirrel	G5	S5	S5	S4	S4		S5	S4	S4?	S5		
Uinta ground squirrel	G5				S4?	S4				S5		S3S4
Southern Idaho ground squirrel	G2T2				S2							
Wyoming ground squirrel	G5			S5	S4?	S3	S5		SX	S2S3	S3S4	
Townsend's ground squirrel	G4										S4	
Rock squirrel	G5	S5	S2	S5	S1		S5	S5		S5		
Washington ground squirrel	G2								S2		S2	
Cliff chipmunk	G5	S5		S2	S1?		S5	S4		S4		S1
Fish Spring pocket gopher	G5TH						SH					
San Antonio pocket gopher	G5TH						SH					
Cebolleta southern pocket gopher	G5T2							S2				
Merriam's kangaroo rat	G5	S5	S5				S5	S5		S3		

Taxonomic group Species	Global rank	State Natural Heritage Program rank and occurrence										
		AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Chisel-toothed kangaroo rat	G5	S3	S4		S3?		S5		S4?	S3		
Ord's kangaroo rat	G5	S5	S3S4	S5	S5	S4	S4	S5	S4	S5	S3S4	S5
Dark kangaroo mouse	G5		S3S4		S1		S2		S4?	S2		
Little pocket mouse	G5	S5	S5		S1?		S5		S4?	S3		
Northern grasshopper mouse	G5	S5	S3S4	S5	S4	S5	S5	S5	S4?	S4S5	S5	S5
Canyon mouse	G5	S4	S5	S4	S3S4		S5	S3	S4	S5		S1
Pinyon mouse	G5	S5	S5	S4	S2		S5	S5	S4?	S4S5		S4
Sagebrush vole	G5		S4	S?	S4	S4	S5		S4	S3S4	S2S3	S5
Black-tailed jackrabbit	G5	S5	S5	S5	S5	S2S3	S5	S5	S4	S5	S4	S5
White-tailed jackrabbit	G5		S3	S4	S5	S4S5	S5	S2	S4?	S3S4	S4	S4
Pygmy rabbit	G4		S3		S3	S2S3	S4?		S2?	S2S3	S1	S2
Plants												
Henderson's ricegrass	G3								S2		S2	
Desert needlegrass	G5	SR	SR	SR			SR		S2	SR		
Cusick's giant-hyssop	G3G4				SR	S1	S2		S2			
Aase's onion	G3				S3							
Two-headed onion	G4		SR		S2		SR		S?			
Constricted Douglas' onion	G2										S2	
Tolmie's onion	G4T3				S3							
Meadow pussytoes	G2				S1		S1					S2
Bodie Hills rockcress	G2		S1				S2					
Grouse Creek rockcress	G1						S1			S1		
Elko rockcress	G1G2						S1S2					
Mount Sapphire rockcress	G2					S2						
Ophir rockcress	G1G2						S1S2					
Small Rock Cress	G1											S1
Prickly-poppy	G4T4	SR	SR		S1		SR		S2	SR		
Mystery Wormwood	G5T1Q									S1?		S1

Taxonomic group Species	Global rank	State Natural Heritage Program rank and occurrence										
		AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Estes' artemisia	G5T2								S2			
Packard's artemisia	G3				S3		S2		S3			
Fuzzy sagebrush	G4				S4		S2		S2			
Porter's sagebrush	G2											S2
Eastwood milkweed	G2Q						S2					
Coral lichen	G3				S3?	S1	S1		OCC	OCC	OCC	
Clokey milkvetch	G2						S2					
Purple milkvetch	G5		S?	SR	SR	SR	SR	SR	SR	SR	S2?	S5
Alvord milkvetch	G4						S2		S4			
Challis milkvetch	G3				S3							
Sheep Mountain milkvetch	G5T2	SH					S2					
Gunnison milkvetch	G2			S2								
Goose Creek milkvetch	G2				S1		S1			S1		
Astragalus anxius	G1		S1									
Lemhi milkvetch	G3				S3							
Palouse milkvetch	G2				SR				SR		S2	
Mourning milkvetch	G4G5T3				S3							
Owyhee milkvetch	G4G5T3				S3		SR		S3			
Barr's milkvetch	G3					S3						S3
Beatley milkvetch	G3						S3					
Brandegee milkvetch	G5	OCC		S1S2				OCC		OCC		
Cronquist milkvetch	G2			S2						S1		
Barren milkvetch	G5T2				S1				S2			
Debeque milkvetch	G2			S2								
Debris milkvetch	G3			S2						S3		
South Fork John Day milkvetch	G3G4								S4		SX	
Duchesne milkvetch	G3			S1S2						S3		
Horseshoe milkvetch	G5T1			S?						S1		
Geyer's milkvetch	G4?T4?		S2		SR	S2	SR		SR		SR	SR

Taxonomic group Species	Global rank	State Natural Heritage Program rank and occurrence										
		AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Gilman milkvetch	G3		S3				S1					
Inyo milkvetch	G2		SR				S1					
Starveling milkvetch	G3T3			S1	S2		SR			S1		S3
Grand Junction milkvetch	G3Q			S3								
Skiff milkvetch	G1			S1								
Pauper milkvetch	G4T3								SR		S3	
Mulford's milkvetch	G2				S2				S1			
Ferron milkvetch	G2			S1						S2		
Newberry's milkvetch	G5	S1	S?	S1	S?		SR	S5	SR	SR		
Picabo milkvetch	G3				S3							
Egg milkvetch	G4	SR	S?	SR			S4	S?	SU	S3		
Lavin eggvetch	G4T2		S1				S2					
Long-calyx eggvetch	G4T2		S?				S2			S1S2		
Peck's milkvetch	G3								G3			
Fisher Tower's milkvetch	G2G3			S1						S2		
Ame's milkvetch	G4T3?		S3?				S1				S1	
Snake River milkvetch	G5T3				S3				S3			
San Rafael milkvetch	G3			S1						S2S3		
Spring Mountain milkvetch	G2						S2					
Ripley's milkvetch	G3			S2				S3?				
Trout Creek milkvetch	G3G4				S3		SR		SR			
Bitterroot milkvetch	G3				S3	S2						
Sandstone milkvetch	G3?	SR		S1						S3		
Whited's milkvetch	G1										S1	
Lonesome milkvetch	G3						S1		S3			
Sterile milkvetch	G5T2				S1				S2			
Bastard kentrophyta	G3		S?						S3			
Four-wing milkvetch	G4	SR			S1		SR		S4	S3		
Toquima milkvetch	G2						S2					

