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SPECIAL SECTION

A Landscape Approach for Ecologically Based Management of Great Basin Shrublands

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Abstract

Native shrublands dominate the Great Basin of western of North America, and most of these communities are at moderate or high risk of loss from non-native grass invasion and woodland expansion. Landscape-scale management based on differences in ecological resistance and resilience of shrublands can reduce these risks. We demonstrate this approach with an example that focuses on maintenance of sagebrush (*Artemisia* spp.) habitats for Greater Sage-grouse (*Centrocercus urophasianus*), a bird species threatened by habitat loss. The approach involves five steps: (1) identify the undesired disturbance processes affecting each shrubland community type; (2) characterize the resistance and resilience of each shrubland type in relation to the undesired processes; (3) assess potential losses of shrublands based on their resistance, resilience, and associated risk; (4) use knowledge from these steps to design a landscape strategy to mitigate the risk of shrubland loss; and (5) implement the strategy with a comprehensive set of active and passive management prescriptions. Results indicate that large areas of the Great Basin currently provide Sage-grouse habitats, but many areas of sagebrush with low resistance and resilience may be lost to continued woodland expansion or invasion by non-native annual grasses. Preventing these losses will require landscape strategies that prioritize management areas based on efficient use of limited resources to maintain the largest shrubland areas over time. Landscape-scale approaches, based on concepts of resistance and resilience, provide an essential framework for successful management of arid and semiarid shrublands and their native species.

Key words: cheatgrass, disturbance, resistance, sagebrush, Sage-grouse, woodlands.

Introduction

The Great Basin of western North America is one of the largest shrubland-dominated ecosystems in the world (West 1999). Over 60% (>18 million hectares) of the Great Basin Ecoregion is composed of sagebrush (*Artemisia* spp.) and salt-desert (*Atriplex* spp.) shrublands (Suring et al. 2005*a*) (Fig. 1). This large arid to semiarid region was little influenced by humans before Anglo-American settlement in the mid-1800s (Vale 2002). Since then, a variety of human-caused disturbances, including livestock grazing, agricultural development, urban and exurban development, and associated water diversions, have caused widespread changes in the structure and ecological processes of shrublands and reduced the associated diversity of native plants and animals (Wisdom et al. 2005*a*, 2005*b*). Additional factors contributing to these changes include atmospheric carbon dioxide enrichment and ongoing climate change (Ziska et al. 2005).

Like many other arid and semiarid regions of the world, these changes are manifest in widespread invasion of non-native species, expansion of woody species, and altered fire regimes (D'Antonio & Vitousek 1992; van Auken 2000; Chambers & Wisdom 2009). The rate and magnitude of the changes occurring in Great Basin shrublands, however, are notable for three reasons (Hemstrom et al. 2002). First, the rate of change has been so rapid that appropriate management responses have had substantial time lags, thus limiting their effectiveness. Second, the spatial extent of change has been so large that the resources required to prevent, stop, or reverse such change has far exceeded available resources. Third, management responses have not matched the large-scale of change and typically have been local and reactive rather than regional and strategic.

Much of the Great Basin's remaining shrublands could be lost in coming decades unless effective changes in management are implemented (Suring et al. 2005*b*). Consequently, we describe and illustrate how landscape-scale approaches can be used to maintain native shrublands in arid and semiarid environments like those of the Great Basin. Our specific objectives were to (1) describe the concepts of ecological resistance and

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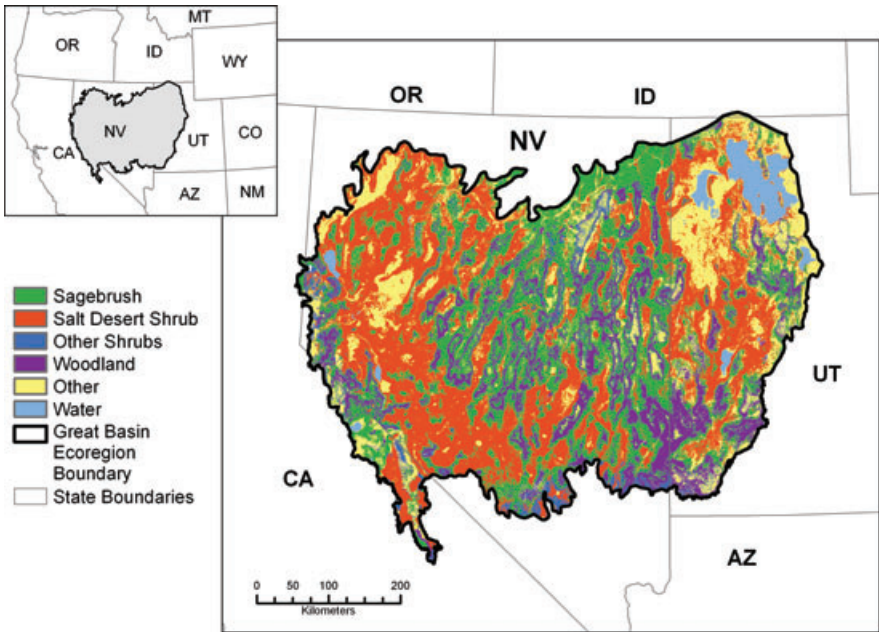

Figure 1. The Great Basin Ecoregion in western North America and its major vegetation types (adapted from Suring et al. 2005*a*).

resilience as they influence maintenance of Great Basin shrublands; (2) highlight the effects of two of the most pervasive threats to these shrublands, non-native annual grass invasion and woodland expansion, based on ecological resistance and resilience; and (3) illustrate how differences in resistance and resilience among shrubland types and associated changes in structure and ecological processes can be used to prioritize management at landscape scales. We believe that landscape approaches for shrubland management, as demonstrated here, can be applied to most arid and semiarid shrubland ecosystems of the world where human land uses and resulting undesired changes in disturbance processes are common.

