Landscape Restoration for Greater Sage-Grouse: Implications for Multiscale Planning and Monitoring

Michael J. Wisdom
Mary M. Rowland
Miles A. Hemstrom
Barbara C. Wales

Abstract—Habitats and populations of greater sage-grouse (*Centrocercus urophasianus*) have declined throughout western North America in response to a myriad of detrimental land uses. Successful restoration of this species' habitat, therefore, is of keen interest to Federal land agencies who oversee management of most remaining habitat. To illustrate the challenges and potential for landscape restoration, we summarized recent findings of restoration modeling for sage-grouse in the Interior Northwest. Changes in amount and quality of habitat were evaluated under proposed Federal management and under two restoration scenarios. Under the two scenarios, the rate of habitat loss was reduced and the quality of habitat was substantially improved compared to proposed management. These results have direct implications for restoration planning and monitoring. First, a strategic, multiscale approach is needed that links the scale of the stand with scales of the seasonal, year-round, and multipopulation ranges of sage-grouse. Second, consideration of connectivity across scales is essential. Third, extensive and sustained use of a holistic suite of passive and active restoration treatments is needed. And finally, monitoring of both habitat and population responses across scales is critical. We offer suggestions on these and related points for effective restoration planning and monitoring of sage-grouse habitat.

Introduction

Habitats and populations of greater sage-grouse (*Centrocercus urophasianus*) have declined substantially across the species' range in response to a variety of detrimental land uses (Connelly and Braun 1997; Schroeder and others 1999). New guidelines were developed recently (Connelly and others 2000a) to help managers conserve and restore habitats for the species at the stand scale, but similar guidelines do not exist for landscape scales that encompass all or major portions of the species' range. The cumulative effects of management at these larger scales can greatly influence regional extirpation of sage-grouse (Raphael and others 2001), and recent landscape evaluations (Hemstrom and others 2002; Raphael and others 2001; Wisdom and others 2000, 2002a,b) offer new insights for effective restoration planning across the species' range.

The prospect of continued and widespread habitat declines for sage-grouse and other sagebrush (*Artemisia* spp.) obligates (Raphael and others 2001; Wisdom and others 2000, 2002a) points to the urgent need for development of restoration efforts across large landscapes. Without such restoration efforts, continued management of Federal lands under current land use plans will likely result in further loss and degradation of sagebrush steppe, with an increasingly high risk of population extirpation for sagebrush-dependent species (Raphael and others 2001).

In this paper, we summarize results of recent landscape evaluations to restore habitats for sage-grouse on lands administered by the U.S. Department of Agriculture, Forest Service, and U.S. Department of the Interior, Bureau of Land Management (FS-BLM) in the Interior Columbia Basin and adjacent portions of the Great Basin (Basin) (fig. 1). The 58 million-ha Basin encompasses a major portion of current and historical range of greater sage-grouse (fig. 1) (Wisdom and others 2002a). Proposed management of the Basin's sagebrush steppe will therefore substantially affect sage-grouse and other sagebrush obligates. That as context, our goals were to summarize the conditions projected for greater sage-grouse from a previous study within the Basin (Raphael and others 2001) in relation to two restoration scenarios recently developed and evaluated by Hemstrom and others (2002) and Wisdom and others (2002a) and to place the results in appropriate biological context for management of sage-grouse, particularly in terms of multiscale land use planning and monitoring.

Michael J. Wisdom is Research Wildlife Biologist, and Barbara C. Wales is Wildlife Biologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry and Range Sciences Laboratory, 1401 Gekeler Lane, La Grande, OR 97850. Mary M. Rowland is Wildlife Biologist, USDI Bureau of Land Management, Forestry and Range Sciences Laboratory, 1401 Gekeler Lane, La Grande, OR 97850. Miles A. Hemstrom is Research Ecologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Station Headquarters, 333 SW First Ave, Portland, OR 97204.

In: Shaw, Nancy L.; Pellant, Mike; Monsen, Stephen B., comps. 2005. Sage-grouse habitat restoration symposium proceedings; 2001 June 4–7; Boise, ID. Proceedings RMRS-P-38. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