Taxonomic group Species	Global rank	State Natural Heritage Program rank and occurrence										
		AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Currant milkvetch	G2						S1S2			S2		
Mud flat milk-vetch	G3				S3		S1		SR			
Blue gramma	G5	SR	SR	SR	S2	SR	SR	SR		SR		S5
Cane Spring evening-primrose	G3Q						S3					
Palmer's evening primrose	G3	SU	SR		S1		SR		SU			
Winged-seed evening primrose	G4	SR	SR		S2		SR		SR	S1		
Green-tinged Indian paintbrush	G3								S3			
Steens Mountain Paintbrush	G4?T3								S3			
Thick-stemmed wild cabbage	G4G5		SR	SR	SR		SR		S4	SR		S2
Wild cabbage	G4T3?		SR				SR		S1			
Hairy wild cabbage	G4		SR		SR		SR		S4	S2?		
Large-flowered chaenactis	G4	SR	SR		SR		SR		S2	SR		
Broad-flowered pincushion	G4	SR	SR	SR	S2		SR	SR	S2	S3		S2
Desert chaenactis	G4G5		OCC				OCC		S1?			
Remote rabbitbrush	G1						S1					
Dwarf gray rabbitbrush	G5T4				S3				S4		S?	
Ownbey's thistle	G3			S2						S1		S2
Bristle-flowered collomia	G3G4				SR				S3S4		S1	
Barren Valley collomia	G1Q						S1		S1			
Low hawkseed	G4G5T		SR	SR	SR	SR	SR		SU		SR	SR
Low cryptantha	G4?	SR	SR	S?	SR	SH	SR		SU	S?		
Tufted cryptantha	G4			S2	S1					S1?		S3
Gray cryptantha	G2G3								SH		S2S3	
Malheur cryptantha	G4				S1				S4			
Schoolcraft's catseye	G3Q						S3					
Snake river cryptantha	G4?		SR		SR	S3	SR		SU	S1	S2?	S1
White River catseye	G3						S3					
Sepal-tooth dodder	G4	SR	S?	SR	S1		SR			SR	S1	
Bodie Hills draba	G2		S2				S2					

Taxonomic group Species	Global rank	State Natural Heritage Program rank and occurrence										
		AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Greeley's cymopterus	G5T2				S2				S1			
Ibapah spring-parsley	G4				S2		SR		SU	SR		
Sanicle biscuitroot	G3G4		S1				S2					
Dermatocarpon	G2				S1							
Gold Butte moss	G2G3			OCC			S1	OCC		OCC		
Yellowstone draba	G5			S1	S2	SR				S1	SR	S3
White eatonella	G4		SR		S3		SR		SR		S1	
Nevada willowherb	G2						S2			S1		
Bisti fleabane	G1							S1				
Broad fleabane	G2				S2		S1					
Piper's daisy	G3										S3	
Windloving buckwheat	G2G3						S2S3					
Brandegee wild buckwheat	G1G2			S1S2								
Welsh's buckwheat	G4T2				S2							
Grand buckwheat	G3			S2						S2		
Crosby's buckwheat	G3						S3		S2			
Cusick's buckwheat	G2								S2			
Ephedra buckwheat	G3			S1						S3		
Clokey buckwheat	G5T2						S2					
Rabbit wild buckwheat	G3					S3						S2
Lewis buckwheat	G3Q						S3					
Steamboat buckwheat	G5T1						S1					
Prostrate buckwheat	G3		S2				S1		S2			
Altered andesite buckwheat	G2						S2S3					
Playa buckwheat	G3G4				S3		SR		S3			
Packard's cowpie buckwheat	G5T2				S2							
Matted cowpie buckwheat	G5T4	SR	S3	SR	S2		SR	SR		SR		
Frisco buckwheat	G1									S1		
Woodside buckwheat	G3			S2						S2		

Taxonomic group Species	Global rank	State Natural Heritage Program rank and occurrence AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Sunnyside green gentian	G1						S1			S1		
Pahute green gentian	G3						S3					
Castle Lake bedstraw	G4?		S?						SR			
Aztec gilia	G3							S2				
Dwarf greasebush	G2G3		S1				S2S3					
White-margined wax plant	G4	SU	SR		S3		SR		SR	SR		
Cronquist's stickseed	G3				S1				S2			
Bugleg goldenweed	G3				S3							
Radiate goldenweed	G3				S3				S2			
Western sweetvetch	G5			SR	SR	SR			SR	S2?	S?	S4
Cooper's hymenoxys	G4G5T4	SR	SR		SR		SR		S1			
**	G5T1T2									S1S2		
Richardson's bitterweed	G4	SR		SR	S1	SR		SR		SR		SR
Longsepal globemallow	G3								S?		S3	
Spreading gilia	G4	SR	SR	SR	S2		SR	SR	SR	SR		S1
Sierra Valley ivesia	G2T2		S2				S1					
Ash Creek mousetail	G2		S2									
Grimy mousetail	G2						S1		S1			
Grimy ivesia	G2T2						S2		S1			
Plumas mousetail	G2		S2				SR					
Webber ivesia	G2		S2				S2					
Grimes vetchling	G3						S3					
Davis' peppergrass	G3				S3		S1		S1			
Slick-spot peppergrass	G2				S2							
Bruneau River prickly phlox	G2				S2		S1					
Hazel's prickly-phlox												
Sidesaddle Bladderpod	G5T2T3			S1								S1
Fremont Bladderpod	G2											S2
Western Bladderpod	G4		SR		S?		SR		SR	SR	SR	