Resistance and Resilience in Great Basin Shrublands

Two of the most pervasive threats to persistence of Great Basin shrublands are invasion of non-native annual grasses and woodland expansion (Suring et al. 2005*b*; Wisdom et al. 2005*b*). Non-native invasive annual grasses from Eurasia, especially cheatgrass (*Bromus tectorum*), have spread rapidly into low- to mid-elevation sagebrush and salt-desert shrublands (Knapp 1996; Meinke et al. 2009). Physical and climatic factors including elevation, slope, aspect, precipitation, and temperature determine the underlying susceptibility of shrublands to invasion by annual grasses (Bradley & Mustard 2005; Chambers et al. 2007; Meinke et al. 2009). Invasion and establishment of the annual grasses are facilitated by natural and anthropogenic disturbances that spread propagules, like roads and trails, remove competition from perennial grasses and forbs, like intensive livestock use, or increase resource availability, like fire and surface perturbations (Wisdom et al. 2005*a*, 2005*b*; Meinke et al. 2009). Once established, annual grasses increase the biomass of fine and highly flammable fuels (Link et al. 2006), resulting in increased fire frequency and size (Whisenant 1990). Cheatgrass and other non-native annual grasses currently dominate millions of hectares of former shrublands (Bradley & Mustard 2005).

During the last century, native woodland communities expanded into large areas of mid- to high-elevation sagebrush and mountain brush (e.g., *Ceanothus* spp., *Purshia* spp., and *Symphoricarpos* spp.) communities (Miller et al. 2008; Miller et al. in press). These woodland communities are composed of pinyon pine (*Pinus monophylla*) and juniper (*Juniperus osteosperma* and *J. occidentalis*). The capacity of these woodland species to expand into sagebrush vegetation types is influenced by physical and climatic factors that include elevation, temperature, precipitation, slope, aspect, and local site conditions (Suring et al. 2005*b*; Miller et al. 2008). Factors that influence expansion include ongoing climate change, favorable conditions for establishment at the turn of the twentieth century, and intensive grazing by livestock (Miller et al. 2005, 2008). Infilling that follows woodland establishment results in a progressive decrease in abundance and richness of plant species in sagebrush communities. Woody fuels subsequently increase on the landscape, resulting in more frequent and larger fires of higher severity (Miller et al. 2008).

Differences exist in the relative resistance and resilience of shrubland types to annual grass invasion, woodland expansion, and other undesired, human-based disturbance processes (Wisdom et al. 2005*b*). For our purposes, we define ecological resistance as the biotic and abiotic factors and ecological processes that limit establishment and population growth of invading species (D'Antonio & Thomsen 2004). Ecological resilience is the amount of disturbance that an ecosystem

can withstand without changes in processes and structures occurring that are of sufficient magnitude to result in new alternative states (Holling 1973; Gunderson 2000). Thresholds are crossed when a given vegetation state does not return to the original state via natural processes following disturbance, and requires active management to restore (Laycock 1991; Briske et al. 2005). Although approaches for applying resistance, resilience, and threshold concepts at the level of ecological sites have been suggested (Briske et al. 2008; D'Antonio et al. in press), their application has only recently been extended to landscape scales for shrubland management (Wisdom et al. 2005*b*; Meinke et al. 2009).

As in other arid and semiarid regions, resilience of shrubland types in the Great Basin increases along gradients of increasing available resources (water and nutrients) and annual net primary productivity (Chambers et al. 2007; Brooks & Chambers in press) (Fig. 2). More resources and a higher level of productivity by functionally diverse native plant communities increase the capacity of the native community to effectively compete with invaders and regenerate following disturbance.

As elevation increases, degree days decrease and available water and site productivity increase across the shrubland types (West 1983; West & Young 2000). Resistance to invasive annual grasses mirrors the current ecological amplitude of these species and is lowest for lower-elevation salt-desert shrub and Wyoming big sagebrush (*A. tridentata wyomingensis*) types, and highest for mountain big sagebrush (*A. t. vaseyana*) and mountain brush types (Fig. 2). Salt-desert shrub types at the low end of the precipitation gradient have insufficient available water to support annual grass establishment and reproduction, whereas mountain brush types at high elevations have insufficient degree days for annual grass growth and reproduction (Chambers et al. 2007). In contrast to annual grasses, resistance to woodland expansion is lowest for mountain big sagebrush and mountain brush types and highest for Wyoming big sagebrush types (Miller et al. 2005, 2008). The environmental conditions in which salt-desert types occur are outside the ecological amplitudes of woodland species.

