Sagebrush Ecosystem Conservation and Management: 1–9, 2011

Introduction: An Ecoregional Assessment of the Wyoming Basins

Steven T. Knick, Steven E. Hanser, Matthias Leu, Cameron L. Aldridge, and Michael J. Wisdom

The Wyoming Basins Ecoregional Assessment (WBEA) area in the western United States contains a number of important land cover types, including nearly one-fourth of the sagebrush (*Artemisia* spp.) in North America. Although relatively unappreciated until recent decades, the broad open landscapes dominated by sagebrush communities have received increasing attention for their ecological value and the resources that they contain (Knick and Connelly 2011). As many as 350 wildlife species depend on sagebrush ecosystems for all or part of their life requirements (Wisdom et al. 2005a). Within the WBEA, intact sagebrush landscapes provide an important stronghold for populations of greater sage-grouse (*Centrocercus urophasianus*), recently listed as a candidate species under the Endangered Species Act (U.S. Department of the Interior 2010). Numerous other plant and vertebrate species of state or national concern also occur within the WBEA study area (Ch. 2). Conserving sagebrush ecosystems is a major conservation challenge that will require an understanding not only of current trajectories and scales of habitat change due to natural and anthropogenic disturbances (Leu and Hanser 2011), but also the potential exacerbation of these trends from climate change (Wiens and Bachelet 2010, Miller et al. 2011).

The WBEA area contains significant amounts of resources important to sustain human populations. Oil, gas, and wind energy development as well as the necessary infrastructure for energy transmission are dominant land uses that can fragment landscapes and influence resource availability (Doherty et al. 2011, Naugle et al. 2011). Livestock grazing also occurs throughout the WBEA area, potentially altering vegetation structure and quality as well as other ecosystem processes (Freilich et al. 2003). Recreation and wilderness amenities on these lands impose additional physical and legal demands to more traditional commodity uses (Knick et al. 2011). Over half of the sagebrush within the WBEA area is public land; the largest land areas are managed by the U.S. Bureau of Land Management (BLM) and the U.S. Forest Service (FS) for multiple uses. Less than two percent of the sagebrush in the WBEA area receives legal protection from conversion of land cover in which only natural processes are allowed to influence the system (Ch. 1). Because most sagebrush habitats are managed by public agencies, federal land use actions can impact a large proportion of sagebrush habitats and their dependent wildlife.

The ecological importance of the WBEA area coupled with its abundant natural resources create a complex challenge for balancing land and resource use with long-term conservation. Systematic conservation planning can help resolve this challenge through development of spatially explicit objectives (Pressey et al. 2007); these objectives can be developed by delineating species distributions relative to habitat gradients and land-use patterns. Management strategies or conservation planning then can be based on trade-offs between land uses and important areas for species or biodiversity (Groves 2003, Doherty et al. 2011). To address these issues, we conducted an ecoregional assessment to determine broad-scale relationships among plant and wildlife species and gradients of habitat and disturbance. Our objec-

FIG. I.1. The Wyoming Basin Ecoregional Assessment study area.

tives were to: (1) identify primary land uses and their potential influence on sagebrush habitats, (2) identify plant and wildlife species of conservation concern, (3) delineate the distribution of sagebrush habitats and environmental and anthropogenic features from existing and updated Geographic Information System (GIS) coverages, (4) conduct field surveys to determine distribution and abundance of wildlife species and invasive plants, (5) integrate field- and GIS-based information to determine habitat relationships using spatially explicit models, and (6) apply spatially explicit models of habitat relationships to delineate species occurrence and abundance. The strength of our ecoregional assessment is based on our capability to accurately model species distributions in relation to both habitat characteristics and human activities across the large extent of the WBEA. These mapped relationships provide information that land managers can use to understand how and where current actions and future development may influence species and habitats within the WBEA study area.

RATIONALE AND PURPOSE OF ECOREGIONAL ASSESSMENTS

The ecoregional assessment process leads to the development of substantial information on wildlife-habitat relationships and the role of disturbance in shaping the patterns of species and habitat distributions (Wisdom et al. 2000, 2005a). Ecoregional assessments are inherently spatial analyses conducted at broad regional scales to identify habitat or species strongholds, quantify landscape features, describe natural disturbances, and delineate human activities (Ricketts et al. 1999, Noss et al. 2001, Jones et al. 2004, Wisdom et al. 2005a). Ecoregional assessments also can detect data gaps and identify key environmental variables that contribute to effective monitoring strategies for broad-scale and long-term change.