Taxonomic group	Global	State Natural Heritage Program rank and occurrence										
Species	rank	AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Prostrate Bladderpod	G3				SR					S1		S1
Spreading pygmyleaf	G5T4?	SR	S?				SR			SR	S1	S1
Colorado desert parsley	G2			S2								
Wideleaf bisquitroot	G1			S1						S1		
Ochoco lomatium	G2G3								S1?			
Packard's lomatium	G2				S1		S1?		S?			
Rose's lomatium	G2G3						S2S3		SR			
Biddle's lupine	G5T3								S3			
Cusick's lupine	G1				SR				S1		SR	
Inch-high lupine	G4		S1		S2		SR		SR			
Dolores River skeletonplant	G1Q			S1						S1		
Fringed waterplantain	G4		SR		S2		SR		SU		S1	
Torrey's malacothrix	G4	SR	SU	SR	S2	S1	SR		S4	SR		S2
Nodding melic	G4		SR				SR		S3	SR		
Smooth mentzelia	G2				S2		S1		S2			
Bank monkey flower	G4				S3				S2		SR	
Egg Lake monkey flower	G4		S3						S4			
Suksdorf's monkey-flower	G4	SR	SR		SR	S3	SR	SR	SR	SR	S2	S3
Bigelow's four-o'clock	G4G5T4	SR	SR				SR		S3	S3		
Annual dropseed	G5	SR	SR	S3?	SR	S3	SR	SR	S2	S2	SR	S2
Green needlegrass	G5	SR	SR	SR	S2	SR		SR		SR		S4
Rigid threadstem	G4		S?		S2		SR		S4			
Coyote tobacco	G4	SR	SR	SR	SR	SR	SR	SR	SR	SR	S2	S2
Challis crazyweed	G5T3				S3							
Bristly combseed	G5	SR	SR		S1		SR		SR	S2?	S2	
Dwarf louse wort	G4	SR	S1	SR			SR	SR	SU	SR		
Simpson's hedgehog cactus	G4T4				S3		SR		S4		S?	
Absaroka Beardtongue	G2											S2
Stemless beardtongue	G2									S1		S1

Taxonomic group Species	Global rank	State Natural Heritage Program rank and occurrence AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Broadbeard beardtongue	G5	SR		SR		S2		SR		S?		S?
Yellow twotone beardtongue	G3T2Q						S2					
Cary's beardtongue	G3					S3						S2
Tunnel Springs beardtongue	G3						S2			S3		
Cordelia beardtongue	G1						S1					
Gibben's Beardtongue	G1			S1						S1		S1
Blue-leaf beardtongue	G3								S3			
Harrington beardtongue	G3			S3								
Idaho penstemon	G1				S1					S1		
Antelope valley beardtongue	G4		SR		S2		SR		SU			
King's beardtongue	G4						S4		SU			
Lemhi beardtongue	G2						S2		S1			
Pahute Mesa beardtongue	G3		SR				S3					
Aquarius Plateau beardtongue	G2									S2		
Minidoka beardtongue	G2G3				SR				SU			
Bashful beardtongue	G1						S1					
Short-lobe penstemon	G4?				S2				S?			
Ward's beardtongue	G2G3									S2S3		
Squaw apple	G4		SR	SR	S2		S5	SR	SR	SR		
Beatley scorpion plant	G3						S3					
Naked-stemmed phacelia	G4		SR				SR		S2			
Obscure scorpion plant	G2				S1		S1					
Playa phacelia	G2		S1				S2?		SU			
Mono phacelia	G3Q		S2				S3					
Chambers' twinpod	G4	SR	SR				SR		SU	S4		
Small-flowered ricegrass	G5	SR	S2S3	SR	S2	SR	SR	SR		SR		S3
Hairy-foot plantain	G5	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	S3
Washington polemonium	G2										S2	
Desert combleaf	G4T1T3Q		SR				S1S2		S1			

Taxonomic group Species	Global rank	State Natural Heritage Program rank and occurrence										
		AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Williams combleaf	G2Q						S2					
Austin's knotweed	G5T4		SR		SR	S2S3	SR		SR		S1?	S2
Modoc County knotweed	G4G5T1		S1						SR			
Pygmy poreleaf	G2						S2					
Alkali primrose	G1				S1	SK						
Snake River goldenweed	G3				S3				S2			
California chicory	G5	SR	SR				SR		SR	S1		
Columbian yellowcress	G3		S1						S3		S2	
Clokey Mountain sage	G5T3						S3					
Blaine pincushion	G1G2						S1			S1		
Mesa Verde cactus	G2			S2				S2				
Nye pincushion	G1Q						S1					
Homgren's skullcap	G3Q		OCC				S2					
Dwarf skullcap	G4		S?		S?		SR		SR			
Ertter's ragwort	G1								S1			
Jan's catchfly	G2						S2					
Jones globemallow	G2						S2			S2		
Biennial prince-plume	G1				S1				S1			
Wooly mock goldenweed	G5		S1		SR	S?	SR		SR		SR	
Malheur wire-lettuce	G1								S1			
Tiehm stroganowia	G2						S2					
Stylocline	G4		SR		S2		SR		SR			
Malheur stylocline	G4		SR		SR		SR		S1	S1		
Long-flowered snowberry	G5	SR	S?	SR	SR		SR	SR	S2	SR		
Wovenspore lichen	G2		OCC		OCC				OCC			
Howell's thelypody	GQT1?		S1						SH		S?	
Purple thick-leaved thelypody	G5T4Q		SR		S2		SR		SR		SR	
**	G2G4			OCC		S1		OCC				
Gypsum Townsend's aster	G2							S2				

Taxonomic group Species	Global rank	State Natural Heritage Program rank and occurrence										
		AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY
Charleston grounddaisy	G4T3						S3					
Scapose townsendia	G4G5		SR		S1		SR		S4	S1		
Currant Summit clover	G3T1						S1					
Owyhee clover	G2G3				S1				S2			
Desert yellowhead	G1											S1

Key to rank designations:

G = Global rank indicator, based on worldwide distribution at the species level
T = Global trinomial rank indicator, based on worldwide distribution at the infraspecific level
S = State rank indicator, based on distribution within the state at the lowest taxonomic level
1 = Critically imperiled due to extreme rarity, imminent threats, or and/or biological factors
2 = Imperiled due to rarity and/or other demonstrable factors
3 = Rare and local throughout its range, or with very restricted range, or otherwise vulnerable to extinction
4 = Apparently secure, though frequently quite rare in parts of its range, especially at its periphery
5 = Demonstrably secure, though frequently quite rare in parts of its range, especially at its periphery
_#_# = Range of uncertainty in a numeric rank (for example, G2G4 or S1S2)
H = Historical occurrence(s) only, presumed still extant and could be rediscovered
R = Reported from the state, awaiting firm documentation
U = Unrankable; present and possibly in peril, but not enough data yet to estimate rank
X = Extirpated from the state (SX) or extinct (GX or TX)
? = Not yet ranked at the scale indicated (G, T, or S)
B = Breeding status within the state; rank for breeding occurrences only
N = Non-breeding status within the state; rank for non-breeding occurrences only
Q = Taxonomic status questionable or uncertain
OCC = Occurrence verified through source other than the Natural Heritage Program.