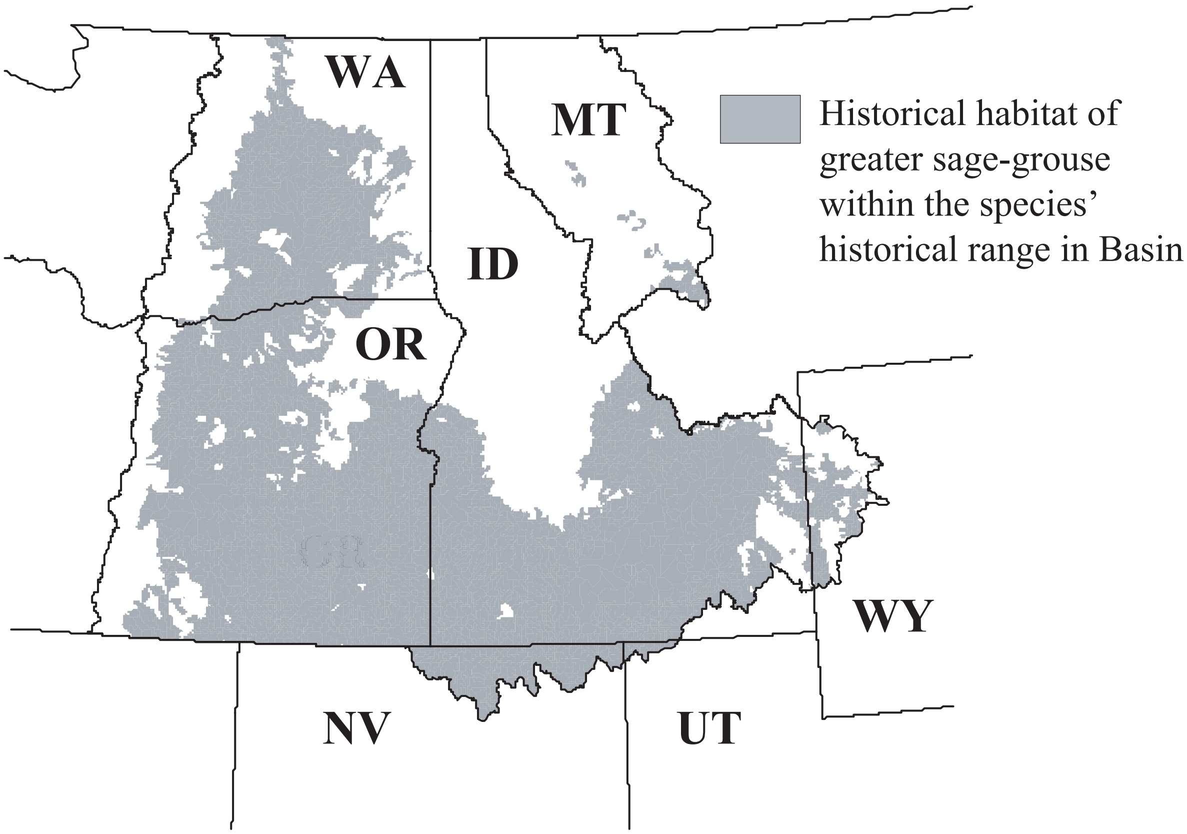

Figure 1—The Interior Columbia Basin assessment area in the Western United States, encompassing eastern Washington (WA), eastern Oregon (OR), most of Idaho (ID), northwestern Montana (MT), and adjacent areas of northwestern Wyoming (WY), northwestern Utah (UT), and northern Nevada (NV), and the historical habitats of greater sage-grouse within the species' historical range in the Basin (from Wisdom and others 2000).

Restoration Scenarios

Raphael and others (2001) evaluated the effects of proposed management of FS-BLM lands, projected 100 years in the future, on sage-grouse and other vertebrates that depend on sagebrush steppe in the Basin. These effects were associated with three management alternatives proposed in the Supplemental Environmental Impact Statement (SEIS) (USDA-FS and USDI-BLM 2000) of the Interior Columbia Basin Ecosystem Management Project (ICBEMP). Under proposed management, as well as current land management, Raphael and others (2001) found that most species that depend on sagebrush steppe, including sage-grouse, had a high probability of local or regional extirpation.

Hemstrom and others (2002) and Wisdom and others (2002a) evaluated the benefits of dramatically increasing the extent and intensity of restoration in sagebrush steppe to gain insight into the potential for improving environmental conditions for sage-grouse and thereby reducing the risk of extirpation compared to that under proposed management. Evaluations were based on Hemstrom and others' (2002) modeling of two restoration scenarios that substantially increased the combination of passive and active restoration of sagebrush steppe within the historical range of sage-grouse in the Basin.

As the basis for the two scenarios, Hemstrom and others (2002) defined passive restoration as "the process of modifying or eliminating existing management activities (for example, livestock grazing, roads, or recreation) that contribute to environmental degradation of desired resources." In contrast, Hemstrom and others (2002) defined active restoration as "the application of treatments that contribute to recovery of targeted resources (for example, appropriate use of wildfire suppression, prescribed fire, or seeding with native plants)." These definitions are similar to those summarized for rangeland restoration by McIver and Starr (2001).

The two scenarios substantially increased the levels of both passive and active restoration in relation to proposed management because of managers' desire to understand the magnitude by which sagebrush habitats could be improved relative to what was originally proposed. Scenario 1 assumed a 50 percent reduction in detrimental grazing effects by livestock as the main form of passive restoration. Detrimental grazing effects were defined as the probability, associated with grazing, of moving from a desired vegetation state, which provides habitat for sage-grouse (for example, gray boxes, fig. 2), to an undesired state (for example, white boxes, or nonhabitat, fig. 2). Accordingly, 50 percent and 100 percent reductions in detrimental grazing effects represented like reductions in the probability of transitioning from desired to undesired states for sage-grouse in relation to livestock grazing. Detailed rationale and supporting literature regarding these grazing effects on sagebrush habitats, and on sage-grouse, are described in Hemstrom and others (2002).

To achieve reductions of 50 percent and 100 percent in detrimental grazing effects, like reductions in stocking rate of livestock were assumed in combination with additional, positive changes in grazing systems (for example, increasing rest periods in rest-rotation systems) (Hemstrom and others 2002). This form of passive restoration under scenario 1 was applied to 6.4 million ha of FS-BLM lands in the Basin that have potential to be sage-grouse habitat or that currently serve as habitat (referred to as potential sage-grouse habitat). Two points are important here. First, not all grazing effects were assumed by Hemstrom and others (2002) to be detrimental to sage-grouse habitat. However, there is growing awareness that the herbaceous component of sagebrush stands, which can be reduced substantially in occurrence and percent cover with intensive livestock grazing (Anderson and Inouye 2001), is a primary requirement for successful nesting and brood rearing by sage-grouse (Barnett and Crawford 1994; Connelly and others 2000a; Crawford 1997). Consequently, there is a need to mitigate the detrimental effects of livestock grazing on native grasses and forbs important to sage-grouse productivity. And second, reduction in stocking rate of livestock can effectively restore native, herbaceous components in sagebrush steppe (Anderson and Inouye 2001). In defense of this point, Hemstrom and others (2002) stated

> Our assumed reductions in stocking rate needed to achieve a desired reduction in detrimental grazing were based on empirical data demonstrating that herbage production on rangelands is affected mostly by variation in stocking rate, and less so by changes in grazing system (Holechek and others 1998; Van Poolen and Lacey 1979). On arid rangelands such as those dominated by sagebrush, a positive response in herbage production must include a reduction in stocking rate in combination with active restoration treatments (see empirical synthesis by Holechek and others 1998).