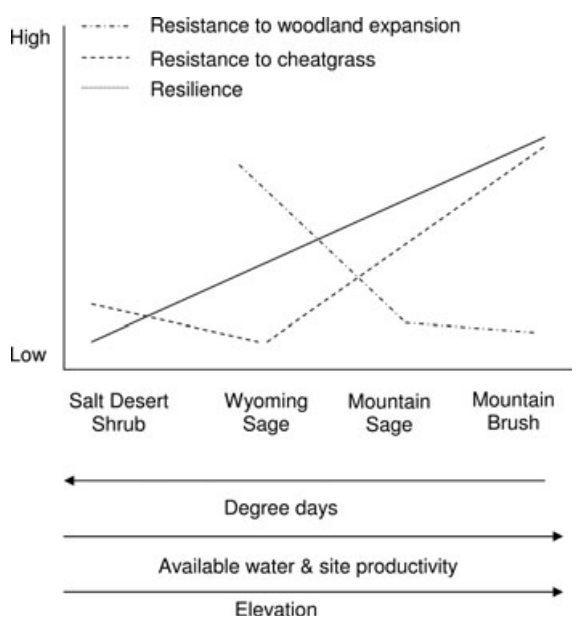

Figure 2. The relative ecological resistance and resilience of Great Basin shrublands to invasion by cheatgrass and expansion of woodlands.

Regardless of shrubland type, both resistance and resilience decrease as a function of the intensity of land uses and management actions that change the structure and ecological processes of native shrublands (Wisdom et al. 2005*a*, 2005*b*). Those shrublands with low resistance and resilience are at high risk of crossing ecological thresholds to alternative states following either natural or human-caused disturbances.

Maintaining Sagebrush Habitats for Sage-Grouse — An Example Landscape Approach

Management application of ecological resistance, resilience, and thresholds at a landscape scale in shrublands involves five basic steps: (1) identifying the undesired disturbance processes that are likely to affect each shrubland type; (2) characterizing and mapping the resistance and resilience of each shrubland type in relation to the identified disturbance processes or, conversely, the risk that desired conditions will be lost and difficult to recover or restore; (3) assessing potential losses of shrublands or associated resources based on the risk levels; (4) using knowledge from steps 1–3 to design a landscape-based, spatially explicit strategy to mitigate higher risk levels by decreasing the probability of transitions to undesired conditions, or maximizing recovery following a change to undesired conditions; and (5) implementing the strategy with a comprehensive set of active and passive management prescriptions that effectively address all human disturbances and processes that contribute to the higher risk levels. We illustrate these steps with an example for Greater Sage-grouse (*Centrocercus urophasianus*, hereafter referred to as Sage-grouse), one of the Great Basin's prominent bird species. Sage-grouse have experienced range-wide contractions in habitats and populations across western North America, including large areas in the Great Basin (Schroeder et al. 1999; Rowland 2004). Populations have been extirpated by human activities in nearly 50% of its range (Schroeder et al. 2004). Consequently, Sage-grouse in the Great Basin and elsewhere are being considered for designation as threatened or endangered under the United States Endangered Species Act (Knick in press).

Sage-grouse cannot persist without large areas of sagebrush and the associated understory of native grasses and forbs (Schroeder et al. 1999). This stringent requirement for large areas of intact, native sagebrush communities provides a useful starting point for landscape planning and management (Wisdom et al. 2005*a*, 2005*b*). Benefits to other resources beyond Sage-grouse, such as to other species (Rowland et al. 2006) and to ecological services (Chambers et al. 2008), can also be efficiently considered in our example or in similar landscape approaches. Thus, the analytical steps illustrated here can be used for landscape management of any shrubland-associated

resources, and Sage-grouse are just one of many possible examples.

The Great Basin Ecoregion used in our example largely follows the boundaries of the hydrological Great Basin, an area of the Intermountain Western United States with no external drainage to the ocean, but also includes adjacent, ecologically similar areas (Nachlinger et al. 2001; Rowland & Wisdom 2005) (Fig. 1). Sagebrush communities in the Ecoregion occupy more than 8 million hectares of semiarid environments that are characterized by annual precipitation of 20–40 cm and winters with freezing temperatures (West 1999). Salt-desert shrublands occupy almost 10 million hectares of the Ecoregion's most arid environments, with annual precipitation of less than 20 cm and saline soils (West 1999).

Step 1: Identify Undesired Disturbances and Processes

All sagebrush community types typically serve as habitats for Sage-grouse (Schroeder et al. 1999; Rowland et al. 2005). Because cheatgrass invasion and woodland expansion are the most widespread threats to persistence of these types (Suring et al. 2005*b*; Wisdom et al. 2005*b*; Miller et al. 2008; Miller et al. in press), we identified these two undesired disturbance processes for our example. Both processes are affected by abiotic and biotic site conditions, past and current land uses, and regional climate regimes (Chambers et al. 2007; Miller et al. 2008).