Conservation strategies developed at regional scales of an ecoregional assessment are an important part of effective conservation and land-use planning because processes operating at regional scales can be decoupled from those at intermediate or local scales (Wiens 1989, Kotliar and Wiens 1990, Jennings 2000). The distributions of many sagebrush-associated species considered in this assessment cover continental scales, which also renders broad regional understanding a necessary part of conservation planning (Knick et al. 2003). Thus, regional planning and analyses are important components of a hierarchical process in which broad-scale data, such as developed in this ecoregional assessment, establish a regional context that is complemented by fine-scale data useful for setting local objectives (Hansen et al. 1993, U.S. Bureau of Land Management 2005, Wisdom et al. 2005b).

Broad-scale assessments and conservation planning often are more cost-effective and efficient at projecting alternate management scenarios and outcomes than smaller-scale efforts. In contrast, small-scale assessments provide more detailed data on individuals or local populations but lack large-scale context (May 1994, Corsi et al. 2000). The large areas included in ecoregional assessments often permit conclusions independent of administrative jurisdictions and land stewardship patterns. Much of the data used in these broad-scale assessments can be existing data, which can improve the cost-effectiveness and efficiency of the process. Ecoregional assessments provide information important for developing management and conservation strategies commensurate with regional or continental distributions of many species (Dinerstein et al. 2000).

STUDY AREA

Boundaries of the WBEA (Fig. I.1) were determined primarily by the distribution of sagebrush within the Wyoming Basins and then expanded to include adjacent regions of ecological and management concern (Ch. 1). The total area encompassed 345,300 km^2, and included most of Wyoming, and smaller portions of southwestern Montana, northern Colorado, northeastern Utah, and eastern Idaho. Private lands constituted 33% of the WBEA area. The BLM and FS each manage one-fourth of the WBEA area; the remaining public lands are managed by state agencies, the U.S. National Park Service, and the U.S. Bureau of Indian Affairs. The Wyoming Basins and Utah-Wyoming-Rocky Mountains ecoregions, as defined by The Nature Conservancy (1997), were included in their entirety as were portions of the Southern Rocky Mountains and Middle Rockies-Blue Mountains ecoregions.

The WBEA area contains approximately 131,600 km^2 of sagebrush (38% of the total area), which represents nearly 24% of all sagebrush lands in the United States. The BLM manages 44% of the sagebrush within the WBEA; private land owners are responsible for 38% and the FS is responsible for 6%. Characteristics of sagebrush landscapes differ among land ownership and agency (Knick 2011). Private lands containing sagebrush typically are associated with more productive sites containing deeper soils and greater water availability. In contrast, lands managed by BLM often have shallow soils, low water availability, and lower precipitation. Sagebrush lands managed by the FS have greater precipitation but generally are on steeper, rockier locations. Consequently, management options vary by land ownership because of relative productivity, resistance to disturbance, and ability to recover or respond to treatment (Knick 2011).

ANALYSIS APPROACH

Assessment Methods

The foundation of an ecoregional assessment rests on analyzing a series of map overlays using a GIS to identify and delineate complex relationships among multiple spatial features. These overlays are effectively the basic components of an assessment; they lay the foundation for increasingly complex analyses to address more targeted questions. Coupled relationships, such as those between existing or proposed land use actions and habitat and species distributions, provide a powerful basis for informing management decisions. This process of data analyses and syntheses can resolve complications related to habitat alteration and loss, identify locations for conservation measures to retain important species or habitat strongholds, and set priorities for habitat restoration or rehabilitation (Pressey et al. 2007).

We combined both coarse- and fine-filter approaches in this assessment (Ch. 2). Coarse-filter assessments focus on species groups or dominant land cover types under the assumption that conserving representative ecological communities will provide the greatest benefit (Groves 2003). In contrast, a fine-filter approach recognizes that rare species or those with a narrow range of habitat requirements will be missed by a coarse-filter and may need individualized data development and analysis. Our hybrid approach captured a broad range of the sagebrush species and communities and also provided information on individual species of concern.