Active restoration under scenario 1 was integrated with passive restoration on the same 6.4 million ha of potential sage-grouse habitat (Hemstrom and others 2002). By contrast, active restoration under proposed management targeted approximately 1.1 million ha of potential sage-grouse habitat. Thus, scenario 1 represented a sixfold increase in areas treated with active restoration beyond that identified in proposed management.

Key forms of active restoration included seedings and plantings of desired vegetation, particularly after fire events; wildfire suppression in vegetation types where such fires would facilitate invasion of exotic plants; prescribed fire in vegetation types where such fires would reduce woodland encroachment; and use of a variety of other chemical and mechanical treatments to control invading conifers and enhance composition of native grasses and forbs (Hemstrom and others 2002). The specific combination of active restoration treatments was tailored to the unique, desired response of each sagebrush community to the treatments. For example, use of prescribed fire to suppress juniper (*Juniperus* spp.) invasion, and enhance growth of herbaceous vegetation, was applied to many areas dominated by mountain big sagebrush (*A. tridentata* ssp. *vaseyana*), where fire effects are largely beneficial (Miller and Eddleman 2000). By contrast, suppression of wildfire, in combination with chemical treatments and native seedings to control spread of exotic grasses, was applied to many areas dominated by Wyoming big sagebrush (*A. tridentata* ssp. *wyomingensis*), where cheatgrass (*Bromus tectorum*) and other annuals often supplant native vegetation following fire events (Miller and Eddleman 2000).

Restoration scenario 2 was based on a 100 percent reduction in detrimental grazing effects by livestock, with a like reduction in stocking rate (Hemstrom and others 2002). This high level of passive restoration was integrated with the same level of active restoration assumed for scenario 1, with the same 6.4 million ha of FS-BLM lands targeted for treatment. Detailed methods, assumptions, and rationale associated with the scenarios are described in Hemstrom and others (2002) and Wisdom and others (2002a).

Conditions under the two restoration scenarios were projected 100 years into the future, as was done for proposed management. Restoration activities for each scenario were sustained throughout the 100-year period, with the frequency, intensity, and type of each activity designed to substantially recover or maintain desired conditions (Hemstrom and others 2002). Three landscape variables for sage-grouse were targeted for improvement as part of the restoration scenarios: (1) habitat amount, and two indices of habitat quality, (2) HRV departure (an acronym for historical range of variability departure, as defined by Hann and others 1997), and (3) uncharacteristic grazing (Hemstrom and others 2002; Wisdom and others 2002a).

Habitat amount is the area of sage-grouse habitat within the Basin, as defined by Wisdom and others (2000). Sage-grouse habitats in the study area primarily include low- to medium-height shrublands in basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*), Wyoming big sagebrush, mountain big sagebrush, and low sagebrush (*A. arbuscula*) communities, as well as herbaceous wetlands.

HRV departure was used to index the degree to which exotic plants have invaded and displaced components of native sagebrush steppe, particularly native grasses and forbs that are required by sage-grouse for successful nesting and brood rearing (Connelly and others 2000a; Crawford 1997; Drut and others 1994; Sveum and others 1998). Uncharacteristic grazing, (UG) was used to index changes in species richness, height, and cover of native understory grasses and forbs in response to livestock grazing, and to subsequent effects on quality of nesting and brood-rearing habitat for sage-grouse (Wisdom and others 2002a).

Restoration activities were designed to enhance habitat quantity (through increased habitat amount) and quality (through reductions in HRV departure and uncharacteristic grazing). Restoration was particularly designed to retard the cheatgrass (*Bromus tectorum*)-wildfire cycle (fig. 2), a pervasive problem in the Wyoming big sagebrush communities that compose >60 percent of sage-grouse habitat in the Basin (Hemstrom and others 2002).