APPENDIX 3: EXAMPLES OF EFFECTIVE REGIONAL HABITAT ASSESSMENTS

A variety of regional assessments have been completed recently for species of conservation concern that are of direct utility to management (Johnson et al. 1999). Four case examples are described below as context for our procedures.

Forest Ecosystem Management Assessment in the Pacific Northwest

This assessment (Thomas et al. 1993*a*, 1993*b*) provided information on ecological, economic, and social systems within the range of the northern spotted owl (*Strix occidentalis caurina*), excluding British Columbia. Approximately 10.1 million hectares (25 million acres) of federal land within Washington, Oregon and California were included in the assessment. The assessment included both current conditions and possible future conditions projected for 10 management scenarios. The focus of ecological assessment was late successional and old growth forests and associated species.

Effects of management were projected for over 1,100 species and species groups including terrestrial and aquatic vertebrates, vascular plants, fungi, bryophytes, lichens, and 11 functional groups of arthropods. Fourteen expert panels estimated these effects, engaging >70 species experts in the analysis.

Assessment of effects on arthropods was particularly challenging because of the large number of species (estimated at >7,000), the percentage of total species that have yet to be described (estimated at 20-30 percent), the lack of adequate surveys, and the lack of information on specific habitat associations. Because of the complexity involved, the experts who assessed the arthropods aggregated them into 11 functional groups based on their ecological roles: 1) coarse wood chewers, 2) litter and soil dwellers, 3) understory and forest gap herbivores, 4) canopy herbivores, 5) epizootic forest species, 6) aquatic herbivores, 7) aquatic detritivores, 8) aquatic predators, 9) pollinators, 10) riparian herbivores, and 11) riparian predators.

Assessments for the arthropods focused on the likelihood that habitat capable of supporting the functional groups would be maintained rather than on the status of individual species. Thus, the approach emphasized ecosystem function rather than species viability. This approach was considered necessary and appropriate because of the lack of information available on individual species, and because of the importance of arthropods to ecological functions within the late successional and old growth forests in the Pacific Northwest.

Source Habitats Assessment in the Interior Columbia Basin

Analysis of habitat trends for terrestrial vertebrates of conservation concern (Wisdom et al. 2000) was conducted as part of the Interior Columbia Basin Ecosystem Management Project (ICBEMP). The purpose of ICBEMP was to develop an ecosystem-based strategy for all FS and BLM lands within the Interior Columbia Basin. The assessment area includes 58.7 million hectares (145 million acres) in 8 northwestern states, and 53% of the area is public land administered by the FS or BLM.

Ninety-one terrestrial vertebrate species of conservation focus were identified using several criteria. These criteria included projected increases or decreases in habitat conditions

(Lehmkuhl et al. 1997), Biodiversity Network global rankings (Master 1991), and expert panel determinations. The identified species were placed into groups based on similarity of their macro-habitat associations. Grouping was accomplished with agglomerative hierarchical cluster analysis (SAS Institute, Inc. 1989), using a habitat association matrix that contained 154 cover type and structural stage combinations. The habitat associations were developed from published literature and expert knowledge. The clustering algorithm used pair wise similarities in source habitats between species. Experts reviewed the initial groups and made recommendations for refining group memberships and the number of groups to bring forward for analysis. The 91 species were placed into 40 groups that were further combined into 12 "families" of larger groups.

The species, groups, and families were used in a hierarchical assessment of habitat trends at increasing broader scales. Objectives of this assessment were to (1) identify broad-scale, robust patterns of habitat change that affect multiple species in a similar manner; (2) identify broad-scale management strategies that address the needs of many species efficiently, accurately, and holistically; (3) determine how well an evaluation of a group of species or a set of multiple groups of species provides for individual species within the groups; and (4) consider dynamics in habitats at multiple spatial scales and across time to facilitate the design and implementation of spatially- and temporally-explicit strategies

The degree to which a given set of management strategies met species needs was quantified by evaluating the efficacy of the management strategies at all three levels: species, group, and family. For example, habitat trends at all three levels were estimated and discussed in terms of management implications. In addition, the correlation of habitat trend between each pair of species within each group and family was calculated to illustrate the degree to which group trends represented the trends of individual species.

Habitat trends estimated under the hierarchical approach were used to develop broad-scale management strategies as part of the Supplemental Environmental Impact Statement for the Interior Columbia Basin Ecosystem Management Project (USDA Forest Service and USDI Bureau of Land Management 2000). Management strategies were developed for families or groups that were shown to have undergone the greatest reduction in habitat since pre-European settlement. Evaluation of the management strategies was conducted using focal species selected from the families of species. For each of the species in each family, additional information was developed on fine-scale habitats used (e.g., snags), home range and dispersal capability, additional ecological requirements (e.g., lack of human disturbance), and range. Based on this information, one or more species was selected that best represented the full array of ecological requirements for all species in the family.

Southern California Mountains and Foothills Assessment

This assessment provides detailed information about current conditions and trends for ecological systems and species in southern California (Stephenson and Calcarone 1999). The objective was to provide information to land managers for use in developing broad land management goals and priorities, while also setting the context for decisions specific to smaller geographic areas. The analysis area included 2.5 million hectares (6.1 million acres) in southern California, of which 64% is public land, including 1.4 million hectares (3.5 million acres) on 4 National Forests. The assessment used a combination of habitat-based ecological groupings and assessment of individual species. Information was compiled from published literature, field surveys, unpublished reports, mapping efforts, satellite imagery, agency files, and expert opinion. The assessment included:

- Trend in the composition, structure, and extent of ecological communities in the planning area;
- The natural and human processes that are driving landscape change;
- Species and communities at risk and the factors affecting their long-term viability; and
- Possible methods and strategies for sustaining species viability and ecological integrity.

