National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Great Basin National Park

An Ecological Landscape Analysis

Natural Resource Report NPS/GRBA/NRR—2019/2002

ON THE COVER
Wind energy development located immediately northwest of Great Basin National Park
Photograph by: Patrick J. Comer

Great Basin National Park

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Natural Resource Report NPS/GRBA/NRR—2019/2002

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Acronyms

Definitions for the acronyms used in this report can be seen in Table 1 below.

Table 1. Definitions for the acronyms used in this report.

Acronym	Definition
AADT	Annual Average Daily Traffic
AresourceC	Area of Critical Environmental Concern
AGI	Annual Grasses Index
AML	Appropriate Management Level
ArcGIS	Arc Geographic Information System
AUC	Area Under the (ROC) Curve
AUM	Animal Unit Month
AWC	Available Water Capacity
AWS	Associate Weather Services
BCM	Basin Characterization Model
BLM	Bureau of Land Management
BpS	Biophysical Settings
CA	Change Agent
CART	Classification and Regression Tree
CBR	Central Basin and Range
CCVI	Climate Change Vulnerability Index
DCMP	Desert Conservation Management Plan
DEM	Digital Elevation Model
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DRECP	Desert Renewable Energy Conservation Plan
DRS	Division of Resource Services
DSS	Decision Support System
EFC	Environmental Flow Components
EIA	Ecological Integrity Assessment

Table 1 (continued). Definitions for the acronyms used in this report.

Acronym	Definition
EIS	Environmental Impact Statement
ENSO	El Niño Southern Oscillation
EO	Element Occurrence
EPA	Environmental Protection Agency
EPCA	Energy Policy and Conservation Act
ESA	Endangered Species Act
ESD	Ecological Site Description
ESRI®	Environmental Systems Research Institute, Inc.
ET	Evapotranspiration
EVT	Existing Vegetation Type
FAO	Food and Agriculture Organization
FGDC	Federal Geographic Data Committee
FLPMA	Federal Land Policy and Management Act
FRCC	Fire Regime Condition Class
FRI	Fire Return Interval
G-1, G-3	Globally Imperiled-Globally Vulnerable
GA	Grazing Allotment
GAP	Gap Analysis Project
GCM	General Circulation Model
GFDL	Geophysical Fluid Dynamics Laboratory
GIS	Geographic Information System
GSG	Greater sage grouse
HA	Herd Area
HMA	Herd Management Area
HRV	Historic Range of Variation
HU	Hydrologic Unit
HUC	Hydrologic Unit Code
IBA	Important Bird Areas
ICLUS	Integrated Climate and Land Use Scenarios
IPCC	Intergovernmental Panel on Climate Change

Table 1 (continued). Definitions for the acronyms used in this report.

Acronym	Definition
ISO	International Organization for Standardization
KEA	Key Ecological Attribute
Kw	K factor (soil erodibility)
LANDFIRE	Landscape Fire and Resource Management Planning Tools Project
LCM	Landscape Condition Model
LFRDB	LANDFIRE Reference Database
LRU	Landscape Reporting Unit
LU/LC	Land Use/Land Cover
LUP	Land Use Plan
Maxent	Maximum Entropy (distribution modeling software)
MDI	Mojave Desert Initiative
MQ	Management Question
MRDS	USGS Mineral Resource Data System
MRLA	Multiple Resource Land Area
NADP	National Atmospheric Deposition Program
NAMC	National Aquatic Monitoring Center
NAS	USGS Nonindigenous Aquatic Species
NCAR	National Center for Atmospheric Research
NresourceP	National Centers for Environmental Prediction
NED	National Elevation Dataset
NEPA	National Environmental Policy Act
NGO	Non-Governmental Organization
NHD	National Hydrography Dataset
NHD Plus	National Hydrography Dataset Plus
NID	National Inventory of Dams
NL	Natural Landscapes
NLCD	National Land Cover Dataset
NPMS	National Pipeline Mapping System
NPS	National Park Service
NRCS	Natural Resource Conservation Service

Table 1 (continued). Definitions for the acronyms used in this report.

Acronym	Definition
NREL	National Renewable Energy Laboratory
NRV	Natural Range of Variability
NTAD	National Transportation Atlas Database
NVDEP	Nevada Department Environmental Protection
NWI	National Wetland Inventory
OHV	Off-Highway Vehicles
ORV	Off-road Vehicle
PADUS	Protected Area Database of the U.S. *(see USPAD)*
PCM	Parallel Climate Model
PEIS	Programmatic Environmental Impact Statement
PET	Potential Evapotranspiration
PJ	Pinyon-Juniper
PLSS	Public Land Survey System
PRISM	Parameter-elevation Regressions on Independent Slopes Model
PWS	Public Water Supply
QA/QC	Quality Assurance/Quality Control
QC	Quality Control
RAS	Rangeland Administration System
REA	Rapid Ecoregional Assessment
ReGAP	Regional Gap Analysis Project
RegCM	International Centre for Theoretical Physics Regional Climate Model
RETI	Renewable Energy Transmission Initiative
RMP	Resource Management Plan
ROC	Receiver Operating Characteristic
SAGEMAP	Sagebrush and Grassland Ecosystem Map Assessment Project
SClass	Succession Class
SDM	Species Distribution Model
SERGoM	Spatially Explicit Regional Growth Model
SMA	Surface Management Agency
SSURGO	Soil Survey Geographic Database

Table 1 (continued). Definitions for the acronyms used in this report.

Acronym	Definition
STATSGO	State Soil Geographic Database
STDV	Standard Deviation (also *stdev*)
SW ReGAP	Southwest Regional Gap Analysis Project
SWAP	State Wildlife Action Plan
SWEMP	Southwest Exotic Plant Mapping Program
SWPA	Southwest Principal Aquifer study
T&E	Threatened and Endangered
TNC	The Nature Conservancy
USAresource	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency (also EPA)
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USPAD	U.S. Protected Areas Database *(see PADUS)*
VDDT	Vegetation Dynamics Development Tool
WBD	Watershed Boundary Dataset
WGA	Western Governors' Association
WHB	Wild Horse and Burro
WMC	Western Center for Monitoring and Assessment of Freshwater Ecosystems

Preface

National Park Service (NPS) managers face challenges of assessing impacts of development outside of park boundaries. Managers must be vigilant to protect park resources but can only be credible in engaging other players on socio-ecological landscapes with science-informed analyses about issues of concern. That is, external park development cannot be criticized as potentially harmful to parks simply due to the proximity to the park. Analyses of likely impacts to specific natural resources, such as birds, or ecological process, such as dust transport, allow for coherent discussions among parties and the potential identification of compatable outcomes.

This report provides a case study for NPS managers based on development scenarios at Great Basin National Park. As it applies data collected for the Bureau of Land Management Rapid Ecoregional Assessments (REA) landscape analysis, it is a proof of concept for the application of landscape metrics and datasets to a park level analysis.

This report can serve as a valuable tool for resource managers in the Great Basin area to identify which ecological resources are most vulnerable to adverse impacts from adjacent development and thereby seek to avoid, minimize, and mitigate those potential impacts in order to retain ecological integrity in the Basin. Moreover, the process utilized in this assessment can be applied to other NPS units. The ability of the NPS to identify and communicate these vulnerabilities to other land management agencies and to developers is a key component to ensuring the protection of those resources as mandated by the NPS Organic Act and its Management Policies.

While this analysis can be applied to infrastructure in general, it builds on scenarios for renewable energy development outside the park. Impacts of specific technologies such as windmills or solar arrays were beyond the scope of this report, but they, as well as other types of development such as water developments and associated pipelines can be inserted into the assessment framework.