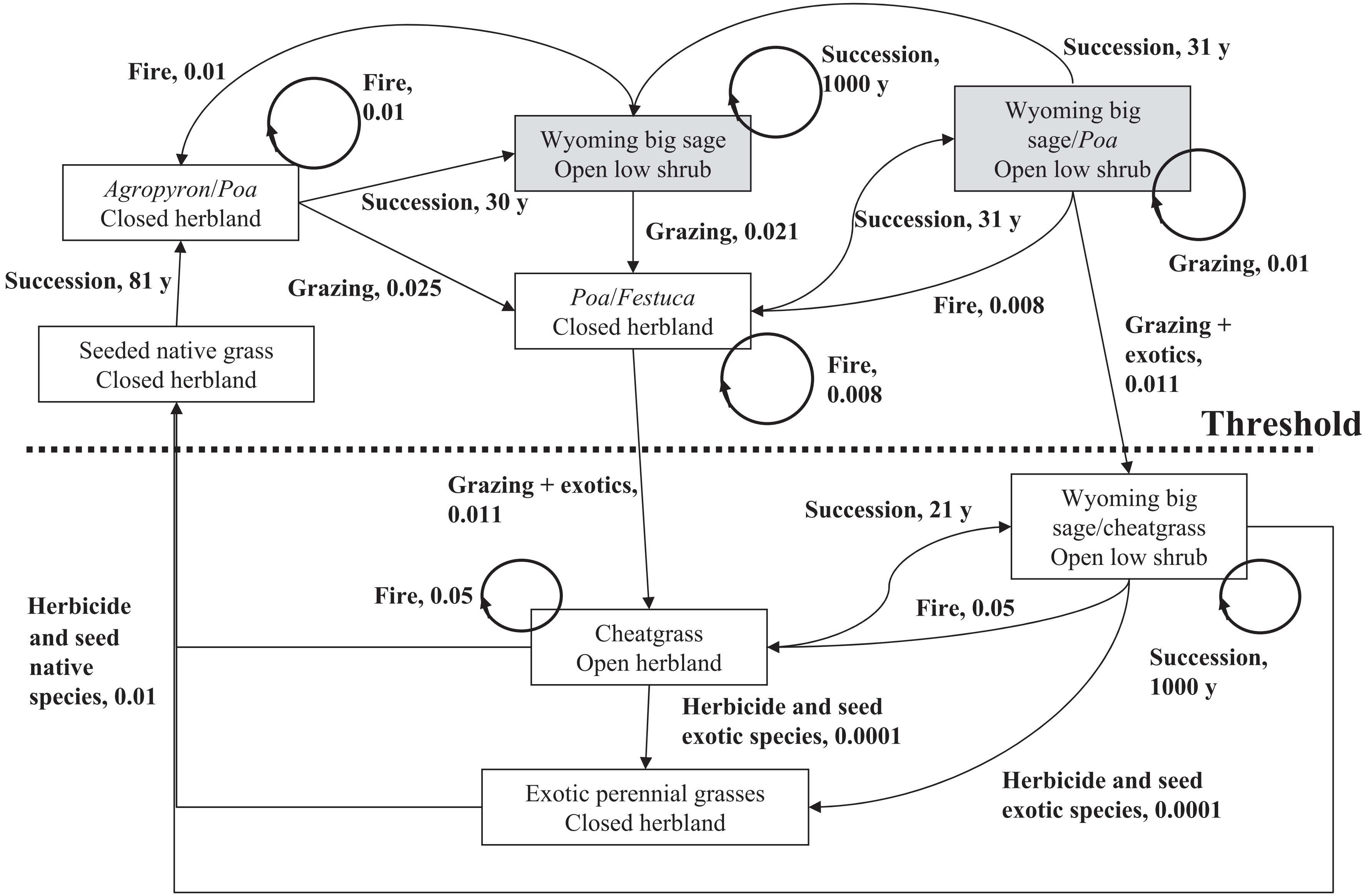

Figure 2—Example state-and-transition model (based on concepts of Westoby and others 1989 and Laycock 1991) for the potential vegetation type of warm, dry Wyoming big sagebrush (defined by Hann and others 1997) under an active restoration prescription in the Interior Columbia Basin (from Hemstrom and others 2002). Boxes are vegetation states and arrows are transitions from one state to another. In this example, transitions are brought about by succession and disturbance agents of fire, grazing, chemical treatments, and seedings. When disturbance is the primary cause for transition, the annual probability of moving from one state to another is shown in association with the disturbance that causes the transition (for example, fire, 0.01). Successional transitions of 1,000 years (y) indicate stable states. The dotted line indicates a transition threshold, below which restoration is difficult and requires a sustained, extensive combination of active and passive treatments.

Methods used to model these improvements under the restoration scenarios were deliberately conservative in terms of the assumed enhancements that such activities could produce. A conservative modeling approach was adopted because of the high uncertainty of restoration outcomes in sagebrush steppe (West 1999). This high uncertainty is related to incomplete knowledge of appropriate restoration methods and technologies, and the logistical challenges posed by sustained and integrated application of restoration treatments across vast areas of sagebrush steppe, which to date has not been attempted (Knick 1999).

Results from the restoration modeling were evaluated in terms of risk of regional extirpation of sage-grouse, as expressed in five outcome classes (see population outcome model described by Wisdom and others 2002b). Outcome A was defined as a very low risk of regional extirpation, followed by low (outcome B), moderate (outcome C), high (outcome D), and very high (outcome E) degrees of risk. These levels of risk corresponded to empirical findings of Wisdom and others (2002b), showing that areas of the Basin historically occupied by sage-grouse were associated with outcome A, whereas areas of current extirpation were associated with outcome E. Moreover, areas of the Basin currently occupied by sage-grouse have undergone an intermediate level of habitat loss and degradation between that estimated for historically occupied areas versus currently extirpated areas, resulting in an intermediate outcome of class C (Wisdom and others 2002b).

Risk of extirpation was assessed for FS-BLM lands and for all lands. The five outcome classes that indexed risk on FS-BLM lands were referred to as environmental outcomes (Raphael and others 2001).