The assessment identified 12 rare plant communities and selected 184 animals and 255 plants as “emphasis species.” These species met one or more of the following criteria:

1. Listed or proposed as threatened or endangered (federal or state)
2. Former FWS Candidate (C1 or C2)
3. FS sensitive species (Region 5)
4. California Species of Special Concern
5. Riparian obligate species of concern (as defined by California Partners in Flight)
6. Any species determined to have viability concerns at a local level
7. Major game species
8. Species of particular public interest (e.g., mountain lion).

The conservation potential and needs of the emphasis species on public lands were summarized by placing each species in one of three categories: (1) Minimal Influence (minimal ability to conserve on public lands within the assessment area); (2) Landscape Level (species best conserved through habitat or landscape-level management); or (3) Site Specific (species requires site-specific conservation attention). Of the 184 animal and 255 plant emphasis species, 28 and 23, respectively, occur incidentally on public lands, and their viability is little affected by management of those lands (Minimal Influence species). Of the remaining emphasis species, 114 animals and 141 plants can be adequately addressed through landscape-scale habitat management (Landscape Level species), while 42 animals and 91 plants are recommended as needing species-specific conservation measures (Site Specific species). Thus, through a habitat-based grouping approach, the assessment revealed where broad-scale habitat measures could be efficiently applied, and also highlighted the species needing individual conservation planning.

The Nature Conservancy Assessment of the Great Basin

This assessment consisted of an extensive and detailed compilation of the diversity, richness, and status of native species, natural communities, and ecological systems present within the Great Basin Ecoregion of California, Nevada, and Utah (Nachlinger et al. 2001). The goal of the assessment was “to develop a portfolio of conservation areas that fully represent the natural communities and species characteristic of the Great Basin in viable populations and landscapes within the least area possible” (Nachlinger et al. 2001:5). The massive ecological compilation contained in the assessment is complemented with a rich and detailed set of conservation targets and goals, identification of >350 conservation areas, or “portfolio sites,” to meet targets and goals, and supporting maps of environmental quality in relation to human activities and threats.

Results were expressed at spatial extents of the Ecoregion, for six sections of the Ecoregion that differed strongly in ecological status and potential, and for individual sites. Conservation goals were established for each portfolio site, based on each site's global distribution, rarity, and vulnerability to loss and degradation from human activities. Moreover, the assessment contained an exhaustive compilation of >2,800 occurrences of targeted species. These occurrences were overlaid with information about environmental quality and threats to the environment for the portfolio sites.

The portfolio sites varied in size, with 94 sites classified as "functional landscape scales" (areas large enough and of sufficient quality to contain many or most of the essential pieces of an effectively functioning landscape). The other 264 portfolio sites were classified as smaller functional sites. A comprehensive list of environmental threats was compiled and discussed in relation to the portfolio sites and at a variety of spatial extents. Results from identifying the portfolio sites, and the associated ecological basis for site selection, are expected to provide the foundation for conservation planning and land management in the Great Basin Ecoregion by The Nature Conservancy with its many federal, state, and private partners.

APPENDIX 4: FEDERAL AGENCIES AND ASSOCIATED LAWS PERTAINING TO MANAGEMENT OF SPECIES OF CONSERVATION CONCERN

USDI Bureau of Land Management

The Federal Land Policy and Management Act (FLPMA), as amended, provides the following direction to the USDI Bureau of Land Management (BLM) relative to managing for the conservation of biological diversity on public lands:

[T]he public lands be managed in a manner that will protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values; that, where appropriate, will preserve and protect certain public lands in their natural condition; that will provide food and habitat for fish and wildlife and domestic animals; and that will provide for outdoor recreation and human occupancy and use (USDI Bureau of Land Management and Office of the Solicitor 2001).

As part of it efforts to protect the quality of ecological values and provide food and habitat for wildlife, the BLM confers special status to species designated by a State as threatened or endangered, by BLM as sensitive species, and to those listed under the Endangered Species Act (USDI Bureau of Land Management 2001*b, c*). It is the policy of BLM to use of all methods and procedures necessary to improve the condition of special status species and their habitats to a point where their special status recognition is no longer warranted. The Agency's objectives in this regard are to:

1) Conserve listed species and the ecosystems on which they depend and
2) Ensure that management actions are consistent with the conservation needs of special status species.

Further, it is the policy of the BLM regarding special status species to:

1) Determine, to the extent practicable, the distribution, population dynamics, current threats, abundance, and habitat needs for candidate species occurring on lands administered by the BLM; evaluate the significance of lands administered by the BLM or actions undertaken by the BLM in maintaining and restoring those species, and
2) Where lands administered by the BLM or BLM-authorized actions have a significant effect on their status, manage the habitat to conserve the species by:
    i) Ensuring the species are appropriately considered in land use plans (BLM 1610 Planning Manual and Handbook, Appendix C),
    ii) Developing, cooperating with, and implementing range-wide or site-specific management plans, conservation strategies, and assessments for these species that include specific habitat and population management objectives designed for conservation, as well as management strategies necessary to meet those objectives,
    iii) Ensuring that BLM activities affecting the habitat of a special status species are carried out in a manner that is consistent with the objectives for managing those species, and

iv) Monitoring populations and habitats of special status species to determine whether management objectives are being met.

It is also the policy of the BLM to consider information from all available sources, including scientific data gained from resource assessments, information regarding ecosystem protection and restoration needs, the reasonably foreseeable development of consumptive and nonconsumptive uses, and social and economic information when making land use plan decisions (USDI Bureau of Land Management 2000*a*). That information may come from regional assessments completed at multiple scales to ensure that decisions properly address all identified issues, trends, and concerns. Multiple scales of planning decisions, from regional to site-specific, provide a comprehensive land use-planning information base for resource management within the context of FLPMA. Assessment and planning at different geographic scales allow the public to better focus on the level where its interests lie and allow the agency to make decisions at a scale most appropriate for the issues at hand and the level of information available. The BLM has also recognized the advantages of working with others to develop landscape-level multi-species approaches to conservation of ecosystems (USDI Bureau of Land Management 2000*b*).