Executive Summary

The Great Basin faces increasing demand for development of energy resources and energy transmission infrastructure--as does most of the arid western U.S. Energy and other development-related concerns for National Parks are the facilities themselves, utility rights of way, and associated roads, and emissions from the facilities. Although these potential sources of stress lie outside of parks, unit managers need to assess the potential for impacts to Park resources and values. It is important though, that managers identify specific concerns to improve the chances of mitigating problems before they occur. This report assesses the sensitivity of ecological resources within the Great Basin National Park (GRBA) to energy development on lands surrounding the Park. Specifically, it tests the value of regional ecological data as applied through the Ecological Integrity Assessment Framework to distinguish the degree of potential threats to specific park resources.

After scoping the geographic scale and related focal resources for the assessment in our 2012 analysis, we identified fourteen focal ecological resources of GRBA that could be sensitive to the impacts of energy development within the study area. The focal resources include seven large-scale ecosystem types, wind erodible soils, three sensitive species assemblages, (migratory waterfowl / shorebirds, tree-roosting bats, and, cave-roosting/riparian-foraging bats), and four individual species for which both the Park and the surrounding landscape provide important habitat, including movement corridors.

We then developed or adapted a conceptual ecological model for each focal resource, to identify key ecological attributes and their indicators and document current understanding of the effects of stressors on the ecological integrity of the resource. The conceptual models identified eighteen indicators or indices – composites of multiple indicators – for which data were available for evaluation among the several key ecological attributes. Eight indicators/indices generated values with little or no variation within the study area, while ten presented sufficient variation to support quantitative analysis. These are:

- Landscape Condition Index
- Fire Regime Departure Index
- Riparian Corridor Continuity Index
- Invasive Annual Grasses Index
- Groundwater Use
- Surface Water Use
- Hydrologic Condition Index
- Mercury Deposition
- Nitrate Deposition
- Water Quality Index

We analyzed the potential impact of energy development on each resource in two ways, in terms of: (1) the overlap between the areas of energy development and the spatial distribution of each focal ecological resource; and (2) the possible impacts of energy development on the ecological integrity of each focal resource across the entire study area.

The assessment results identify two ways in which the ecological resources of Great Basin National Park may be affected by energy development on lands surrounding the Park.

First, significant percentages of the current spatial distribution of several focal ecological resources fall within the 2012 footprint of energy development, and even larger percentages within the footprint forecasted for 2025. The inter mountain basins big sagebrush shrubland, inter-mountain basins greasewood flat, Great Basin foothill and lower montane riparian woodland and shrubland/stream, and inter-mountain basins wash system types; the migratory waterfowl & shorebird assemblage; the cave-roosting, riparian-foraging bat assemblage; and the golden eagle and pygmy rabbit are forecasted to experience the greatest increases in the percentages of their areas included within the footprint of energy development. Wind erodible soils, greater sage grouse lek sites, and bighorn sheep movement corridors may also be highly vulnerable, with large percentages of their areas falling within the footprint of energy development even in 2012.

Second, forecasted energy development will result in a shift toward more degraded conditions- i.e., toward decreasing ecological integrity – by 2025 for five focal ecological resources within their ranges across the entire study area, as measured by the quartile distributions of Landscape Condition Index scores: the inter-mountain basin big sagebrush shrubland ecosystem, the riparian-foraging bat assemblage, bighorn sheep, greater sage grouse, and pygmy rabbit. These “ecological integrity” results differ from the first set for two reasons. First, the “footprint” analysis looks at the percentage of the spatial distribution of each focal resource included within area of analysis around the areas of utility development, while the Landscape Condition Model looks at a finer spatial scale before aggregating the results by spatial reporting unit. Second, the analysis of Landscape Condition Index scores aggregates these scores by quartile, which results in some loss of detail.

Although they were somewhat limiting for this analysis, Central Basin and Range REA datasets and spatial reporting units permit an initial, rapid assessment to help managers consider whether any more refined analyses are warranted. Another limitation to the results of this assessment is that the actual pattern of energy development in the areas surrounding the park may be implemented in ways other than as forecasted today, and the forecasts themselves may change. The assessment reported here can be updated as data, knowledge of energy impacts, and forecasts of energy development improve.

Finally, the methodology implemented here – particularly the assessment of multiple focal ecological resources across a large study area encompassing the Park and the surrounding ecosystems with which it interacts – encourages an awareness of the wide spectrum of stressors that can affect the ecological integrity of a Park unit at different spatial scales. Such awareness is crucial for safeguarding Park ecological resources and other natural resource values against the numerous large

and small insults that can threaten any protected area surrounded by areas with fewer or no protections.

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Introduction

The National Park Service (NPS) needs to assess the sensitivity of ecological resources within its units in response to external development. Even when it might view this development as undesirable, NPS must provide a clear and rational reponse to development proposals in terms of which of its resources may be negatively affected by particularly aspects of the development, be it the construction of a facility, or its operation, or related infrastructure. This type of analysis can also focus on the identification of alternative approaches to the development, thereby relieving the stressor on the park resources. We have selected the Great Basin National Park (GRBA) as a case study for analysis. NPS believes that, with appropriate analysis and planning, renewable energy development can occur with minimal impacts to NPS and other sensitive natural resources. The "Ecological Integrity Assessment Framework" (Unnasch et al. 2018), adapted for the National Park Service by Sound Science and NatureServe, provides tools and methods for this kind of assessment. The framework guides the identification of focal ecological resources for a Park, along with key ecological attributes of these resources and their ecologically acceptable (reference) ranges of variation; guides the identification of quantifiable indicators of these key ecological attributes that need to be monitored to support adaptive management; and guides the identification of stressors to which the key ecological attributes are sensitive, along with indicators of these stressors. Together, these bodies of information comprise a conceptual ecological model for a Park and its focal ecological resources. The framework thus provides a means for (a) explicitly identifying the ways in which the focal resources within a Park depend on ecological conditions and processes external to the Park boundaries; and (b) explicitly identifying the ways in which ecological conditions and processes both within and external to the Park boundaries may be vulnerable to specific kinds of stressors.

This assessment builds directly on the results of a Rapid Ecoregional Assessment (REA) of the Central Basin and Range ecoregion, completed by NatureServe and Sound Science for the U.S. Department of the Interior, Bureau of Land Management (Comer et al. 2013). Specifically, the present assessment uses the Ecological Integrity Assessment Framework to assess the vulnerability of ecological resources within the Great Basin National Park to energy infrastructure development on ***surrounding*** lands. Although the potential sources of stress lie outside the Park, the potential for impacts within the Park may require responses from Park staff**.**

This assessment identifies focal ecological resources of GRBA, based on Park management reports and the results of the REA. The assessment then examines the vulnerability of these focal ecological resources to current and potential future sustainable energy infrastructure through 2025. This infrastructure consists of areas of "industrial wind facility" development, utility rights of way, and associated roads, for which map data and map-based forecasts are available. Additional infrastructure could include wells, pumps, piping and power sources for groundwater extraction outside the park. This assessment specifically addresses fourteen focal ecological resources identified to provide an effective representation for those that are potentially sensitive to this infrastructure development:

- Inter-Mountain Basins Big Sagebrush Shrubland
- Wind Erodible Soils

- Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream
- Great Basin Springs and Seeps
- Inter-Mountain Basins Greasewood Flat
- Inter-Mountain Basins Playa
- Inter-Mountain Basins Wash
- Migratory Waterfowl & Shorebirds Species Assemblage
- Tree-Roosting Bat Assemblage (represented by the Hoary Bat, *Lasiurus cinereus*)
- Cave-Dwelling, Riparian Foraging Bat Assemblage (represented by the Brazilian Free-tailed Bat, *Tadarida brasiliensis*)
- Rocky Mountain Bighorn Sheep (*Ovis canadensis canadensis*)
- Golden Eagle (*Aquila chrysaetos*)
- Greater Sage Grouse (*Centrocercus urophasianus*)
- Pygmy Rabbit (*Brachylagus idahoensis*)

The assessment identifies the specific key ecological attributes for each of these fourteen resources that render them vulnerable to the impacts of sustainable energy development and the geographic areas across which they are vulnerable; identifies measurable (and mappable) indicators for these key ecological attributes; and compares the spatial distribution of these indicators to the existing and forecasted spatial distribution of sustainable energy development, to evaluate the spatial extent and potential magnitude of vulnerability.