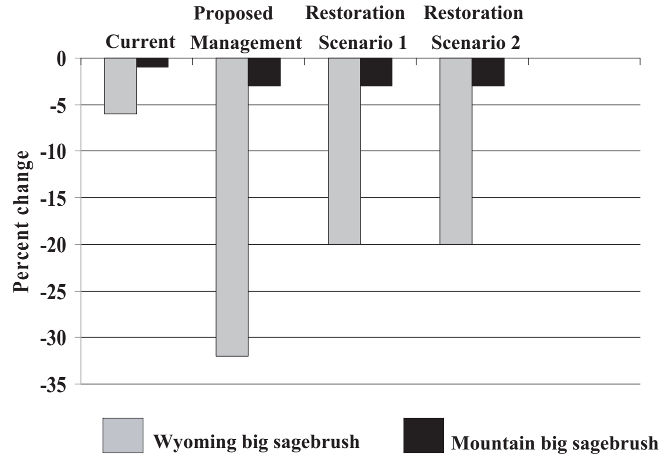

Figure 3—Percent change in habitat amount for sage-grouse, by major sagebrush communities, in 1,831 FS- and BLM-dominated subwatersheds within the historical range of sage-grouse in the Interior Columbia Basin (adapted from Hemstrom and others 2002). Results for proposed management (PM) and the restoration scenarios are for 100 years in the future. Decline is relative to amount of habitat estimated for historical conditions (circa 1850–1900) (Hann and others 1997).

Restoration Effects ______________

Results from Hemstrom and others (2002) showed that under proposed management, sage-grouse habitat on FS-BLM lands would decline by 27 percent compared with the current amount (weighted average of percent declines across the sagebrush communities shown in fig. 3). However, habitat declined more slowly under restoration scenarios 1 and 2 (by about 19 percent and 17 percent, respectively), but neither scenario halted the long-term downward trend. Most future habitat loss was associated with sagebrush transitions to herblands and grasslands dominated by cheatgrass and other exotic plants in large areas of the Wyoming big sagebrush communities. Substantially smaller habitat losses were projected in the future in mountain big sagebrush communities, with losses due mostly to encroachment by juniper. In mountain big sagebrush communities, however, some loss to exotic plant invasion was projected at lower elevation, drier sites, while loss to woodland and forest encroachment was projected at higher elevation, mesic sites. Additionally, small declines in habitat amount were projected for other sagebrush communities, such as low sagebrush (Hemstrom and others 2002).

Restoration scenarios 1 and 2 increased habitat amount, relative to proposed management, by about 0.6 million ha and 0.8 million ha, respectively. The model projections indicated that a substantial increase in habitat from passive and active restoration would be offset by large (>1 million ha) losses associated mostly with wildfire and the subsequent invasion of cheatgrass in the Wyoming big sagebrush communities.

In contrast to results for habitat amount, the quality of habitat improved substantially under the restoration scenarios compared with proposed management, as indexed by substantial reductions in UG and HRV departure (fig. 4). Only 22 percent and 12 percent of subwatersheds were characterized by high UG under scenarios 1 and 2, whereas high UG occurred in 68 percent and 53 percent of subwatersheds during the current period and under proposed management, respectively. Percentage of subwatersheds with high HRV departure under the restoration scenarios (2 percent) also was substantially lower than the percentage with high HRV departure currently (6 percent) and under proposed management (7 percent). The restoration scenarios also were associated with a higher percentage of subwatersheds in the low and none classes of UG and HRV departure compared to current conditions and proposed management (fig. 4).

Risk of sage-grouse extirpation on FS-BLM lands was reduced to a moderate level under the two restoration scenarios compared to a high risk under proposed management (fig. 5). The moderate risk of extirpation under the restoration scenarios was the same as that estimated for the current period (fig. 5). The difference between a moderate versus a high risk of extirpation, as evaluated under the outcome classes for sage-grouse, was found by Wisdom and others (2002b) to represent a substantial difference in the probability of regional extirpation for the species.

Three landscape variables contributed to the increased risk of sage-grouse extirpation under proposed management (Wisdom and others 2002a): (1) reduced habitat quantity and quality, as reflected in an overall reduction in habitat capacity; (2) increased contraction of the species' range,

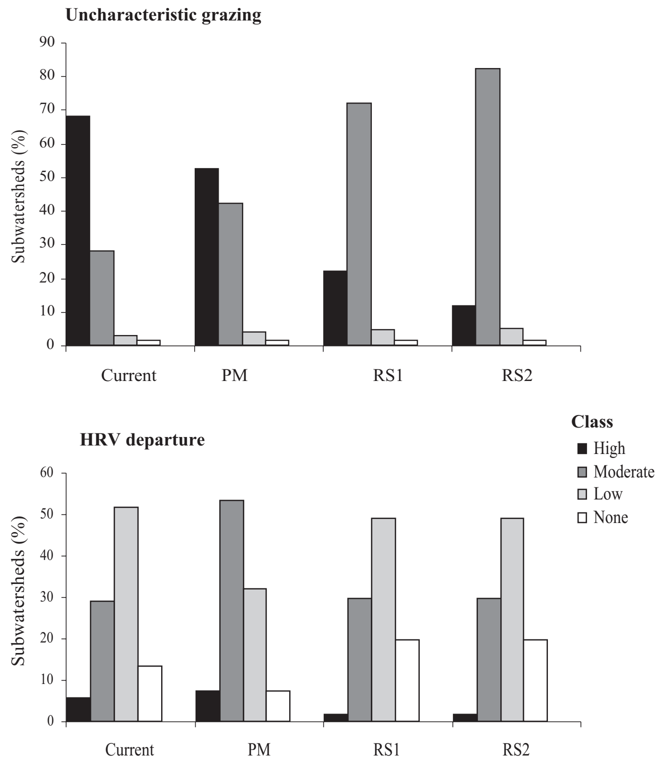

Figure 4—Changes in habitat quality for sage-grouse across time, as indexed by classes of uncharacteristic grazing and HRV departure in 1,831 FS- and BLM-dominated subwatersheds within the historical range of sage-grouse in the Interior Columbia Basin (from Hemstrom and others 2002). Results for proposed management (PM) and the two restoration scenarios (RS1 and RS2) are for 100 years in the future.