USDA Forest Service

The National Forest Management Act of 1976 (16 U.S.C. 1600) (NFMA) directs the USDA Forest Service to "…provide for diversity of plant and animal communities based on the suitability and capability of the specific land area in order to meet overall multiple-use objectives…" In regulations developed to implement NFMA, the following direction is provided: "Fish and wildlife habitat shall be managed to maintain viable populations of existing native and desired non-native vertebrate species in the planning area" (NFMA Planning Rule [36 CFR 219]).

It is also the policy of the FS to identify and manage for the maintainance and recovery of populations of sensitive species (USDA Forest Service 1995). Sensitive species are those plant and animal species identified by a Regional Forester for which population viability is a concern, as evidenced by:

1) Significant current or predicted downward trends in population numbers or density, or
2) Significant current or predicted downward trends in habitat capability that would reduce a species' existing distribution.

Objectives for the management of sensitive species by the FS include:

1) Development and implementation of management practices to ensure that species do not become threatened or endangered because of FS actions,
2) Maintainence of viable populations of all native and desired nonnative wildlife, fish, and plant species in habitats distributed throughout their geographic range on National Forest System lands, and
3) Development and implementation of management objectives for populations and/or habitat of sensitive species.

USDI Fish and Wildlife Service

Direction provided to the USDI Fish and Wildlife Service regarding the conservation of biological diversity in the management of National Wildlife Refuges is most pertinent to conservation of sagebrush ecosystems. That direction states: "In administering the [National Wildlife Refuge] System, the Secretary shall . . . ensure that the biological integrity, diversity, and environmental health of the System are maintained for the benefit of present and future generations of Americans…" (National Wildlife Refuge System Administration Act of 1966 as amended by the National Wildlife Refuge System Improvement Act of 1997, 16 U.S.C. 668dd-668ee). The FWS also administers the Endangered Species Act, whose premise is based on preemptive management designed to prevent federal listings of species, a concept directly pertinent to conservation and restoration of habitats for species of conservation concern, such as the 350 or more species of concern associated with the sagebrush ecosystem (Appendix 2).

US Department of Defense

The US Department of Defense (DOD) is the steward of lands possessing a variety and richness of natural resources, including sensitive ecosystems and habitats for threatened and endangered species (US Department of Defense 2000). The US Department of Defense's Legacy Program (enacted through legislation in 1990) balances the intensive use of Department of Defense lands for military training and testing with the protection of the Department's natural resources. The Legacy Program incorporates an ecosystem approach that assists DOD in maintaining biological diversity, and the sustainable use of land and water resources for US Department of Defense mission and other uses.

Further, the 1994 "Ecosystem Management Policy Directive," issued by the Deputy Under Secretary of Defense (Environmental Security), articulates the biodiversity conservation policy embraced by the US Department of Defense and the military departments (US Department of Defense n.d.). The goal of this policy is to: *"Maintain and improve the sustainability and native biological diversity of terrestrial and aquatic, including marine, ecosystems while supporting human needs, including the DOD mission."*

The US Department of Defense Environmental Conservation Instruction (US Department of Defense 1996) lays out specific management approaches to achieve conservation goals:

1) Shift from single species to multiple species management,
2) Maintain or restore remaining native ecosystem types across their natural range of variation,
3) Maintain or reestablish viable populations of all native species in areas of natural habitat, when practicable,
4) Maintain evolutionary and ecological processes, such as disturbance regimes, hydrological processes, and nutrient cycles,
5) Manage over sufficiently longtime periods to allow for changing system dynamics, and
6) Plan to accommodate human use as necessary.

APPENDIX 5: SHORTCUT APPROACHES TO MULTI-SPECIES ASSESSMENT

Because an ecoregion assessment by definition is of large spatial extent, the number of species under consideration can easily exceed 100 or even 1000 (e.g., Thomas et al. 1993*a*, 1993*b*). Moreover, detailed information about many species' requirements, habitat conditions, and population status may be unavailable for much of an ecoregion. Various methods of grouping species, or using single species to represent a larger set of species, have been proposed to gain efficiency in conducting such multi-species assessments. These approaches have been described as "shortcuts" for conservation planning (Fleishman et al. 2000). Below we review some of these approaches; our summary draws heavily on the work of Andelman et al. (2001) and Wisdom et al. (2001).

The primary purpose of any "shortcut" method for multi-species assessment is to eliminate or reduce the number of individual species that are explicitly considered in an assessment and in subsequent management. Presumably, use of a shortcut in a regional assessment results in increased efficiency, in contrast to dealing explicitly with hundreds of species. As an example, 40 broadly distributed species associated with sagebrush in the Great Basin Ecoregion were identified as being of conservation concern, including 1 amphibian, 9 reptiles, 13 mammals, and 17 birds (Wisdom et al. 2003). Such a diverse set of species makes assessment and management a challenging task if all species are considered individually.

In addition, assessing habitats or populations exclusively on a species-by-species basis results in fine-scale focus on individual species that not only contradicts holistic management, but results in little understanding of the interactions among species and their commonalities and differences (Wisdom et al. 2001). Regardless of the shortcut chosen, the methods of assessment will be constrained by the quantity and quality of information available (Andelman et al. 2001), and driven by the objectives of the assessment (Caro and O'Doherty 1999).

Shortcut Approaches

Two categories of shortcut approaches for multi-species assessment can be distinguished. The first uses sets of species to represent all species of concern in the analysis area. This approach includes species groups and some types of coarse-filter management and landscape indicators. The second approach uses individual species to represent a suite of species, based on some common attribute. This second approach consists of fine-filter strategies (see Glossary, Appendix 1), which include indicator, keystone, umbrella, flagship, focal, and surrogate species (Noss 1990, Marcot et al. 1994, Caro and O'Doherty 1999, Andelman et al. 2001, Wisdom et al 2001). A species-by-species assessment of all species can also be done under a fine-filter strategy, perhaps first ranking species by degree of risk (e.g., ESA-listed species first, followed by federal or state sensitive species) and conducting more thorough assessments for these top-ranked species (Wisdom et al. 2001).