The report has four main sections: The Introduction discusses the challenges that energy development poses for the conservation of biological diversity; and summarizes information on the location, natural resources, and regional context of Great Basin National Park. The Study Approach section presents the Ecological Integrity Assessment Framework and describes each step of its application to the assessment of the potential impacts to Great Basin National Park from energy development around the Park. The Results section presents the findings from the application of the study approach in both narrative and map form, identifying areas where energy development presents current or potential future conflicts for resource management within the Park. The Conclusions section reviews the methods and findings and offers recommendations concerning the potential applicability of the study approach to other Park units. Four appendixes present (a) a glossary and units of measurement; (b) conceptual models for all focal resources addressed in the assessment; (c) a description of the methods for the spatial models used to gauge the ecological integrity of the focal resources; and (d) maps of the locations and indicator scores for all focal resources.

Energy Development and Biodiversity

Energy demand in the United States is projected to grow 0.5-1.3% annually for the next 20 years (Outlook 2010) and an estimated 206,000 km^2 of lands will be directly impacted by new energy development in that time. Since the late 1990s, as energy development intensified throughout the West, scientists have studied this development and its effect on wildlife populations and ecosystems.

Investigations over the past two decades have greatly increased our knowledge of both the primary and secondary impacts of such large-scale development on many species and natural communities. These investigations have focused on a relatively small number of species – primarily big game and listed, candidate, and declining species. Nevertheless, the investigations reveal some consistent impacts.

Energy development results in a wide diversity of changes to an area including:

- Increased fragmentation as a result of the development itself and the construction of roads, pipelines, and transmission lines to service that development.
- Increased noise associated with the construction and operation of these facilities.
- Increased human disturbance as a result of the construction, operation, and maintenance of the facilities. Service roads can also provide vehicular access to remote parts of a landscape, thereby increasing recreational use and its associated disturbance.
- Dramatic changes in the physical structure within a landscape. Electrical transmission lines, for example, provide new perching and nesting structures for raptors and corvids, and alter above-ground electrical fields.
- Changes in ecological processes including flows of air, water, and fire; increases in soil erosion, increased airborne particulates; and invasion by exotic, system-changing species (e.g., cheatgrass).

These impacts are not unique to energy development; they are present in greater or lesser degrees with any infrastructure development from the construction of a cabin in a forest inholding to the development of hundreds of square kilometers (or square miles) for petroleum development (e.g., the Jonah Field in Wyoming). Yet, energy development tends to be large-scale and requires significant supporting infrastructure, making its impacts noticeable across large areas.

Potential impacts of specific energy developments, such as wind tubine-related bird mortality, or groundwater drawdowns required by solar arrays are beyond the scope of this report. This information is rapidly increasing and changing and would require site and project specific information. This report focuses on the use of energy development as a case study for a methodology to examine multiple forms of development, and how the NPS can provide a rational and well-articulated identification of concerns to these developments.

The documented responses of individual animal species to the development of energy infrastructure include changes in behavior, physiology, vital rates, and population dyanamics. These responses vary by species and vary over different spatial scales for any given species. Similarly, responses can vary by season and over years.

An animal's first response to the appearance of new infrastructure is avoidance. For example, Boyce and McDonald (1999) reported that elk avoided active oil fields by at least 2 km. During the winter when human use was at a minimum, this avoidance distance declined to ~1 km, but the animals continued to avoid the areas of development. Similarly, Morgantini (1985) reported that 54% of

migratory elk found a pipeline under construction to be a barrier and turned back. Tablado and Jenni (2017) documented avoidance of oil wells sites by Pronghorn. Finally, several studies of Greater sage grouse have shown that the birds avoid areas of energy development by up to 16 km (e.g., Walker et al. 2007).

Living in the vicinity of large infrastructure causes animals to be more vigilant. This may be the direct result of activities associated with development or because the increased background noise makes it more difficult for the animals to detect predators. Several physiological studies of ungulates have demonstrated that animals living close to petroleum development have increased the level of stress hormones (e.g., corticosteroids) in their blood, likely reflecting their constant "on guard" situation. In turn, animals living close to petroleum fields show lower weights and less fat accumulation that likely result in lower survivorship (Tablado and Jenni 2017).

Mortality from predation increases and reproductive success decreases for many species in association with infrastructure development. Declines in reproductive rates after infrastructure development have been noted for many species ranging from voles, to pronghorn, to waterfowl (Tablado and Jenni 2017, Forman and Alexander 1998, Frid and Dill 2002). One study has documented Greater sage grouse nest success decreases in proximity to transmission line and petroleum development (Walker et al. 2007). These decreases are believed to be the result of increased raven populations perching and nesting on transmission towers and other structures. Nest loss is the result of both harassment of the hens and direct nest predation by the ravens.

Other species experience increased mortality in relation to infrastructure. Depending on the species this can be the result of increased vehicle strikes, changes in the behavior of predators, or direct mortality caused by the infrastructure. Service roads in boreal forests have been shown to be used by wolves, and this is thought to have resulted in their increased predation success on woodland caribou, resulting in dramatic declines in caribou populations in Canada. Wind turbines have been documented to cause significant direct-strike mortality to raptors, some passerine birds, and several species of bat (Kunz, et al. 2007).

Great Basin National Park Mission

The mission of Great Basin National Park is to preserve for the benefit, inspiration, and enjoyment of present and future generations a representative segment of the Great Basin of the Western United States and to promote an understanding of the natural and cultural heritage of the entire physiographic region.

The Great Basin encompasses nearly all of Nevada and parts of western Utah and small portions of California, Oregon and Idaho-roughly 517,998 km^2 of arid basins and rugged, isolated mountain ranges. On October 27, 1986, a small piece in east central White Pine County, NV 312.34 km^2 of the southern Snake Range was set aside as Great Basin National Park (GRBA).

The enabling legislation for the Park (Public Law 99-565) rests on long-standing law pertaining to National Parks:

> *The Secretary shall protect, manage, and administer the Park in such a manner as to conserve and protect the scenery, the natural, geologic, historic, and archaeological resources of the Park, including fish and wildlife, and to provide for the public use and enjoyment of the same in such a manner as to perpetuate these qualities for future generations.*

The Park also complies with standing environmental protection and preservation legislation, including: the Antiquities Act of 1906, the National Park Service Organic Act of 1916, the National Environmental Policy Act of 1969, the Endangered Species Act of 1973, Migratory Bird Treaty Act of 1918, the Federal Water Pollution Control Act as amended in 1977, the Clean Air Act as amended in 1977, the American Indian Religious Freedom Act of 1978, the Archeological Resources Protection Act of 1979, the National Historic Preservation Act of 1966 as amended, Executive Order 11987 requiring archeological and historic resource inventories, the Clean Water Act, Wetlands Protection Legislation and the Federal Cave Resource Protection Act of 1988.