We conducted field surveys during 2005 and 2006 to collect data on plant and wildlife distributions relative to gradients of land cover and human land use. The hierarchical sampling design represented a novel approach that maximized efficiency for collecting information on a broad range of plant and wildlife species distributed over large areas and minimized personnel time and expense (Ch. 4). In contrast to ecoregional assessments based on existing information, the data collected from these surveys permitted us to develop empirical models relating species to habitats and disturbance that were directly applicable to the WBEA area and not extrapolated from elsewhere. We grouped individual species from field surveys into separate chapters on sage-grouse (Ch. 5), songbirds (Ch.6), other wildlife species (Ch. 7), pronghorn (*Antilocapra americana*) (Ch. 8), small mammals species (Ch. 9), and exotic plants (Ch. 10) (Table I.1).

Procedural steps for conducting an ecoregional assessment vary widely because data availability, existing knowledge, size of the region being assessed, funding, and the opportunity to collect empirical data to develop or validate modeled predictions likewise are highly variable (Dinerstein et al. 2000, Groves 2003, Wisdom 2005a, The Nature Conservancy and World Wildlife Fund 2006). Our approach for the WBEA was based on a process conducted in the Great Basin Ecoregion (Wisdom et al. 2005a) and included the following steps:

1. Identify spatial extents for the assessment (Ch. 1)
2. Identify species of conservation concern (Ch. 2)
3. Delineate ranges for species of conservation concern (Ch. 2, 5–9)
4. Estimate habitat requirements of species of conservation concern (Ch. 5–8)
5. Identify regional threats and their effects on habitats (Ch. 3, 10)
6. Estimate and map the risks of habitat loss or degradation posed by example threats (Ch. 3, 5–9, 10)
7. Estimate potential effects of threats on individual species of concern (Ch. 5–9)

TABLE I.1. Wildlife and plant species modeled for the Wyoming Basins Ecoregional Assessment by chapter. Abundance varied by species but was either (1) a predicted density estimate or (2) predicted probability ranking for classes ranging from absent to high abundance. These were based on either count of individuals or, in some cases, sign (e.g., pellets) indicating presence of the species. Probability of occurrence for a species was based simply on presence.

Chapter	Species	Scientific name	Abundance	Occurrence
5	Greater sage-grouse	*Centrocercus urophasianus*	X	X
6	Brewer's sparrow	*Spizella breweri*	X	X
	Sage sparrow	*Amphspiza belli*	X	X
	Sage thrasher	*Oreoscoptes montanus*	X	X
	Green-tailed towhee	*Pipilo chlorurus*		X
	Lark sparrow	*Chondestes grammicus*	X	X
	Vesper sparrow	*Pooecetes gramineus*	X	X
7	Harvester ant	*Pogonomyrmex* spp.	X	X
	Thatch ant	*Formica* spp.		X
	Short-horned lizard	*Phrynosoma hernandesi*		X
	White-tailed jackrabbit	*Lepus townsendii*		X
	Cottontail	*Sylvilagus* spp.		X
	Least chipmunk	*Tamias minimus*		X
8	Pronghorn	*Antilocapra americana*		X
9	Deer mouse	*Peromyscus maniculatus*		X
10	Crested wheatgrass	*Agropyrun cristatum*		X
	Cheatgrass	*Bromus tectorum*		X
	Halogeton	*Halogeton glomeratus*		X
	Russian thistle	*Salsola* spp.		X

8. List management guidelines, major assumptions, and limitations (Ch. 11)

Ecological Scales and Landscapes

Scale issues play an important role in understanding and interpreting our results. The ecological scale of an object or process is defined by its spatial and temporal dimensions (Table I.2), and generalizing across spatial scales can lead to inappropriate conclusions (Wiens 1989). Our study was designed to detect broad-scale patterns in species response to environmental characteristics at the cost of fine-scale conclusions. For example, at the scale of the WBEA, white-tailed jackrabbits (*Lepus townsendii*) were likely to occur when >82% of the land cover within a 0.27-km radius was dominated by sagebrush (Ch. 7). It is incorrect to conclude that jackrabbits will occupy every place having these land cover characteristics within the WBEA area.