Step 2: Map Shrubland Resistance and Resilience in Relation to the Undesired Processes

Sagebrush types in the Great Basin have varying degrees of resistance and resilience in response to cheatgrass invasion and woodland expansion (Fig. 2). This is illustrated by the risk models built and applied by Suring et al. (2005*b*), which estimated the probability that each sagebrush type will transit to cheatgrass or to woodlands during the next 30 years (Figs. 3 & 4). The 30-year period represents near-term infilling of existing woodlands within existing sagebrush types, as well as the near-term increase in cover and abundance of cheatgrass already present within existing sagebrush types. Additional risk over longer periods is posed by changes in climate but specific effects are highly uncertain and thus were not modeled (Suring et al. 2005*b*). Risk levels in these models—low, moderate, and high—directly reflect opposite degrees of resistance and resilience of each sagebrush community to invasion by woodlands or cheatgrass, that is, high risk communities have low resistance and resilience, low risk communities have high resistance and resilience.

In general, the Suring et al. (2005*b*) models predict that Wyoming big sagebrush and other sagebrush communities on warmer, drier sites, which typically occur at lower elevations, have a higher risk of conversion to cheatgrass (Chambers et al. 2007) but a lower risk of conversion to woodlands (Miller et al. in press). In contrast, mountain big sagebrush and other sagebrush communities on colder, wetter sites, typically at higher elevations, have a higher risk of conversion to woodlands (Miller et al. in press) but a lower risk of conversion to cheatgrass (Chambers et al. 2007).

These estimated risks reflect not only abiotic and biotic site conditions but also current land uses in the Great Basin (Wisdom et al. 2005*a*, 2005*b*). Land uses that increase the probability of sagebrush conversion to cheatgrass on sites with low resistance include: (1) a level of grazing pressure by bulk-feeding herbivores (e.g., cattle, horses, or elk) that diminishes native grass cover, creates open seedbeds, and thus confers competitive advantage to cheatgrass; (2) motorized uses of a large network of roads and trails on public lands, as well as cross-country motorized travel on these lands, which serve as landscape vectors for spread of cheatgrass; (3) continued expansion of electric transmission lines, cellular towers, and associated right-of-ways and supporting human activities, which also act as landscape vectors for spread of cheatgrass; (4) continued build-out of energy infrastructure and associated transportation routes, mines and mining transportation routes, agricultural and exurban land developments, and associated water developments and diversions, all of which facilitate cheatgrass invasion near these land uses. Recent increases in atmospheric deposition of carbon dioxide also favor exotic brome species like cheatgrass in arid and semiaird shrubland systems (Ziska et al. 2005).

Current land uses that underlie the estimated risk levels of sagebrush conversion to woodlands (Miller et al. 2005, 2008; Miller et al. in press) include: (1) a level of long-term ungulate grazing pressure on grasses that substantially decreases these fine fuels, reduces fire frequency, and allows woodland expansion and establishment; and (2) long-term fire suppression that further allows woodland species to survive and eventually out-compete sagebrush. Projected changes in climate also favor woodlands over sagebrush on many sites (Neilson et al. 2005; Miller et al. in press).

Step 3: Assess Potential Losses of Shrublands and Associated Resources Based on Resistance and Resilience

The resistance and resilience of Sage-grouse habitats to invasion by cheatgrass and woodlands reflect the estimated risks of sagebrush loss obtained from the risk models of Suring et al. (2005*b*) (Figs. 3 & 4). Approximately 35% (1.9 million hectares) of current Sage-grouse habitats in the Great Basin Ecoregion are at moderate risk of conversion to cheatgrass, and another 17% (0.9 million hectares) are at high risk (Suring et al. 2005*b*). Approximately 6% of Sage-grouse habitats are at moderate risk of conversion to woodlands, and another 35% are at high risk, based on estimates for the East-central portion of the Ecoregion (Suring et al. 2005*b*).

If all sagebrush habitats at moderate or high risk to cheatgrass invasion or to woodland expansion are eliminated by these disturbance processes, the probability of Sage-grouse extirpation in the Ecoregion would increase substantially. Wisdom et al. (in press) estimated the degree of environmental similarity of each 100,000-ha block that encompasses current Sage-grouse range with blocks of the same size in areas where Sage-grouse have been extirpated. An extent of 100,000 ha