Congress has been steadfast in its intent to hold the NPS to its goal of preservation. The 1970 act that established Redwood National Park reaffirmed the NPS mandate of preservation:

> *The authorization of activities shall be construed and the protection, management and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided by Congress." (Public Law 91-383).*

Furthermore, cultural and natural resource management objectives for GRBA identified in the General Management Plan (GMP), 1993, are to:

1) Manage the Park to maintain the greatest degree of biological diversity and ecosystem integrity within the provisions of the authorizing legislation.
    a) Eliminate or mitigate any impacts that threaten biological resources.
    b) Determine the extent of plant and animal diversity, monitor changes that are occurring and identify the sources of change; eliminate or mitigate any identified adverse impacts, recognizing that native populations fluctuate naturally.
    c) Monitor and evaluate biological diversity in relation to the influences of major climatic and environmental change, particularly those caused by man.
    d) Protect threatened, endangered, and endemic species and restore them within their natural ranges.
    e) Manage the grazing program to minimize effects on natural process to adhere to the best range management practices with an emphasis on protecting sensitive species.
2) Determine the natural role of wildland fire in the South Snake Range ecosystem, and manage the Park to restore and maintain this process.
    a) Develop an action plan for fire management.

3) Maintain the pristine quality of the air, water, geologic and scenic resources in the Park.
    a) Establish a baseline to determine resource conditions, monitor changes, and identify sources of change; eliminate or mitigate any human-caused impacts that threaten abiotic and scenic park resources.
    b) Restore previously disturbed and abandoned areas (sites of mining activity, undesignated roads and trails, etc.) to natural conditions.
4) Preserve and protect caves and cave systems in the Park.
    a) Identify, inventory, and classify caves and cave systems, and eliminate or mitigate impacts on cave resources.
    b) Avoid potentially harmful development in, above, or adjacent to caves unless it can be demonstrated that such development would not significantly affect natural cave conditions.
5) Allow only those recreational activities that contribute to understanding and appreciation of the Park's resources and only to the extent that natural, cultural, and scenic values are not impaired.
6) Establish and maintain a broad spectrum of management zones and subzones to avoid limiting visitor use to the extremes of paved and primeval.
7) Develop an interpretive initiative, including facilities, programs, and activities, that makes GRBA the primary area for interpreting the theme of the Great Basin physiographic region.
8) Provide a sense of anticipation for visitors before they reach the Park.
9) Locate NPS management facilities outside park boundaries whenever the management functions can be adequately supported from such locations.
10) Work with local communities and assist them in meeting community goals.
11) Work with adjacent communities to help them maximize economic benefits.

Great Basin National Park: Setting and Natural Resources

Detailed information on geographic, historic and natural resource settings are found in the Great Basin National Park: Natural Resource Condition Assessment (Comer, et. al. 2016). This includes current condition analysis for key resources such as cave, water, and air resources, fish, wildlife and threatened species, and backcountry areas.

Study Approach

Ecological Integrity Assessment Framework

This assessment follows the principles and methods of the Ecological Integrity Assessment Framework (EIAF; Unnasch et al. 2018). The EIAF was modified for the National Park Service by Sound Science and NatureServe to provide tools and methods for natural resources assessments for Park units. The methodology incorporates and builds on core principles of biodiversity conservation planning, established and tested by the conservation science community over the past several decades (e.g., Margules and Pressey 2000, Parrish et al. 2003, Knight et al. 2006, Sarkar et al. 2006, CMP 2007). This methodology provides a transparent and consistent process to focus resource assessment based on the best available science; highlights conditions requiring management attention; identifies efficient indicators for management and monitoring; and highlights critical information gaps, monitoring needs, and hypotheses with crucial implications for adaptive management. The methodology specifically addresses three broad questions:

- What is important? That is, what resources need to be included in the management process?
- How is it doing? That is, what is the current condition of these resources conditions (i.e., "very good condition" to "poor" condition), as evidenced by indicators for their critical features, drivers, and dynamics?
- What do we want? That is, what are the desired conditions of these resources, as evidenced by measured indicators of the range of possible for their critical features, drivers, and dynamics; the "acceptable" status of existing and potential stressors; and the critical information gaps that need filling to support management decisions?

The framework provides an appropriate methodology for the present assessment for two reasons. First, it explicitly identifies the ways in which focal resources within a Park may depend on ecological conditions and processes external to the Park boundaries. Second, it explicitly identifies the ways in which ecological conditions and processes both internal and external to the Park boundaries may be vulnerable to specific kinds of stressors. In this sense, ***the EIAF is used to identify issues that may arise from patterns of energy development surrounding GRBA that may require a response from GRBA staff.***

Addressing the first of the three EIAF questions involves four steps: (1) identifying the geographic scope of the analysis effort; (2) identifying the suite of biological and ecological resources of potential concern to the Park unit; (3) identifying stressors known, suspected, or anticipated to affect these resources; and (4) selecting a subset of the potential resources to serve as "focal" ecological resources for management, based on the findings from the first three steps. The focal resources are selected based on a "coarse-filter/fine-filter" method (e.g., Noss 1987; Parrish et al. 2003) to ensure that (a) all resources of concern are represented either directly by a focal resource or indirectly as a component of a focal resource; and (b) all stressors of concern are represented through their effects on one or more focal resources. The selection process typically involves development of a conceptual ecological model for the affected region as a whole.

Addressing the second of the three EIAF questions also involves four steps: (1) identifying the key ecological attributes for each focal resource, on which to further focus management attention; (2) identifying indicators for each key attribute, for each resource; (3) identifying an ecologically acceptable range of variation for each indicator, for each resource; and (4) assessing the status of each focal resource based on indicator data. The first three of these four steps result in the development of a conceptual ecological model for each focal resource. Key ecological attributes include defining characteristics of a resource, its abundance, and its distribution; and key environmental associations, drivers and constraints. Indicators may incorporate data from remote sensing, from ground-level rapid assessment, or from ground-level intensive sampling.

Finally, addressing the third of the three EIAF questions, also involves four steps: (1) identifying desired conditions for each focal resource based on its key ecological attributes and indicators; (2) identify stressors that affect or threaten to affect these key attributes and indicators; (3) setting a timeline for action to establish or ensure continuity of desired conditions; and (4) establishing metrics or benchmarks with which to evaluate these actions. This final phase also includes a parallel process, to assess the sufficiency of the data and knowledge used to build the conceptual ecological models for the individual focal resources assess their condition, and address critical hypotheses concerning the resources and their stressors.

The present assessment addresses only the first two core questions of EIAF methodology. Addressing the third question lies outside the scope of the present project in that, as stated above, our intent is limited to identifying management issues that *may* arise from surrounding energy development. Subsequent decisions and priority-setting would involve the third phase of the EIAF framework.

Relationship to Other Studies

The specific objective of this study was to assess the potential ecological effects of energy development surrounding GRBA on resources of concern to the Park. This objective led our research team to consider the ways that recent and ongoing assessments could be used to meet study objectives. Two primary efforts include recently completed BLM Rapid Ecoregional Assessment for the Central Basin and Range (CBR) ecoregion (Comer et al. 2013), and the NPS Natural Resource Condition Assessment for GRBA (Comer et al. 2016).

Various influences affect the western landscapes that are managed by the National Park Service, the Forest Service, and Bureau of Land Management (BLM). In one response, BLM launched Rapid Ecoregional Assessments (REAs) to improve contextual understanding of status and trends in the condition of these regional landscapes, and how conditions may be altered by ongoing environmental changes and land use demands.