Our ability to detect patterns in species response rested on correctly aligning the scales at which a species perceives its environment and the scales at which habitat or disturbance shapes the features within that environment. We attempted to align these scales for each environmental feature by varying the radius surrounding sampling locations, allowing us to assess influences on individual species that might be expressed at different spatial scales. The length of the radius was varied to reflect the home range size of the different

TABLE I.2. Definition of terms used to define spatial relationships (Turner et al. 1989) for the Wyoming Basins Ecoregional Assessment.

Term	Definition
Extent	The size of the study area or spatial area of interest. Extent can be used to describe radius of a moving window analyses used in a Geographic Information System to captured varying areas of interest.
Grain	The finest level of spatial resolution in the data. No finer patterns can be detected within the grain size (e.g., small habitat features covering 1-2 ha cannot be depicted in land cover maps with a grain size of 1 km). For all analyses conducted in this assessment, our grain size was 90 m.
Resolution	The precision of the measurement used in the analysis. Resolution ranges from fine to coarse but cannot be finer than the grain size. Data may be resampled to coarser resolution and still retain the original grain size.
Ecological scale	The spatial dimensions of an object or process. Ecological scale has been described by terms such as as broad, local, or landscape. Our ecoregional assessment was designed to identify patterns that occur over broad spatial scales.
Cartographic scale	The ratio of map to earth units used to reduce features represented on a map. Cartographic scale is often confounded with ecological scale, and is further confused because fine-scale ecological processes often are measured at a large cartographic scale (ratio of map to actual dimensions).

species in our assessment (Ch. 4). Thus, we assumed that the ecological scale of an individual home range was related to ecosystem structure (Holling 1992). The final predictive equations often combined environmental variables measured from multiple ecological scales. As such, our developed habitat relationships and mapped distributions of occurrence and abundance reflect a multi-scaled response by species to their environment.

Choice of spatial extent and grain of the data used in an investigation often are arbitrary because the true dimensions of ecological scale are frequently unknown (Wiens 1989). We used spatial extent in two contexts: the boundaries of the WBEA and the buffered distance or window surrounding a point within which environmental characteristics were measured. Even though the spatial extent of the analysis window changed with different radii length, the underlying grain of the data (90-m grid cells) remained the same.

MANAGEMENT CONTRIBUTIONS

This ecoregional assessment provides significant new information on distributions, abundances, and habitat relationships for a number of species of conservation concern that depend on sagebrush in the WBEA area. This information was primarily derived from field surveys. For some species, such as greater sage-grouse, we already have large amounts of information on distribution, habitat requirements, population trends, response to disturbance, and seasonal movements in the WBEA area (Holloran et al. 2005, 2010; Johnson et al. 2011; Naugle et al. 2011). However, most species in our assessment have been less thoroughly studied, and we have little data available on distributions and habitat relationships other than anecdotal information or relationships developed elsewhere. Our empirically driven spatial models provide significant new understanding of landscape-level needs for species across a range of taxa spanning insects, reptiles, birds, and mammals. Moreover, we documented response and dominant spatial scales to anthropogenic disturbance, including energy development, power lines, and major roads for 15 sagebrush-associated species in the WBEA including 10 species of conservation concern.

Our maps of predicted occurrence and abundance based on spatially explicit models of habitat relationships provide managers with information needed to effectively manage habitat for a suite of sagebrush-associated species. Our maps also provide a working hypothesis of areas that contain suitable environmental conditions to guide field surveys, to confirm species presence, and to evaluate species-habitat relationships. For example, our surveys for pygmy rabbits (*Brachylagus idahoensis*) were conducted independent of the known range map because ongoing work (Purcell 2006) identified that the species occurred in the WBEA outside of previously published range maps. We documented the presence of pygmy rabbits at several locations outside of the known range including one observation >100 km from any previously known location.