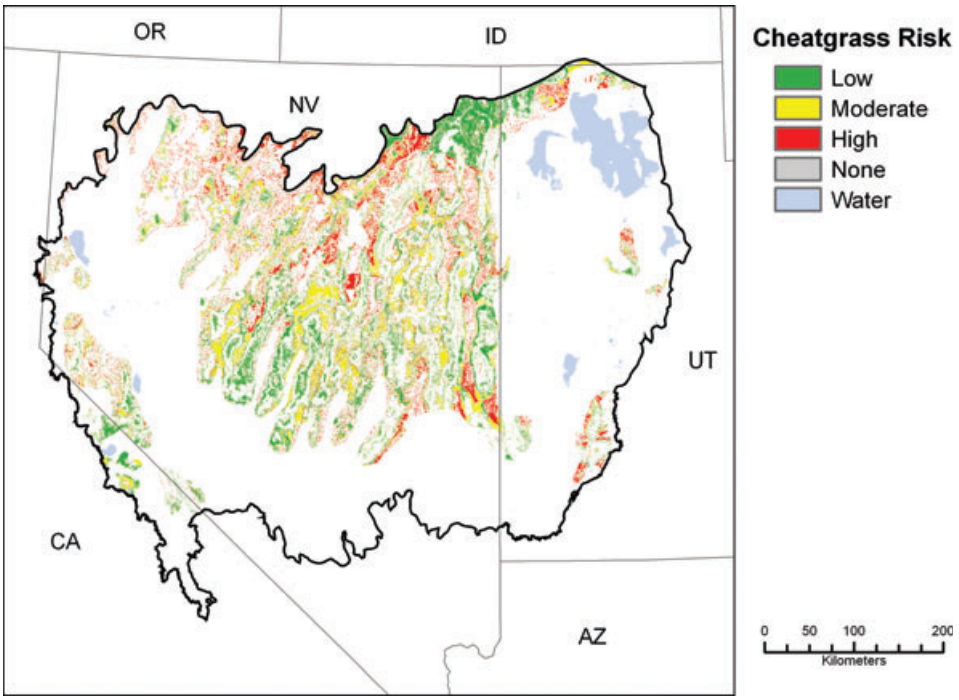

Figure 3. Sagebrush habitats for Greater Sage-grouse in the Great Basin Ecoregion, classified by the risk of loss to cheatgrass (from Suring et al. 2005*b*). Over half of the current sagebrush area is classified at moderate or high risk of conversion to cheatgrass during the next 30 years. Only sagebrush within the current range of Greater Sage-grouse in the Ecoregion is shown.

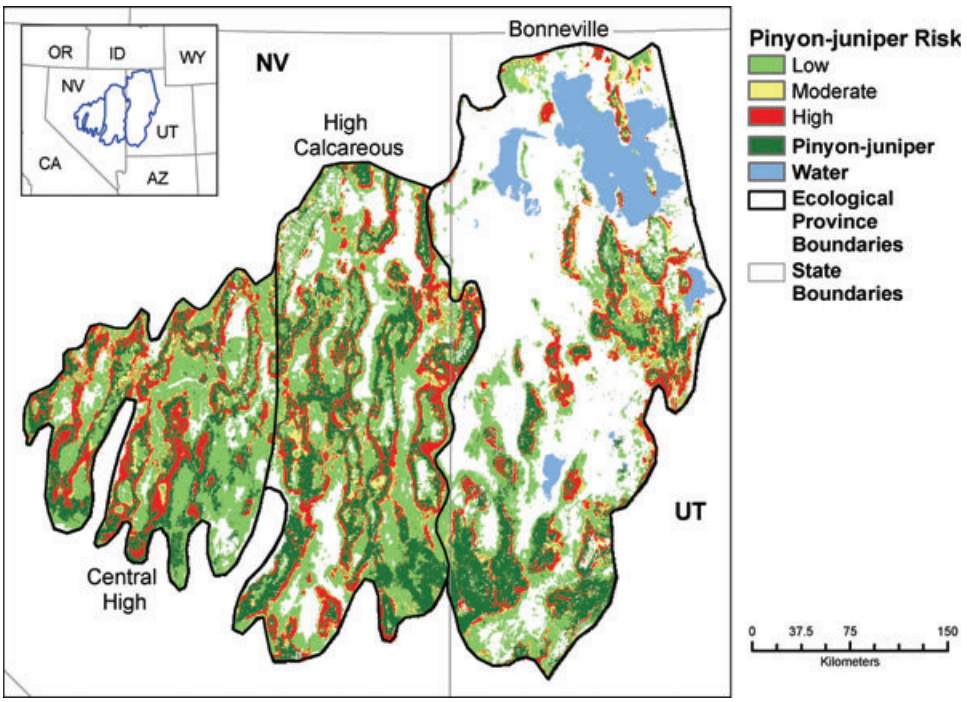

Figure 4. Sagebrush habitats within the current range of Greater Sage-grouse in three ecological provinces in the East-central portion of the Great Basin Ecoregion, classified by the risk of habitat loss to woodlands (from Suring et al. 2005*b*). Almost half of the current sagebrush area is classified at moderate or high risk of conversion to woodlands during the next 30 years. In addition, most sagebrush areas at moderate or high risk of conversion to woodlands do not overlap with, and thus are additive to, sagebrush areas at moderate or high risk of conversion to cheatgrass.

was used for this evaluation because this size of area typically encompasses the year-round range of a given Sage-grouse population (Wisdom et al. in press).

A key model predictor was the percent area of sagebrush in a given 100,000-ha block, regardless of sagebrush configuration or contiguity. A block containing less than 27% of area in sagebrush had a high probability of being associated with areas where Sage-grouse once occurred but now are extirpated (Wisdom et al. in press). Consequently, blocks containing less than 27% of area in sagebrush may represent a "sagebrush threshold" for the presence of Sage-grouse. This "threshold" is consistent with results from two other studies (Wisdom et al. 2002; Aldridge et al. 2008) that documented Sage-grouse extirpation within large (>100,000 ha) landscapes containing less than 26% of area in sagebrush.