The REAs are assessments of ecological resources within ecoregions, spanning administrative jurisdictions and boundaries. Assessments of these larger areas provide planners with answers to management questions common to many management units across the ecoregion. They provide contextual information and tools to use in subsequent resource planning and decision-making. They may identify important resource values and patterns of environmental change that may not be evident

when managing local management units. REAs are called "rapid" assessments because they synthesize existing region-wide information, do not conduct research or collect new field data, and are generally completed within two years. REAs do not prioritize or allocate resource uses or document management decisions; but they do provide science-based information and tools for land managers and stakeholders to consider in subsequent decision-making processes.

REAs describe and map "conservation elements" or ***focal resources***, which are features of high ecological value or sensitivity. REAs look across all lands in an ecoregion to identify characteristic ecosystems and regionally important locations for fish, wildlife, and species of concern. REAs then gauge the potential of these locations to be affected by four overarching environmental ***change agents:*** climate change, wildfires, invasive species, and development (e.g., energy development, urban growth). Assessment of change agents consider current location and effects, as well as those that can be forecasted out to 2060. REAs also map and describe ***places*****,** including lands under different ownership jurisdiction or management, and areas that have been previously identified for providing important ecological or cultural resource values.

In addition to mapping the location of focal resources relative to change agents, REAs characterize relative ecological integrity. Through development of both conceptual and spatial models, the ecological effects of interacting change agents on focal resources are measured and reported by fifth level watershed or 4x4 km grid. Results reported for these spatial units aim to provide sufficient precision that should assist with identifying areas that are, and are not, ecologically intact or readily restorable; and where development activities may potentially be directed to minimize impacts to important ecosystem values. In characterizing focal resources and change agents, REAs analyze and summarize baseline ecological data to gauge the effect and effectiveness of future management actions. In this way, REAs provide a foundation for an adaptive management approach that enables implementation strategies to adjust to new information and changing conditions.

The present project relied on datasets developed for the Central Basin and Range REA. Their spatial and thematic resolution, along with documented levels of accuracy, is documented in Comer et al. (2013). The primary limitation in these data – as related to their use in this study – is that REA data sets were required to have a nearly comprehensive coverage for the Central Basin and Range ecoregion. For this reason, additional datasets may exist for the landscape surrounding GRBA that were not utilized in the CBR REA.

NPS is now implementing Natural Resource Condition Assessments (NRCAs) across the system. NRCAs resemble BLM REAs in their objectives and approaches. NRCAs evaluate and report on the following key questions for a subset of important natural resources in national park units:

- What are current conditions for important park natural resources?
- What are the critical data and knowledge gaps?
- What are some of the factors that are influencing park resource conditions?

In addition to credible condition reporting for individual resources and indicators, NRCAs also strive to provide a meaningful discussion of overall findings and recommendations by park areas

(watersheds, habitats, or other areas of interest to park managers). This helps to highlight emerging or cross-cutting issues and park areas and resources in greatest need of management attention.

Again, given the specific objectives of the present project – to assess the potential ecological effects of energy development surrounding GRBA on resources of concern to the Park – we have utilized output from the BLM REA for a selected subset of focal resources and change agents of interest to the Park. This analysis aims to report results at spatial scales that are likely of lower spatial resolution than those that will be desired for the NRCA. Nevertheless, the REA data should still provide sufficient detail to GRBA staff to better understand and respond to the issues of energy development surrounding the Park.

Study Area Delineation

Effective resource assessment begins with a clear and explicit identification of the scope of the planning effort. This includes determining the appropriate geographic area of interest and requires clear management questions. The primary management question addressed here is:

> *What are the potential ecological effects on GRBA resources from current and anticipated energy development in the area surrounding the Park?*

Given this core management question, one needs to determine the specific resources of interest to GRBA within the surrounding area. Following an iterative process, several generalized geographic areas were delineated while considering the spatial configuration and aerial requirements of major GRBA park resources. The goal of this process was to develop a clear understanding of potentially affected resources and the spaces where they occur, and then arrive at a practical outer boundary for the study area. Fourth- and fifth-level watershed units (hydrologic catalog units, or HUCs) were used initially to characterize the area surrounding GRBA. Table 2 includes a summary of major resources – derived from regional vegetation maps and park documents – which initially characterize both the GRBA land area and that from the surrounding watersheds. From this table, one can see that the characteristic vegetation across middle to upper elevations of the basin and range landscape can be found both within and outside of GRBA. Wildlife, such as bighorn sheep and characteristic bat species, are also found both within the Park and throughout this surrounding landscape. However, ecological systems that characterize lower-elevation basins, from sagebrush shrubland down to desert playas, are mainly found only outside the GRBA boundaries. In turn, several other resources, specifically cave and karst features, quality viewsheds, night skies, and solitude, are concentrated within the GRBA boundaries.

We established the outer project boundary for the present assessment by considering the ecological connections among major park resources and the resources of the surrounding landscape. Specifically, we took into account the proximal linkages between montane and basin communities, the known spatial extent of bighorn sheep and bat populations, and the distribution of erodible soils across the landscape surrounding the Park, the mobilization of which could affect visibility within the Park. Figure 1 depicts the combination of 5^{th}-level watersheds used for this assessment. We extended the study area to include lands further southwest of GRBA specifically to account for highly erodible soils that occur upwind of the Park.

Table 2. Initial characterization of major park resources compared with those in surrounding watersheds. Shared resources occur on the same table row, and are also shaded in light gray.

Major Park Resources	Resources of Assessment Area
Alpine, bedrock, scree, and turf	Alpine, bedrock, scree, and turf
Bristlecone, Spruce-fir forest (old growth)	Bristlecone, Spruce-fir forest (old growth)
Aspen and Mixed conifer forest	Aspen and Mixed conifer forest
Great Basin Pinyon-Juniper Woodland	Great Basin Pinyon-Juniper Woodland
Mountain Mahogany Woodland	Mountain Mahogany Woodland
Montane Sagebrush Steppe	Montane Sagebrush Steppe
Xeric Sagebrush shrubland	Xeric Sagebrush shrubland
Foothill Riparian woodland/shrubland	Foothill Riparian woodland/shrubland
Bats (cave vs. tree roosting)	Bats (cave vs. tree roosting)
Bighorn Sheep	Bighorn Sheep
Caves or karst features	–
Quality Viewsheds	–
Solitude	–
Night sky	–
–	Big Sagebrush Shrubland
–	Mixed Salt Desert Scrub
–	Greasewood Flat
–	Desert Wash/Playa

We identified current (2012) and potential future (2025) energy infrastructure in the study area[1] These included projects proposed and likely to be implemented, from the perspective of BLM, and incorporated in the Rapid Ecoregional Assessment. Additional proposed infrastructure sites could be included in future iterations of this analysis, as they are identified by NPS staff. The primary energy footprint within the study area consists of infrastructure associated with a industrial wind facility in Spring Valley, including its associated electrical utility lines. Figure 2 depicts the combination of current and forecasted energy infrastructure, including electrical utility rights-of-way planned for installation by 2025, including current paved road infrastructure. These installations reflect the judgment of regional BLM staff with responsibility for energy project review, concerning energy infrastructure that presently can be reasonably forecast up to 2025. Of course, changes in demand or in the process of project approval could result in a different pattern of energy development by 2025.