The response curves developed for each of the modeled species in the WBEA represent the changes in the probability of a species presence relative to changes in a single or suite of environmental variable(s). By using maps of predicted habitat change coupled with knowledge of the species response, managers can establish habitat protection and restoration plans that promote effective use of available and projected resources. Management of sagebrush ecosystems in the WBEA area currently is being driven by a core areas concept for a single-species based on sage-grouse distributions (Doherty et al. 2011). Thus, our multi-species assessment of distribution and response to disturbance provides additional information for managers to evaluate the efficacy of this management concept to benefit other species that depend on sagebrush in the WBEA area.

LITERATURE CITED

Block, W. M., D. M. Finch, and L. A. Brennan. 1995. Single-species versus multiple-species approaches for management. Pp. 461–476 *in* T. E. Martin and D. M. Finch (editors). Ecology and management of neotropical migratory birds. Oxford University Press, New York, NY.

Corsi, F., J. de Leeuw, and A. K. Skidmore. 2000. Modeling species distribution with GIS. Pp. 389–434 *in* L. Boitani and T. K. Fuller (editors). Research techniques in animal ecology: controversies and consequences. Columbia University Press, New York, NY.

Dinerstein, E., G. Powell, D. Olson, E. Wikramanayake, R. Abell, C. Loucks, E. Underwood, T. Allnutt, W. Wettengel, T. Ricketts, H. Strand, S. O'Connor, and N. Burgess. 2000. A workbook for conducting biological assessments and developing biodiversity visions for ecoregion-based conservation. Conservation Science Program, World Wildlife Fund, Washington, DC.

Doherty, K. E., D. E. Naugle, H. E. Copeland, A. Pocewicz, and J. M. Kiesecker. 2011. Energy development and conservation trade-offs: systematic planning for greater sage-grouse in their eastern range. Pp. 505–516 *in* S. T. Knick and J. W. Connelly (editors). Greater sage-grouse: ecology and conservation of a landscape species and its habitats. Studies in Avian Biology 38. University of California Press, Berkeley, CA.

Groves, C. R. 2003. Drafting a conservation blueprint. A practioner's guide to planning for biodiversity. Island Press, Washington, DC.

Hansen, A. J., S. L. Garman, and B. Marks. 1993. An approach for managing vertebrate diversity across multiple-use landscapes. Ecological Applications 3:481–496.

Holling, C. S. 1992. Cross-scale morphology, geometry, and dynamics of ecosystems. Ecological Monographs 62:447–502.

Holloran, M. J., B. J. Heath, A. G. Lyon, S. J. Slater, J. L. Kuipers, and S. H. Anderson. 2005. Greater sage-grouse nesting habitat selection and success in Wyoming. Journal of Wildlife Management 69:638–649.

Holloran, M. J., R. C. Kaiser, and W. A. Hubert. 2010. Yearling greater sage-grouse response to energy development in Wyoming. Journal of Wildlife Management 74:65–72.

Jennings, M. D. 2000. Gap analysis: concepts, methods, and recent results. Landscape Ecology 15:5–20.

Johnson, D. H., M. J. Holloran, J. W. Connelly, S. E. Hanser, C. L. Amundson, and S. T. Knick. 2011. Influences of environmental and anthropogenic features on greater sage-grouse populations, 1997–2007. Pp. 407–450 *in* S. T. Knick and J. W. Connelly (editors). Greater sage-grouse: ecology and conservation of a landscape species and its habitats. Studies in Avian Biology 38. University of California Press, Berkeley, CA.

Jones, A., J. Catlin, T. Lind, J. Frelich, K. Robinson, L. Flaherty, E. Molvar, J. Kessler, and K. Daly. 2004. Heart of the West conservation plan. Wild Utah Project, Salt Lake City, UT.

Knick, S. T. 2011. Historical development, principal legislation, and current management of sagebrush habitats. Pp. 13–31 *in* S. T. Knick and J. W. Connelly (editors). Greater sage-grouse: ecology and conservation of a landscape species and its habitats. Studies in Avian Biology 38. University of California Press, Berkeley, CA.

Knick, S. T., and J. W. Connelly. 2011. Greater sage-grouse and sagebrush: an introduction to the landscape. Pp. 1–9 *in* S. T. Knick and J. W. Connelly (editors). Greater sage-grouse: ecology and conservation of a landscape species and its habitats. Studies in Avian Biology 38. University of California Press, Berkeley, CA.