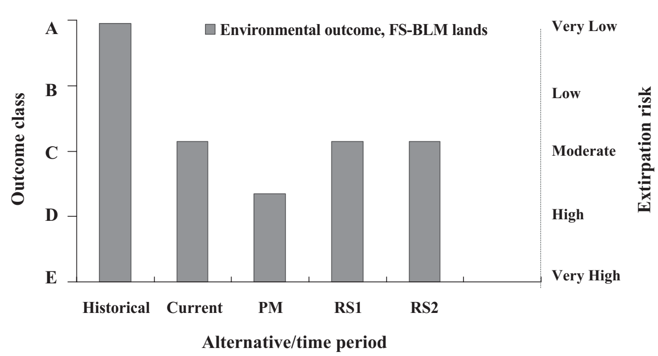

Figure 5—Risk of regional population extirpation for sage-grouse in the Interior Columbia Basin (adapted from Wisdom and others 2002a), as indexed by classes of environmental outcome (A = very low risk, B = low, C = moderate, D = high, and E = very high) projected for historical and current periods and 100 years in the future under proposed management (PM) and two restoration scenarios (RS1 and RS2). Results for environmental outcomes are for Forest Service (FS) and Bureau of Land Management (BLM) lands. Historical, current, and PM results are from Raphael and others (2001).

owing to continued habitat loss; and (3) decreased connectivity of habitats that remained within the contracted range. Wisdom and others (2002a) provide details.

Implications for Multiscale Planning and Monitoring

Results of restoration modeling by Hemstrom and others (2002) and Wisdom and others (2002a) have substantial and direct implications for management of sage-grouse habitats. We offer the following suggestions for planning and monitoring restoration activities that follow directly from results of the restoration scenarios:

1. **A strategic, multiscale approach is needed that links the scale of individual sagebrush stands with scales of the seasonal, year-round, and multi-population ranges of sage-grouse.** Identification of nesting and brood-rearing areas is critical for effective management of sage-grouse summer range. Similarly, identification of wintering areas is important for maintaining conditions adequate for winter survival. Information about conditions of individual sagebrush stands within seasonal ranges, as well as information about overall conditions on seasonal ranges, can be synthesized at larger scales to evaluate composite conditions for the species on a year-round basis. In turn, this information can be further synthesized to scales of local or multiple populations of sage-grouse, with patterns identified and summarized at larger, regional scales, such as the Snake River Plain or Columbia River Plateau. At each scale, relevant information is available for identifying management threats, setting restoration priorities, and implementing and monitoring a desired suite of restoration activities. While local areas are the traditional focus for restoration planning and implementation, the larger, regional scales are a critical and effective complement to local work. Information at regional scales, for example, can be used to target large areas that may deserve high priority for restoration and monitoring. By contrast, information about conditions on seasonal ranges, or of individual stands within seasonal ranges, is important for effective implementation of local restoration priorities.

2. **Consideration of connectivity across scales is essential.** Connectivity of summer range with winter range, and of local populations with multiple populations, is critical for maintaining viable populations of sage-grouse across the species' range. Raphael and others (2001) and Wisdom and others (2002a,b) used a landscape method to evaluate connectivity of sage-grouse habitats in the Basin as part of their population outcome model of extirpation risk. The method assessed the degree to which subwatersheds containing sage-grouse habitat fell within the median dispersal distance of juvenile grouse. This measure of connectivity was later validated as an important landscape measure of extirpation risk (Wisdom and others 2002b). Specifically, the connectivity of subwatersheds in areas currently occupied by sage-grouse was 61 percent (on a scale of 0 to 100 percent, where 100 percent represents habitats that are fully connected across the range of the species). By contrast, connectivity in areas where sage-grouse have been extirpated was only 23 percent (Wisdom and others 2002b). Similar

measures of connectivity need development and validation at a variety of scales to allow managers to understand how well restoration plans might improve the connectivity of habitat for sage-grouse, and to monitor the population response of sage-grouse to presumed improvements in connectivity. Development and validation of such connectivity measures will be most successful if conducted as a partnership between land managers and scientists, owing to the absence of research on this topic and the challenges of management application at multiple scales.

3. **Sustained use of a comprehensive suite of passive and active restoration treatments over extensive areas is needed.** Hemstrom and others (2002) and Wisdom and others (2002a) found that restoration of sagebrush habitats will require monumental spatial and temporal scales of application if downward trends are to be slowed or reversed. Expansive and sustained habitat restoration can maintain desired conditions and reduce the future risk of sage-grouse extirpation on FS-BLM lands. Local restoration efforts, without coordination and implementation across large areas as an adaptive management experiment, appear to have a low probability of reducing extirpation risk for sage-grouse in the Basin. This is due to the vast areas over which restoration must occur and the comprehensive, integrated manner in which a suite of restoration treatments must be implemented (Knick 1999). Knowledge voids about effective methods of restoration pose a major challenge. For example, few methods exist for effective restoration of native forbs in sagebrush habitats, and these forbs are critical for successful nesting and brood rearing by sage-grouse (Barnett and Crawford 1994; Drut and others 1994). Continued spread of exotic plants presents a formidable challenge to successful restoration, and warrants substantial research and management attention. In particular, the lower elevation, Wyoming big sagebrush communities are most susceptible to future loss from wildfire and subsequent invasion by cheatgrass. These areas warrant special attention for restoration activities. Moreover, results from Hemstrom and others (2002) suggest that suppression of wildfire, combined with improvements in grazing management, are critical for preventing expansive conversions of sagebrush to cheatgrass in Wyoming big sagebrush communities (fig. 2).