[1] http://corridoreis.anl.gov/eis/fmap/gis/index.cfm

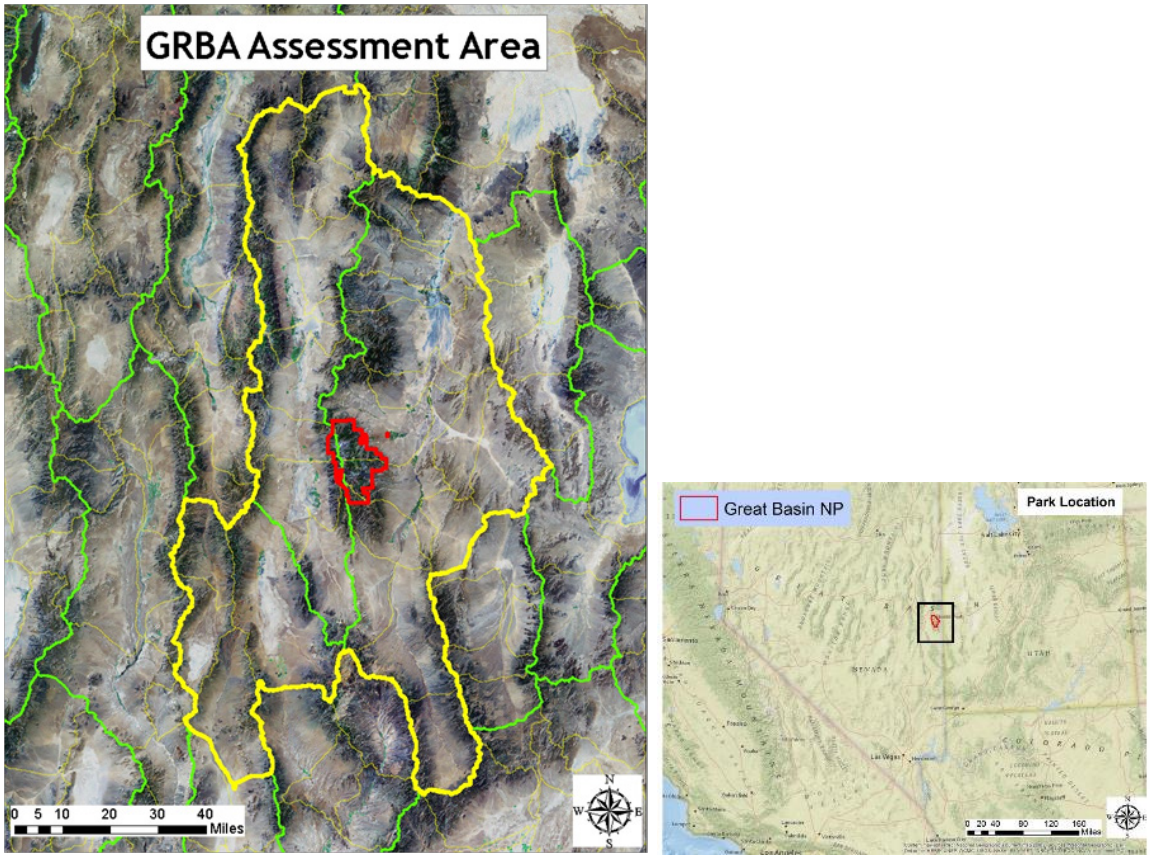

Figure 1. Final study area for energy effects assessment for GRBA (and GRBA location in NV).

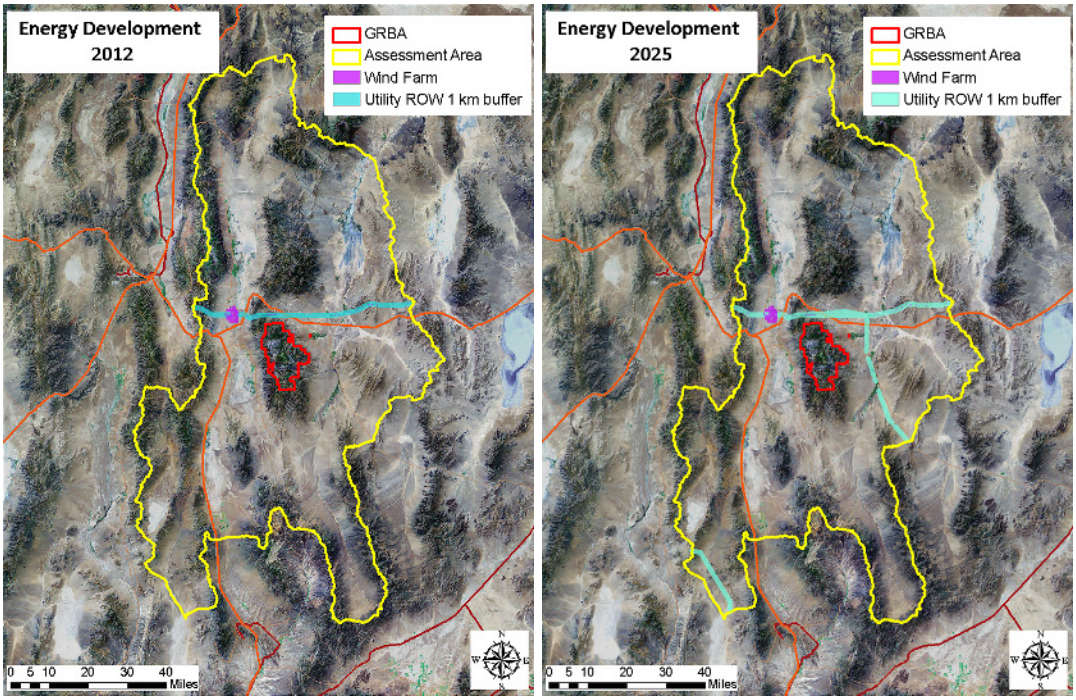

Figure 2. Current and forecasted energy development within the study area. A 1 km buffer was applied to linear utility corridors.

Energy Development within Study Area

As indicated in Figure 2, the current primary footprint of energy development is from the Spring Valley industrial wind facility, currently operating and set to encompass as much as 38.9 km^2 to the immediate northwest of GRBA and an associated east-west utility corridor. As also indicated in Figure 2, the forecast (2025) primary footprint is from the Spring Valley industrial wind facility; a slightly expanded east-west utility corridor; an additional utility corridor branching off the east-west corridor to the northeast of the Park and running south in Snake Valley; and a portion of an additional utility corridor cutting across the far southwestern corner of the study area.

In order to explore the potential for interactions of these two energy footprints with natural resources, we delineated three spatial buffers of 1 km, 5 km, and 10 km. "Buffer" in this instance refers to a commonly used spatial construct for GIS analysis. To test the efficacy of these buffer widths, we overlaid the mapped areas of these buffers on the mapped distributions of focal resources from the BLM REA. Table 3 illustrates one result of these overlays, depicting results only for the Spring Valley industrial wind facility, sorted by the center column using the 5 km buffer. Percentages in the table indicate the proportion of the distribution for each resource within the study area that currently intersects with the energy footprint.

Table 3. Overlay of Spring Valley industrial wind facility (with spatial buffers) on resource distributions from the BLM Central Basin and Range ecoregion REA.