Factors in addition to percent area of sagebrush increased the accuracy of model predictions of environmental similarity with extirpated range (Aldridge et al. 2008; Wisdom et al. in press), but sagebrush area was the best-performing individual variable. Thus, if sagebrush habitats at high risk of conversion to cheatgrass or woodlands are eliminated by these processes, 66% (83) of the 126 blocks in the East-central part of the Great Basin Ecoregion, where both types of risk were evaluated (Suring et al. 2005*b*), would be below the 27% sagebrush threshold. If sagebrush habitats at moderate risk to cheatgrass or woodlands are eliminated, an additional 28% (35) of the blocks would be below the threshold. By contrast, 19% (24) of the 126 blocks currently are below this threshold.

Step 4: Design Spatially Explicit Strategy to Mitigate Risks of Undesired Effects

An effective strategy to reduce the risk of future loss of sagebrush to cheatgrass and to woodlands, and thus maintain Sage-grouse habitats, could be based on establishing a comprehensive set of landscape-based spatial priorities and objectives compatible with the scale of Sage-grouse requirements (Meinke et al. 2009). Given limited resources for management, an efficient approach to establish and implement spatial priorities could focus on maintaining the largest areas of Sage-grouse habitat that require mostly passive management (little or no active resource inputs, see Step 5; also see Meinke et al. (2009) for a similar approach). In this case, the 100,000-ha blocks dominated by larger areas of sagebrush with higher resistance and resilience (lower risk of loss) would have high priority for management. Less focus would be placed on blocks with smaller areas of sagebrush of lower resistance and resilience.

One demonstration of such an approach is described here. The approach first characterizes each block as one of four types, based on percent area of sagebrush and its resistance to invasion by cheatgrass and woodlands. A spatial priority of high, moderate, or low is assigned to each type of block, based on the assumed efficiency by which sagebrush can be maintained above the 27% threshold associated with Sage-grouse presence (Table 1). Blocks of high spatial priority contain both adequate sagebrush area (above the threshold) and are dominated by sagebrush of higher resistance. These blocks are referred to as "strongholds" because they contain adequate, secure areas of sagebrush that can be maintained efficiently for Sage-grouse. Blocks of moderate or low priority have substantially less sagebrush area, either currently or projected, with lower resistance. These blocks are referred to as "support" because they may not provide adequate area in sagebrush by themselves, but would benefit Sage-grouse when stronghold blocks also are present.

Although our block types are designed for Sage-grouse, the process of characterizing block types by different combinations of sagebrush area and resistance can be used for landscape planning and management of any sagebrush-associated resources. In addition, the types of active and passive management prescriptions we describe for each block type have direct

Table 1. Characteristics of four block types in the East-central portion of the Great Basin Ecoregion within the current range of Greater Sage-grouse.

Block Type	*Current Condition*	*Projected Condition*	*Spatial Priority*	*Management to Maintain Sagebrush*
Primary stronghold	Above threshold	Above threshold	High	Current management
Secondary stronghold	Above threshold	Below threshold if sagebrush areas at moderate risk to cheatgrass or woodlands are eliminated	High	Passive management to treat the large areas at moderate risk of conversion to cheatgrass
Primary support	Above threshold	Below threshold if sagebrush areas at moderate or high risk to cheatgrass or woodlands are eliminated	Moderate	Passive management to treat the large areas at moderate risk of conversion to cheatgrass Passive and active management to treat the large areas at high risk of conversion to cheatgrass or woodlands
Secondary support	Below threshold	Below threshold	Low	Same as primary support blocks

Characteristics are based on whether the block contains at least 27% of area in sagebrush as Greater Sage-grouse habitat (above threshold) under current and projected conditions. Projected condition is based on estimated future losses of sagebrush to cheatgrass invasion or woodland expansion (Suring et al. 2005*b*), and the type of management approaches appropriate to prevent or reduce such losses.

relevance to long-term maintenance of sagebrush, regardless of the associated resource management goals.

- *Primary stronghold blocks (high priority):* These blocks currently are above the sagebrush threshold associated with Sage-grouse presence (27%) and projected to remain above the threshold even if all sagebrush at moderate or high risk to cheatgrass or woodlands is eliminated by these disturbance processes. Primary strongholds represent areas where current management is likely to maintain adequate area in sagebrush because of high resistance and resilience. Seven percent (9) of the 126 blocks in the East-central part of the Great Basin Ecoregion fit this condition (Fig. 5).
- *Secondary stronghold blocks (high priority):* These are blocks currently above the sagebrush threshold but projected to fall below the threshold if all sagebrush at moderate risk to cheatgrass or woodlands is eliminated. These blocks would not fall below the threshold if current sagebrush at high risk is eliminated. Sagebrush maintenance in these blocks is likely to require extensive changes in current