4. **Monitoring of both habitat and population responses across scales is critical.** Three types of monitoring have been defined and used by Federal land management agencies: (1) implementation, (2) effectiveness, and (3) validation monitoring. Implementation monitoring is the assessment of whether restoration and other management actions are implemented in the manner specified. By contrast, effectiveness monitoring evaluates whether the desired results from implementation were achieved, while validation monitoring determines the scientific validity of the concepts, methods, and predictions associated with the expected benefits of the management actions. For sage-grouse, all three types of monitoring are needed. For example, goals may be set for improving the amount, quality, and distribution of sage-grouse habitat under a restoration plan. The primary goal may be to improve habitat attributes, but invariably, the ultimate goal of such plans is to increase population growth of sage-grouse and associated species. Measuring such population responses will require regional scales of monitoring, and are best accomplished as part of research. Nonetheless, implementation monitoring is needed to determine whether the treatments are applied in the manner specified. Moreover, effectiveness monitoring is needed for two purposes: (1) to assess whether the desired habitat improvements were achieved with successful implementation (for example, were the desired improvements in habitat amount, quality, and distribution actually accomplished?); and (2) to determine whether the associated population of sage-grouse responded positively from the habitat improvements (for example, did the improvements in composition of understory bunchgrasses and forbs increase nest success and brood survival?). Finally, validation monitoring may be needed to understand why certain habitat restoration efforts might have failed, or how such restoration efforts worked successfully. Unfortunately, nearly all management and research of sage-grouse has focused on habitats or populations, but not both. Consequently, few monitoring efforts have considered effects on both habitats and populations, and considered all three types of monitoring. A notable exception is Connelly and others' (2000b) monitoring of sage-grouse response to prescribed burning in southeastern Idaho; this integrated type of habitat and population monitoring is needed to guide future restoration work. The model of Edelmann and others (1998), which evaluates the quality of sage-grouse habitat and predicts effects on growth rate of sage-grouse populations, provides a comprehensive framework for conducting all three types of monitoring at stand and landscape scales.

5. **A comprehensive set of species that depend on the sagebrush ecosystem needs to be targeted for restoration planning and monitoring.** A common management assumption about restoration efforts for sage-grouse is that such efforts will confer like benefits to a larger set of plants and animals that depend on sagebrush steppe. This assumption, however, has not been evaluated with empirical research and needs testing at multiple scales (Rich and Altman 2001). Moreover, new approaches that explicitly consider the needs of a comprehensive set of species need to be developed for effective restoration planning for all key attributes of the sagebrush ecosystem. Recently, Wisdom and others (2002c) developed a habitat network for a large set of vertebrates of conservation concern that depend on sagebrush steppe in the Basin. Watersheds for these species were characterized as one of three habitat conditions: Condition 1—habitats of high resiliency, abundance, and quality; Condition 2—habitats of high abundance but moderate resiliency and quality; and Condition 3—habitats that are highly degraded, fragmented, and isolated, or that have been extirpated. This type of characterization of a comprehensive, multispecies habitat network could be used 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 and quality (Condition 3), and to improve connectivity where spatial gaps have developed (Condition 3).

Conclusions

Restoration of sage-grouse habitat represents a daunting task. Without consideration of multiple scales of planning and monitoring, chances for success may be substantially reduced. New approaches that integrate a holistic suite of restoration treatments, including changes in management of livestock, are essential. Results of recent restoration modeling for sage-grouse provide a starting point for development of multiscale strategies that could facilitate effective recovery of key habitats across large areas of sage-grouse range. In addition to restoration planning and monitoring for sage-grouse, efforts that consider a comprehensive set of sagebrush-dependent species are needed. An example is the development of a habitat network and related multispecies approaches for restoration planning (Wisdom and others 2002c), which could facilitate a more holistic recovery of the sagebrush ecosystem. Without such efforts, managers will be faced with a high likelihood of continued habitat loss and increasing extirpation risk for species that depend on sagebrush habitats.

Acknowledgments

We thank T. Quigley, T. Mills, and R. Graham for their longstanding support of this work. We also thank A. Miller, C. McCarthy, and N. Shankar for mapping and analysis, and J. Augsburger, S. Sather-Blair, and G. Buckner for comments on our paper. Our work was funded by the U.S. Department of Agriculture, Forest Service, and the U.S. Department of the Interior, Bureau of Land Management.

References

Anderson, J. E.; Inouye, R. S. 2001. Landscape-scale changes in plant species abundance and biodiversity of a sagebrush steppe over 45 years. Ecological Monographs. 71: 531–556.

Barnett, J. K.; Crawford, J. A. 1994. Pre-laying nutrition of sage-grouse hens in Oregon. Journal of Range Management. 47: 114–118.

Connelly, J. W.; Braun, C. E. 1997. Long-term changes in sage-grouse *Centrocercus urophasianus* populations in western North America. Wildlife Biology. 3: 229–234.

Connelly, J. W.; Reese, K. P.; Fischer, R. A.; Wakkinen, W. L. 2000b. Response of a sage-grouse breeding population to fire in southeastern Idaho. Wildlife Society Bulletin. 28: 90–96.

Connelly, J. W.; Schroeder, M. A.; Sands, A. R.; Braun, C. E. 2000a. Guidelines to manage sage-grouse populations and their habitats. Wildlife Society Bulletin. 28: 967–985.

Crawford, J. A. 1997. Importance of herbaceous vegetation to female sage-grouse *Centrocercus urophasianus* during the reproductive period: a synthesis of research from Oregon, USA. Wildlife Biology. 3: 271.