Knick, S. T., D. S. Dobkin, J. T. Rotenberry, M. A. Schroeder, W. M. Vander Haegen, and C. Van Riper, III. 2003. Teetering on the edge or too late? Conservation and research issues for avifauna of sagebrush habitats. Condor 105:611–634.

Kotliar, N. B., and J. A. Wiens. 1990. Multiple scales of patchiness and patch structure: a hierarchical framework for the study of heterogeneity. Oikos 59:253–260.

May, R. M. 1994. The effect of spatial scale on ecological questions and answers. Pp. 1–17 *in* P. J. Edwards, R. M. May, and N. R. Webb (editors). Large-scale ecology and conservation biology. Blackwell Scientific, Oxford, UK.

Miller, R. F., S. T. Knick, D. A. Pyke, C. W. Meinke, S. E. Hanser, M. J. Wisdom, and A. L. Hild. 2011. Characteristics of sagebrush habitats and limitations to long-term conservation. Pp. 145–184 *in* S. T. Knick and J. W. Connelly (editors). Greater sage-grouse: ecology and conservation of a landscape species and its habitats. Studies in Avian Biology 38. University of California Press, Berkeley, CA.

Noss, R., G. Wuerthner, K. Vance-Borland, and C. Carroll. 2001. A biological conservation assessment for the Utah-Wyoming-Rocky Mountains Ecoregion: a report to The Nature Conservancy. Conservation Science, Inc., Corvallis, OR.

Pressey, R. L., M. Cabeza, M. E. Watts, R. M. Cowling, and K. A. Wilson. 2007. Conservation planning in a changing world. Trends in Ecology and Evolution 22:583–592.

Purcell, M. J. 2006. Pygmy rabbit (*Brachylagus idahoensis*) distribution and habitat selection in Wyoming. M.S. Thesis, University of Wyoming, Laramie, WY.

Ricketts, T. H., E. Dinerstein, D. M. Olson, C. J. Loucks, W. Eichbaum, D. DellaSala, K. Kavanagh, P. Hedao, P. T. Hurley, K. M. Carney, R. Abell, and S. Walters. 1999. Terrestrial ecoregions of North America: a conservation assessment. Island Press, Washington, DC.

The Nature Conservancy. 1997. Designing a geography of hope: guidelines for ecoregion-based conservation in The Nature Conservancy. The Nature Conservancy, Arlington, VA.

The Nature Conservancy and World Wildlife Fund. 2006. Standards for ecoregional assessments and biodiversity visions. The Nature Conservancy, Arlington, VA.

Turner, M. G., V. H. Dale, and R. H. Gardner. 1989. Predicting across scales: theory development and testing. Landscape Ecology 3:245–252.

U.S. Bureau of Land Management. 2005. Land use planning handbook. BLM Handbook H-1601-1.

U.S. Department of the Interior. 2010. Endangered and threatened wildlife and plants; 12-month findings for petitions to list the greater sage-grouse (*Centrocercus urophasianus*) as threatened or endangered; proposed rule. Federal Register 75:13910–13958.

Wiens, J. A. 1989. Spatial scaling in ecology. Functional Ecology 3:385–397.

Wiens, J. A., and D. Bachelet. 2010. Matching the multiple scales of conservation with the multiple scales of climate change. Conservation Biology 24:51–62.

Wisdom, M. J., R. S. Holthausen, B. C. Wales, C. D. Hargis, V. A. Saab, D. C. Lee, W. J. Hann, T. D. Rich, M. M. Rowland, W. J. Murphy, and M. R. Eames. 2000. Source habitats for terrestrial vertebrates of focus in the interior Columbia Basin: broad-scale trends and management implications. USDA Forest Service General Technical Report PNW-GTR-485. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Wisdom, M. J., M. M. Rowland, and L. H. Suring (editors). 2005a. Habitat threats in the sagebrush ecosystem: methods of regional assessment and applications in the Great Basin. Alliance Communications Group, Lawrence, KS.

Wisdom, M. J., M. M. Rowland, and R. J. Tausch. 2005b. Effective management strategies for sage-grouse and sagebrush: a question of triage? Transactions North American Wildlife and Natural Resources Conference 70:206–227.