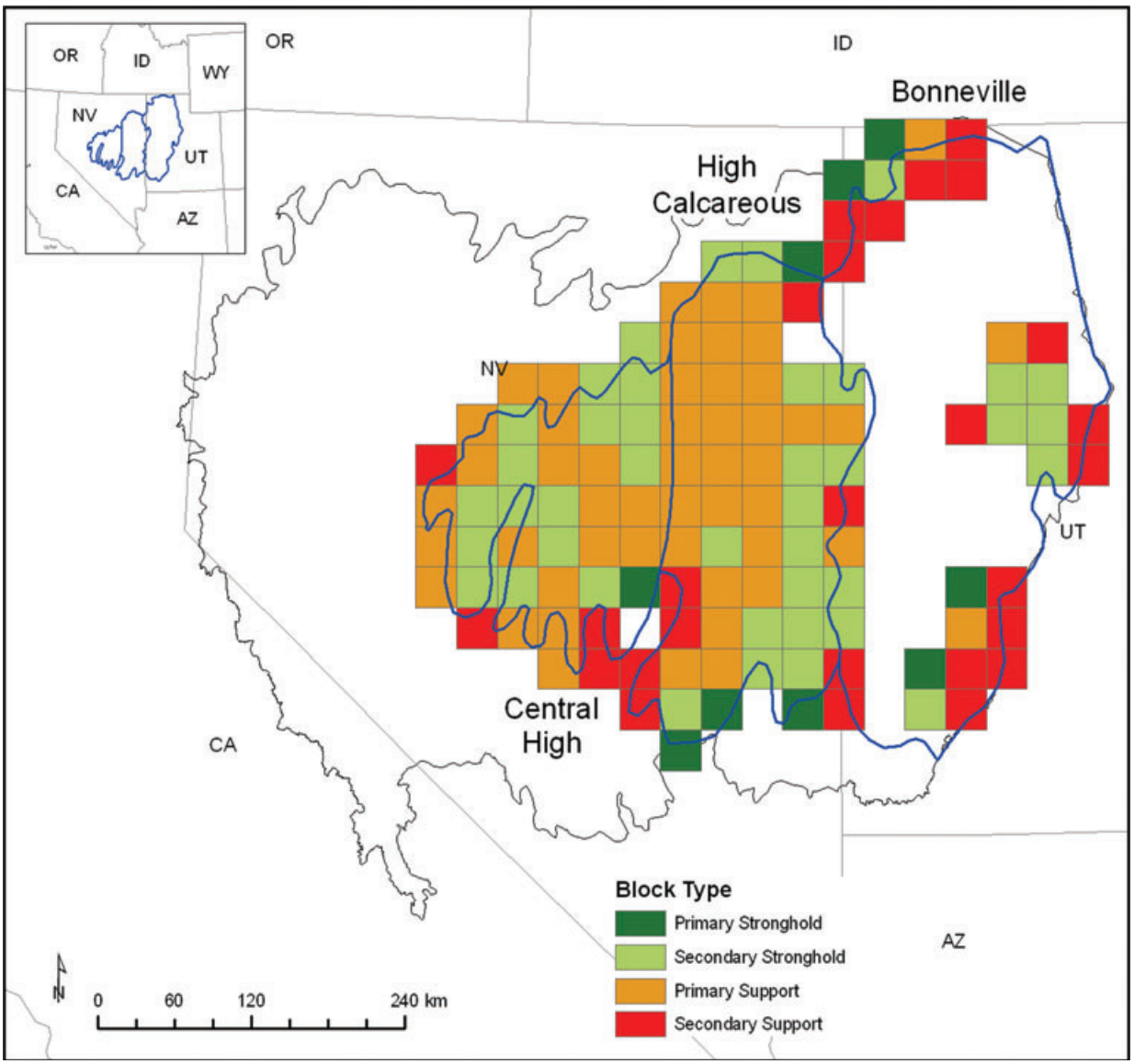

Figure 5. Characterization of 126 blocks, each 100,000 ha in size, in three ecological provinces in the East-central portion of the Great Basin Ecoregion where the risk of sagebrush conversion to cheatgrass and to woodlands was evaluated within the current range of Greater Sage-grouse. Blocks were characterized as one of four types, based on whether the block contained at least 27% of area in sagebrush (above threshold for the presence of Greater Sage-grouse), currently and as projected in the future under potential losses to cheatgrass invasion or woodland expansion. Percent area of sagebrush is currently above the threshold in primary strongholds, secondary strongholds, and primary support blocks but is projected to drop below the threshold in secondary strongholds if sagebrush at moderate risk to cheatgrass or woodlands is eliminated, and in primary support blocks if sagebrush at moderate or high risk to cheatgrass or woodlands is eliminated. Percent area of sagebrush in secondary support blocks is below the threshold.

management, mostly with passive management, to reduce the moderate risk of potential widespread habitat loss to cheatgrass (Step 5). Secondary strongholds compose 32% (40) of the 126 blocks (Fig. 5).

- *Primary support blocks (moderate priority):* These are blocks currently above the sagebrush threshold but projected to fall below the threshold if all sagebrush at moderate or high risk to cheatgrass or woodlands is eliminated. Primary support blocks represent areas that are challenging to maintain or restore, and that require an extensive and sustained combination of passive and active management (Step 5) to assure their maintenance, owing to large areas at high risk of conversion to cheatgrass. These blocks compose 40% (50) of the 126 blocks (Fig. 6).
- *Secondary support blocks (low priority):* These are blocks with insufficient area in sagebrush to support Sage-grouse independent of other areas of sagebrush. Secondary support blocks compose the remaining 21% (27) of the 126 blocks. These blocks are located along the edges of current Sage-grouse range.