Drut, M. S.; Crawford, J. A.; Gregg, M. A. 1994. Brood habitat use by sage-grouse in Oregon. Great Basin Naturalist. 54: 170–176.

Edelmann, F. B.; Ulliman, M. J.; Wisdom, M. J.; Reese, K. P.; Connelly, J. W. 1998. Assessing habitat quality using population fitness parameters: a remote sensing based habitat-explicit model for sage-grouse. Tech. Bull. 25. Moscow: University of Idaho, Forest, Wildlife, and Range Experiment Station. 33 p.

Hann, W. J.; Jones, J. L.; Karl, M. G.; Hessburg, P. F., Keane, R. E.; Long, D. G.; Menakis, J. P.; McNicoll, C. H.; Leonard, S. G.; Gravenmier, R. A.; Smith, B. G. 1997. Landscape dynamics of the basin. In: Quigley, T. M.; Arbelbide, S. J., tech. eds. An assessment of ecosystem components in the Interior Columbia Basin and portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-GTR-405 Vol. II. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 337–1055.

Hemstrom, M. A.; Wisdom, M. J.; Rowland, M. M.; Wales, B.; Hann, W. J.; Gravenmier, R. A. 2002. Sagebrush-steppe vegetation dynamics and potential for restoration in the Interior Columbia Basin, USA. Conservation Biology. 16: 1243–1255.

Holechek, J. L.; Pieper, R. D.; Herbel, C. H. 1998. Range management: principles and practices. 3rd ed. Upper Saddle River, NJ: Prentice Hall. 542 p.

Knick, S. T. 1999. Requiem for a sagebrush ecosystem? Northwest Science. 73: 53–57.

Laycock, W. A. 1991. Stable states and thresholds of range condition on North American rangelands: a viewpoint. Journal of Range Management. 44: 427–434.

McIver, J. L.; Starr, L. 2001. Restoration of degraded lands in the Interior Columbia River Basin: passive vs. active approaches. Forest Ecology and Management. 153: 15–28.

Miller, R. F.; Eddleman, L. L. 2000. Spatial and temporal changes of sage-grouse habitat in the sagebrush biome. Tech. Bull. 151. Corvallis: Oregon State University, Agricultural Experiment Station. 35 p.

Raphael, M. G.; Wisdom, M. J.; Rowland, M. M.; Holthausen, R. S.; Wales, B. C.; Marcot, B. M.; Rich, T. D. 2001. Status and trends of habitats of terrestrial vertebrates in relation to land management in the Interior Columbia River Basin. Forest Ecology and Management. 153: 63–88.

Rich, T.; Altman, B. 2001. The greater sage-grouse as an umbrella species. Grouse Partnership News. 2: 20.

Schroeder, M. A.; Young, J. R.; Braun, C. E. 1999. Sage-grouse (*Centrocercus urophasianus*). In: Poole, A.; Gill, F., eds. The birds of North America: life histories for the 21st century. Vol. 11. No. 425. Philadelphia, PA: The Birds of North America, Inc. 28 p.

Sveum, C. M.; Edge, W. D.; Crawford, J. A. 1998. Nesting habitat selection by sage-grouse in south-central Washington. Journal of Range Management. 51: 265–269.

U.S. Department of Agriculture, Forest Service, and U.S. Department of the Interior, Bureau of Land Management (USDA-FS and USDI-BLM). 2000. Interior Columbia Basin supplemental environmental impact statement, BLM/OR/WA/Pt-00/019+1792. Portland, OR: U.S. Bureau of Land Management. variously paginated.

Van Poolen, H. W.; Lacey, J. R. 1979. Herbage response to grazing systems and stocking intensities. Journal of Range Management. 32: 250–253.

West, N. E. 1999. Managing for biodiversity of rangelands. In: Collins, W. W.; Qualset, C. O., eds. Biodiversity in agroecosystems. Boca Raton, FL: CRC Press: 101–126.

Westoby, M.; Walker, B.; Noy-Meir, I. 1989. Opportunistic management for rangelands not at equilibrium. Journal of Range Management. 42: 266–276.

Wisdom, M. J.; Holthausen, R. S.; Wales, B. C.; Hargis, C. D.; Saab, V. A.; Lee, D. C.; Hann, W. J.; Rich, T. D.; Rowland, M. M.; Murphy, W. J.; Eames, M. R. 2000. Source habitats for terrestrial vertebrates of focus in the Interior Columbia basin: broad-scale trends and management implications. Gen. Tech. Rep. PNW-GTR-485. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Wisdom, M. J.; Rowland, M. M.; Wales, B. C.; Hemstrom, M. A.; Hann, W. J.; Raphael, M. G.; Holthausen, R. S.; Gravenmier, R. A.; Rich, T. D. 2002a. Modeled effects of sagebrush-steppe restoration on greater sage-grouse in the Interior Columbia Basin, USA. Conservation Biology. 16: 1223–1231.

Wisdom, M. J.; Wales, B. C.; Rowland, M. M.; Raphael, M. G.; Holthausen, R. S.; Rich, T. D.; Saab, V. A. 2002b. Performance of greater sage-grouse models for conservation assessment in the Interior Columbia Basin, USA. Conservation Biology. 16: 1232–1242.

Wisdom, M. J.; Wales, B. C.; Holthausen, R. S.; Hann, W. J.; Hemstrom, M. A.; Rowland, M. M. 2002c. A habitat network for terrestrial wildlife in the Interior Columbia Basin. Northwest Science. 76: 1–14 .