The First Approach: Grouping Species or Coarse-filter Strategies--Among the more general strategies is that of forming groups of species. With this approach, the criterion by which to classify species into groups must be selected, based on available data and the objectives of the assessment. Several classification criteria have been proposed, including risk (e.g., degree of risk and risk factors); ecological characteristics such as habitat associations or guilds; ecological functions; and body size or home range size (e.g., categories of body size and dispersal capability) (Wisdom et al. 2001). A recent report on species viability assessments under the National Forest Management Act recommended grouping species by factors that increase risk of population decline (Andelman et al. 2001). For an evaluation of habitat status and trends of >90 broad-scale terrestrial vertebrates of concern in the Interior Columbia Basin, Wisdom et al. (2000) classified species into nested hierarchical groups based on similarities in source habitats among species. The advantage of hierarchical grouping is that species can be efficiently addressed at multiple scales (e.g., by individual species, groups of species, or groups of groups; Wisdom et al. 2001).

Coarse-filter approaches, such as GAP analysis (Scott et al. 1993) or the coarse-filter conservation targets of The Nature Conservancy (e.g., matrix communities; Groves et al. 2000), are those in which conservation and assessment are based on larger sets of species, typically vegetation communities. The assumption is made that identifying and protecting these communities also will protect the majority of species associated with those communities, without having to measure environmental conditions for all species individually.

Similarly, landscape-indicator models rely on measurements of broad-scale characteristics (e.g., extent of native habitats converted to agricultural land) to indicate geographic areas of concern, without ever measuring conditions for individual species (Ator et al. 2001, Gergel et al. 2002). Thus, this method minimizes or eliminates an explicit connection to individual species, or to a larger set of species. Instead, the assumption is made that if the correct indicators are effectively addressed in management, the health of the ecosystem, including its native species, will be maintained. For example, landscape indicators may be used to specify an amount, distribution, and quality of native plant communities to be managed for the benefit of all associated species of concern.

The Second Approach: Focal Species or other Fine-filter Strategies--Fine-filter strategies use one or a small number of species to represent conditions for a much larger set of species (Marcot et al. 1994). Umbrella, surrogate, and focal species approaches all use a single species to represent a larger set of species, in order to gain efficiency when conducting assessments over large areas supporting many species (Fleishman et al. 2000). While definitions of these single-species approaches may differ, each rests on the key assumption that a given species' requirements, and its response to management, can approximate those of a much larger set of species whose needs are similar to the umbrella, surrogate, or focal species (Wisdom et al. 2001). While intuitively appealing, these approaches are challenging because each species occupies its own niche (e.g., see MacArthur and MacArthur 1961, Root 1967), and may respond differently to management in relation to its unique needs.

Although definitions exist for the plethora of single-species approaches (e.g., focal, keystone, or umbrella species; see definitions in Appendix 1 and Table 1 of this Appendix), confusion in use of terms abounds (e.g., Caro 2000, Armstrong 2002). One commonly used concept--focal species--has been proposed as a means to efficiently evaluate viability or habitat conditions for a suite of related species. As such, a focal species is deemed to provide "insights to the integrity of the larger ecological system to which it belongs" (Andelman et al. 2001).

Prior to identification of focal species, the environmental requirements, such as habitat associations and home range sizes, of all species of concern in the assessment area must be determined (Lambeck 1997, Wisdom et al. 2001). Otherwise, application of the focal species concept may be doomed, because the adequacy of the focal species to represent the larger group will remain unknown (Wisdom et al. 2001). If a focal species approach is selected, we recommend following the sequence previously outlined by others (Lambeck 1997, Wisdom et al.

2001, Andelman et al. 2001), in which all species of concern are assigned to groups, after which a focal species is selected to represent each group.

If the number of species of concern is small (e.g., <25 species), the best solution may be to dispense with any shortcut approaches and instead to assess each species individually. Without first examining environmental requirements and habitat conditions for each species, it remains unknown whether any shortcut approaches will adequately address the needs of each species of concern. Once this information has been gathered for each species, the utility of the shortcut may be moot.

Advantages, Disadvantages, and Caveats

Although coarse- and fine-filter approaches for multi-species assessment have been considered for several decades by the conservation community and land management agencies, their efficacy remains largely unknown (Table 1, this Appendix). Moreover, evaluation of the performance of single-species approaches requires an assessment of all species that the single species is assumed to represent, thereby reducing the efficiency of the shortcut. Also, such single-species approaches often lack clear, operational definitions that can be tested, may fail to identify the larger set of species the approach is designed to represent, and rarely are evaluated for performance.

The umbrella species concept was found to be of equivocal value for black rhinos (*Diceros bicornis*) and other herbivores in Africa (Berger 1997), and was largely unsuitable when used for California Gnatcatchers (*Polioptila californica*; Rubinoff 2001), primarily because the invertebrate community was poorly represented by the presence of gnatcatchers in coastal scrub habitats. Fleishman et al. (2000) recommend that a suite of umbrella species be used, rather than single species, and that these concepts undergo rigorous testing to evaluate their utility.

An obvious advantage of a coarse-filter approach such as landscape indicators is the broader consideration of landscape conditions in the ecosystem, and the efficient focus on managing such conditions to address resources comprehensively. The disadvantage is that no explicit connection is made to species of conservation concern. Consequently, whether or not the indicators account for the varied needs of these species is uncertain. Alternatively, to evaluate how well the indicators represent the needs of species would require explicit knowledge of each species' relationship with the indicators, thus diminishing the purpose and efficiency of the indicators.

Despite the appeal of greater efficiency by assessing conditions for groups of species, single-species approaches will likely continue to dominate most assessments and monitoring efforts for two reasons: (1) single species are easier to understand than are ecological processes, or groups of species; and (2) laws such as the U.S. Endangered Species Act (ESA) tend to focus on single species rather than on "other levels of organization" (Noss 1990). In addition, data on habitat conditions and population trends for wildlife have traditionally been collected with a focus on single species, rather than on communities or assemblages of species.

Use of species groups, however, need not be exclusive of an assessment of individual species. On the contrary, Wisdom et al. (2000) specifically defined their grouping approach to include both single- and multi-species assessment, depending on objectives (Figure 14, main text). To address both single and multiple species in their assessment, Wisdom et al. (2000)

established a hierarchical system to evaluate habitats for individual species, for groups of species, and for "families" of groups (Figure 14, main text). Species selected for analysis were clustered into groups based on similarities in habitats. Likewise, groups of species were placed within families 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 (Figure 14). That is, each species was assigned to one group, and each group assigned to one family.