Spatial objectives could be tiered to these priorities (Meinke et al. 2009). Objectives could consist of an explicit list of desired vegetation states to be maintained or restored for each type of sagebrush community within blocks of high spatial priority. These objectives also could apply to blocks of moderate priority, after assuring that management designs and available resources are likely to maintain enough sagebrush in high-priority blocks. Objectives within a given block might include, in order of priority: (1) maintain sites that have an intact sagebrush overstory and native understory; (2) increase or restore desired understory plant species at sites containing an intact sagebrush overstory but co-dominated by cheatgrass or woodlands; and (3) replace cheatgrass or woodlands with desired plant species on former sagebrush sites to facilitate transitions back to sagebrush.

Objectives represent a second level of expected management efficiencies (Table 1). Spatial priorities first are used to identify large areas (blocks of different types) where management can efficiently maintain adequate sagebrush. Objectives, in turn, identify vegetation states for efficient management focus within each block of higher spatial priority.

Step 5: Implement Comprehensive Passive and Active Management Prescriptions to Support Strategy

A variety of passive and active management prescriptions can be implemented to address spatial priorities and objectives. Passive management includes the removal or attenuation of existing disturbances or management practices that contribute to an undesired effect (McIver & Starr 2001). Active management, by contrast, uses new inputs to the system to stop, mitigate, or reverse undesired effects (McIver & Starr 2001). Passive management is effective where the structure and ecological processes of the shrubland are intact and can recover without new resource inputs. This may be the situation for many sagebrush types at low or moderate risk of conversion to cheatgrass (Suring et al. 2005*b*; Wisdom et al. 2005*c*). In this case, passive management prescriptions that mitigate effects of existing land uses, such a grazing, motorized activities, and energy development, are required to maintain current conditions or reduce risk (Suring et al. 2005*b*; Wisdom et al. 2005*c*).

The effectiveness of such prescriptions depends on their cumulative benefits. Such approaches must be landscape-based and applied consistently across large areas of each block to be effective. Ideally, these prescriptions are applied across a variety of risk conditions and shrubland communities within high-priority or moderate-priority blocks to meet goals across the spectrum of vegetation conditions.

Most sagebrush types at high risk of conversion to cheatgrass, or at moderate or high risk of conversion to woodlands, require a combination of passive and active management to effectively reduce these risks (Suring et al. 2005*b*; Wisdom et al. 2005*c*). Without active management, the potential is high for crossing thresholds to alternative, undesired states (Suring et al. 2005*b*; Wisdom et al. 2005*c*). On sites with high risk of conversion to cheatgrass, active prescriptions include reductions in sagebrush biomass to decrease competition with perennial herbaceous species, herbicide treatments to control cheatgrass, and seeding of desired grasses and forbs that can decrease the future invasibility of the site (Suring et al. 2005*b*; Wisdom et al. 2005*c*; D'Antonio et al. in press). The passive management prescriptions described above also are required to ensure recovery of these areas.

For sagebrush sites at moderate or high risk of conversion to woodlands, active prescriptions are required (Suring et al. 2005*b*; Wisdom et al. 2005*a*, 2005*c*). These can include prescribed fire or mechanical treatments to reduce the cover of juniper or pinyon pine, followed by seeding of desired plant species and grazing rest. Repeated use of fire or mechanical treatments over time may be required to prevent further invasion of juniper or pinyon pine and to maintain sagebrush communities. If these sites also are at high risk of conversion to cheatgrass, the use of fire or mechanical treatments to control woodland expansion may enhance cheatgrass invasion at lower elevations. Consequently, use of both active and passive management prescriptions described for cheatgrass control may be required.

In general, primary stronghold blocks may require little passive or active management beyond the extent and types of prescriptions used under current management (Table 1). Secondary stronghold blocks, however, are likely to require extensive changes in management, using a variety of passive management prescriptions, to prevent potential losses of large sagebrush areas at moderate risk of conversion to cheatgrass (Table 1). Active management prescriptions would also be required to treat smaller areas within these blocks at moderate risk or high risk of conversion to woodlands.

In contrast to strongholds, primary support blocks are dominated by sagebrush at high risk of loss to cheatgrass or woodlands, or a mix of sagebrush at moderate and high risk. Extensive and sustained applications of both passive and active management prescriptions will be required to successfully mitigate these risks and maintain or recover

adequate areas in sagebrush (Table 1). Secondary support blocks also would require a variety of passive and active management prescriptions to maintain sagebrush, but the presence of relatively low area of sagebrush suggests that these blocks are lower priority for Sage-grouse management.

Implications for Practice

- The concepts of ecological resistance and resilience provide a foundation for the development and implementation of effective landscape strategies to maintain native shrublands.
- We describe a five-step process that illustrates how landscape strategies, priorities, and objectives can be developed based on shrubland resistance and resilience. Results can be used to guide implementation of effective management prescriptions across landscape extents where the greatest benefits to shrublands and associated resources can be realized.
- New collaborations among management agencies, landowners, and public groups are required to establish landscape-scale spatial goals and design and implement effective strategies and prescriptions.
- New national and regional policies that reflect the concepts and approaches presented here, combined with budgets for shrubland maintenance and recovery that match the scale and diversity of challenges to be addressed, would increase the likelihood of success.

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