Focal Resources	1 km Buffer (%)	5 km Buffer (%)	10 km Buffer (%)
Wind Erodible Soils – High	4.64	10.1	13.7
Greater Sage Grouse Lek – Very high density	1.49	4.9	10.6
Big Sagebrush Shrubland	0.80	2.3	4.4
Greater Sage Grouse Core Occupied Habitat	0.48	2.3	10.3
Pygmy Rabbit Distribution	0.83	2.2	4.0
Wind Erodible Soils – Medium	0.91	2.1	3.6
Greasewood Flat	0.26	1.4	2.5
Inter-Mountain Basins Playa	0.02	1.4	3.2
Desert Springs and Seeps	0.35	1.0	4.1
Inter-Mountain Basins Wash	0.16	0.9	3.0
Bighorn Sheep Distribution	0.00	0.3	4.2
Lower Montane Riparian Woodland	0.00	0.3	2.7
Golden Eagle Distribution	0.00	0.0	0.0

Table 3 shows that over 10% of soils designated as highly erodible within the study area occur within the current footprint of the Spring Valley industrial wind facility. Other resources notably affected

include Greater sage grouse (*Centrocercus urophasianus*) (both active lek sites and overall occupied habitat), big sagebrush (*Artemisia tridentata*) shrubland, Pygmy rabbit (*Brachylagus idahoensis*), and other natural communities that characterize basin bottoms (greasewood flats, desert wash, playa, etc.). This initial overlay approach was also applied using utility right-of-ways that were also buffered by 1, 5, and 10 km. This indicated relatively higher potential overlap with golden eagle (*Aquila chrysaetos*), bighorn sheep (*Ovis canadensis*), and desert springs and seeps. The Results chapter, below, discusses the full results of applying this overlay method to the final list of focal resources for the present assessment.

Conceptual Model of Regional Ecological Context

Identifying focal resources for applying the EIAF to an individual study area requires a conceptual model of the regional ecological context of the study area. This regional model guides the use of the "coarse-filter/fine-filter" methodology for identifying focal resources, described later in this chapter.

Numerous ecoregional classifications provide descriptions of the region known as the Great Basin. These descriptions provide general context for organizing a conceptual ecological model of the landscape that includes GRBA. The following material is adapted from the BLM Central Basin and Range REA (Comer et al. 2013, see also Nachlinger et al. 2001).

As described by USEPA (2007), "The Central Basin and Range ecoregion is internally drained and is characterized by a mosaic of xeric basins, scattered low and high mountains, and salt flats. It has a hotter and drier climate, more shrubland, and more mountain ranges than the Northern Basin and Range ecoregion to the north. Basins are covered by Great Basin sagebrush or saltbush-greasewood vegetation that grow in Aridisols; cool season grasses are less common than in the Mollisols of the Snake River Plain and Northern Basin and Range. The region is not as hot as the Mojave Basin and Range ecoregion to the south and it has a greater percent of land that is grazed."

Regional Biophysical Controls

*Regional Physiography***:** Between the Sierra Nevada to the west and Wasatch ranges to the east, more than three hundred long, narrow, roughly parallel mountain ranges are separated by broad elongated valleys (Grayson 1993). According to Nachlinger et al. (2001), the valley floors are highest in the center of the ecoregion and lowest at the western and eastern margins, the result of stretching tectonic forces. The structures of mountain ranges are roughly similar, but their compositions are diverse. This pattern structure is the result of high angle block faulting. The ranges are uplifted horsts and the basins are lowered grabens. Granite and basalt mountains occur in the west and south, rhyolite mountains prevail in the center, and limestone mountains predominate in the east. Elevations in the ecoregion vary from 324 m on the east flank of the Inyo Mountains to 4,342 m at the summit of the White Mountains, both in the southwest portion. Valley floors in the Lahontan and Bonneville basins average 1,158-1,524 m above sea level, whereas valley floors in the central sections average 1.676-1,951 m in elevation.

Regional Climate Regime: Due to its location in the rain shadow of major mountain ranges, the climate of the Central Basin and Range is semiarid. The Sierra Nevada range effectively captures most moisture from east-moving Pacific fronts while the Rocky Mountains intercept most moisture

coming from the Gulf of Mexico. There is also a limited Mediterranean influence (winter precipitation and pronounced dry summers) as defined through some bioclimatic classifications (Sayre et al. 2009, Cress et al. 2008). The climate regime is somewhat continental; with relatively high annual temperature fluctuations due to distance from moderating oceanic climates (Hidy and Klieforth 1990). Temperatures have both daily and seasonal extreme variation while spatial distinctions occur from valley floors to mountaintops. The mountains tend to be cooler and windier than the valleys. Surface air heating during the day yields very high valley temperatures, often accompanied by strong local turbulence that creates dust devils. At night, valleys lose heat rapidly by radiation and cool air pools below warmer air above. The cold winter temperatures are typically -12 to 4 C and the hot summers are typically10 to 32 C. Daily temperatures vary up to 20 C, while seasonal averages vary more than 22.8 C. Near the heart of the Central Basin and Range, Elko boasts an 83.4 C temperature range, from -41.7 to 41.7 C (Trimble 1989). However, given the proximity and influence of the Great Salt Lake, temperatures throughout the northwest portion of the ecoregion are comparatively moderate. Salt Lake City temperatures average -1.7 C January and in 25.6 C in July.

There are three principal precipitation regimes in the ecoregion. Frontal cyclones from the Pacific cause winter maximum precipitation mostly as snowfall in the western and northern Central Basin and Range. Cold continental cyclones result in spring maximum precipitation in the central and eastern Central Basin and Range. Summer thunderstorms in subtropical air masses from the Gulf of Mexico cause a secondary summer maximum in the southeastern Central Basin and Range, which is often heaviest in the valleys. The average annual regional precipitation is 216 mm, however there is great variation. In Wendover, the average is 114 mm, while at the base of the Ruby Mountains only 95 km to the west, the average is 432 mm. At the edges of the ecoregion, the average annual precipitation in the rain shadow of the Sierra Nevada is 127mm, while it is 254 mm along the Wasatch Front. No surface water leaves the Central Basin and Range except by evaporation. At Pyramid Lake, the evaporation rate exceeds the precipitation rate by a ratio of about twelve to one.

Due to tectonic stretching, the earth's crust is relatively thin throughout the ecoregion, more so than any other place in North America (Fiero 1986), allowing water to percolate upward from heated subterranean zones. As a result, many thermal springs are found throughout the ecoregion. Some 30,000 springs are estimated to occur in the Central Basin and Range ecoregion (Sada 2001).

Major Systems for Regional Conceptual Modeling

We followed current recommended approaches (e.g., Gross 2005) to organize a conceptual ecological model for the ecoregion, drawing upon a wealth of existing descriptive information, including conceptual models developed for the National Park Service Inventory and Monitoring programs (Miller 2005, Chung-MacCoubrey et al. 2008); ecoregion descriptions of the Natural Resources Conservation Service (NRCS 2006) and US Forest Service (McNab et al. 2007); and the Great Basin Ecoregional Blueprint of The Nature Conservancy (Nachlinger et al. 2001). The purpose of the present ecoregional conceptual model is to articulate key assumptions about regional landscape pattern and process to inform the selection and analysis of focal resources and change agents. *This*

overarching description and model also provides an organizing framework for conceptual models for individual focal resources for the Park.

We adapted existing model concepts developed by Chung-MacCoubrey et al. (2008) to characterize the climatic and regional physiographic patterns. The pervasive influences of climatic regimes interacting with the basin and range physiography establish overarching biophysical controls that shape the individual ecosystems of the ecoregion. Affected in part by variation in solar radiation and air density, seasonal temperature regimes vary along longitudinal, latitudinal, and elevational gradients. Seasonal precipitation regimes vary along these gradients, but are also affected by rain-shadow effects. Combined, these controlling regimes set up regional patterns in precipitation and humidity/aridity, wind, dry/wet atmospheric deposition, and air quality (e.g., visibility).