This hierarchical nesting allowed for analysis to be flexible and adaptive. For example, managers often must generalize or blend the habitat requirements of many species to accommodate the composite needs of all species under ecosystem management. Each species, however, occupies its own niche and therefore has a unique set of habitat requirements, suggesting that broad-scale, ecosystem-based management strategies may address the needs of some species better than others (Marcot et al. 1994). Under this grouping approach, the degree to which a given set of management strategies meets the needs of each species can be quantified by evaluating the efficacy of the management strategies at all three levels: species, group, and family. Often, results of the family or group evaluations likely reflect the species evaluations accurately; in such cases, the higher levels of generalization (group or family) index the species-level phenomenon more efficiently than a species-by-species approach. When the requirements of a given species are not reflected well at the level of the group or family, however, evaluations of individual species can be used to complement the group- or family-level evaluations. For example, a species listed as federally threatened or endangered may have specialized or stringent habitat requirements that dictate specific consideration within a broader, ecosystem-based approach. Under the hierarchical system of species-, group-, and family-level evaluations, managers can choose multiple levels of display regarding habitat trends for species, groups, or families, depending on objectives and the level of generalization desired.

Which Approach to Use?

Selection of a particular shortcut to increase the efficiency of multi-species assessments may not matter as much as the means by which the shortcut is used to meet objectives. We recommend that any shortcut method include the following criteria for application:

(1) Identify all species of concern, including supporting rationale for inclusion;
(2) Document and summarize the status, requirements, and other pertinent information related to population or habitat concerns for each species;
(3) Use knowledge documented from the full set of species of concern to select the particular single-species shortcut, such as umbrella, surrogate or focal species;
(4) Provide a detailed explanation of how and why the shortcut was chosen, and describe the limitations, caveats, and guidelines for ecological understanding of the approach's shortcomings and subsequent application in management; and
(5) Describe the research needed to evaluate performance of the shortcut approach, particularly how use of the approach in regional assessments, and in subsequent management, may be constrained or diminished if key sources of uncertainty about the use of the shortcut are not evaluated.

Table 1. Comparison of multi-species approaches for assessing habitat conditions and trends for species of concern in regional assessments.

Method	Definition	Source(s)	Advantages	Disadvantages	Assumptions
Coarse-scale approaches					
Coarse-filter management	"Conservation of land areas and representative habitats with the assumption that the needs of all associated species, communities, environments, and ecological processes will be met"	Marcot et al. 1994:36	Increased efficiency from not having to address environmental requirements of individual species	Efficacy of method is unknown; likelihood of not representing the needs of some species is high	Conservation of selected habitats or geographic areas will conserve all associated species and processes in the area
Grouping species	Assigning all species of concern in the assessment area to groups, based on pre-determined criteria (e.g., macro-habitat associations, type of risk factor)	Wisdom et al. 2000, 2001; Andelman et al. 2001	Increased efficiency by analyzing several species as one; all species are accounted for in the analysis	Requires cross-checking to ensure that needs of individual species are met through the groups	All species under consideration can be classified and assigned to a mutually exclusive group
Landscape indicator	A measurement of the landscape, calculated from mapped or remotely sensed data, used to describe spatial patterns of land use and land cover across a geographic area.	Ator et al. 2001, Gergel et al. 2002	Increased efficiency from not having to address environmental requirements of individual species	Efficacy of method is unknown; likelihood of not capturing the needs of some species is high; relations between landscape metrics and species' requirements are not well established	Indicators of landscape quality, as assessed through a variety of metrics, will appropriately index the needs of the species occupying the landscape
Single-species approaches					
Ecological indicator species	"Species that signal the effects of perturbations on a number of other species with similar habitat requirements;" population size and trend reflect those of other species associated with same area and habitats	Noss 1990:360, Marcot et al. 1994 (see also Landres et al. 1988)	Help simplify development and implementation of management guidelines for multiple species	Approach cannot account for unique niches of each species; similar responses in indicator species and others may be due to different underlying conditions	Similar habitat and population trends in indicator species and other species are not coincidental
Flagship species	Popular, charismatic species that serve as symbols and rallying points for major conservation initiatives; typically large, long-lived species that are sensitive to human disturbance	Noss 1990:361, Caro and O'Doherty 1999	Concept has intuitive appeal and may increase public support for conservation efforts which ultimately result in protection for a large	Emphasis is on charismatic species that may not be ecologically significant and may not well represent the needs of the larger set of species of concern	

Method	Definition	Source(s)	Advantages	Disadvantages	Assumptions
			number of species		
Focal species	"Serve as indicator of ecological sustainability…;" "umbrella species whose area requirements include the habitat needs of many other species;" "representative of larger groups of species with similar habitat requirements or functional roles"	Andelman et al. 2001 (also see Wisdom et al. 2001)	Use allows simplification of management for multiple species in an assessment area	Little empirical evidence that approach is valid or effective; term may be so imprecise as to be of little value in some applications	Focal species will adequately represent the requirements of multiple species
Keystone species	"Pivotal species upon which the diversity of a large part of a community depends;" impact of keystones is large relative to their abundance	Noss 1990:360, Caro and O'Doherty 1999	Provides for proper functioning of important ecological processes	Needs of other species in the ecoregion may not be adequately addressed	Adequate knowledge exists to identify keystone species in the ecosystem
Surrogate species	Species used to indicate the extent of anthropogenic influences or track population changes of other species; may also encompass indicator, umbrella, or flagship species	Caro and O'Doherty 1999:806	(See ecological indicator, flagship, and umbrella species)	(See ecological indicator, flagship, and umbrella species)	(See ecological indicator, flagship, and umbrella species)
Umbrella species	Species with large area requirements, which if given sufficient protected habitat area, will bring many other species under protection	Noss 1990:361, (also see Berger 1997, Fleishman et al. 2000, 2001)	Concept relatively easy to grasp; increased efficiency in assessment realized by selecting umbrella species	Validity of approach is less well substantiated than that of similar concepts (e.g., indicator species)	Umbrella species has a high probability of persistence; taxa of different trophic levels will be similarly protected; protecting areas for the umbrella species will protect areas used by other species