Figure 3 illustrates the major components of the ecoregional conceptual model, acknowledging the central role of water in this desert ecoregion. This overarching conceptual model distinguishes upland "dry-land" ecosystems shaped generally by water scarcity from aquatic, riparian, and wetland ecosystems shaped by water discharge regimes. Given the influence of interacting climate and physiography, the overarching conceptual model further divides the "dry" and "wet" systems into "Montane Dry Land" vs. "Basin Dry Land" and "Montane Wet" vs. "Basin Wet" systems. The dry land systems include natural drivers of soil moisture infiltration, erosion, soil organic matter accumulation, and natural disturbance dynamics such as wind throw and wildfire. These vary considerably between higher, cooler montane settings and warmer basin settings. Likewise, "wet" systems, including streams, larger rivers, lakes, springs, desert sinks, wetlands, and riparian environments, are strongly driven by seasonal water flow regimes and the relative influence of surface to groundwater dynamics. Montane wet systems are most strongly shaped by surface water discharge regimes, while those within the basins combine surface flow dynamics with groundwater discharge, recharge, and evaporation. All of these natural abiotic drivers constrain and influence biotic responses, such as predator/prey dynamics, herbivory, etc.

The human dimension is included in the overarching ecoregional conceptual model as a distinct model component. This component addresses socioeconomic and demographic drivers of change in land and water use. While there are many positive interactions between human and natural components (e.g., economic development, outdoor recreation, and solitude), natural system drivers such as herbivory, wildfire, and biotic soil crust processes can be directly altered by human activities – e.g., through grazing regimes and altered fire regimes in the dry land systems. Predator/prey dynamics are influenced by human/wildlife conflicts, hunting, horse/burro congregation, and collecting. Land conversion and introduction of invasive plant species closely follow human land use patterns for settlements, energy development (e.g., mining, oil/gas, solar, industrial wind facilitys, geothermal), irrigated agriculture, or transportation/ communication infrastructure. Within wet systems, human impacts can include water withdrawals and diversions, water pollution, wetland alterations through hydrologic alteration and watershed development, wetland conversion, livestock trampling, and introductions of nonnative and often invasive species.

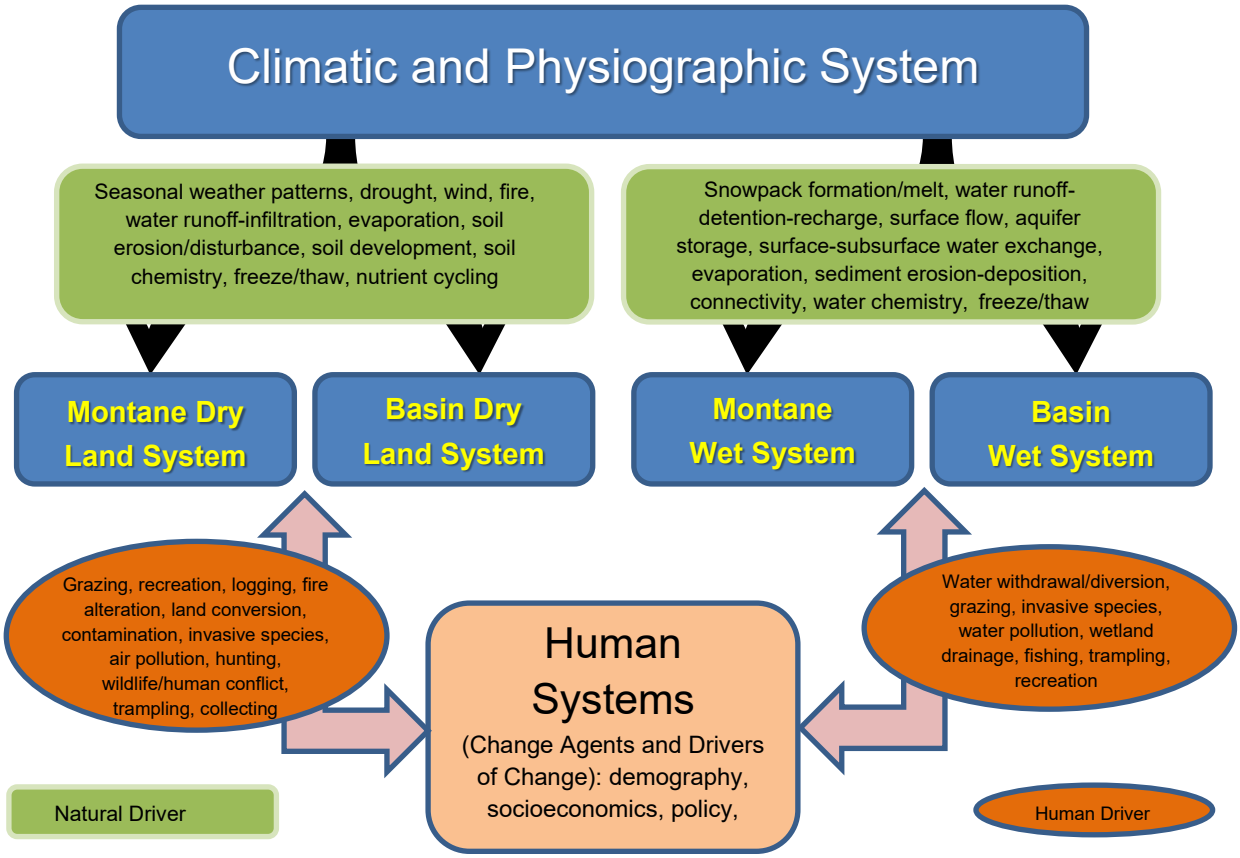

Figure 3. Conceptual model for the Central Basin and Range ecoregion (Comer et al. 2013).

Regional Subsystem Models

Each of the four major natural components of the ecoregional conceptual model – "Montane Dry Land" vs. "Basin Dry Land" and "Montane Wet" vs. "Basin Wet" systems – encompasses several component submodels representing a finer level of categorization of natural systems. The submodels take into account "slow" natural drivers, such as landform, soil development, and other properties and processes that change on decadal and longer timeframes, vs. "fast" physical drivers, such as wildfire and flooding regimes, soil erosion, and other dynamics that occur over relatively short time frames. Biotic drivers, including the responses and interactions of biota within stated physical bounds and regimes, are also differentiated in the submodels.

GRBA is primarily characterized by Montane Systems (both "dry" and "wet"). The Montane Dry Land System conceptual model includes submodels that encompass landscape pattern, dynamics, and biotic assemblages for alpine uplands, subalpine woodlands and forests, montane aspen and mixed conifer forests, pinyon-juniper woodlands, and montane shrublands (including montane sagebrush and chaparrals), and montane cliff and canyon environments. The Basin Dry Land System conceptual model includes submodels that encompass landscape pattern, dynamics, and biotic assemblages for semi-desert shrublands, shrub steppe, desert scrub, desert cliff and outcrops, and sand dunes (Figure 4).

Figure 4. Subsystem Model Components for the Central Basin and Range Ecoregion (Comer et al. 2013).

The Montane Wet System conceptual model includes submodels that encompass landscape pattern, dynamics, and biotic assemblages for alpine-to-montane lakes, streams, wetlands, and riparian communities. The Basin Wet System conceptual model includes submodels that encompass landscape pattern, dynamics, and biotic assemblages for low-elevation lakes, streams, desert springs, marshes, floodplain and riparian communities, and seasonally or intermittently wet desert washes, playas and greasewood flats (Figure 4).

Focal Resource Selection

Establishing an appropriate focus for natural resource assessment presents a challenge. Commonly, when aiming to evaluate ecological conditions, assessment teams avoid making difficult decisions by creating long lists of seemingly "crucial" resources or "threats" that must be addressed. Unfortunately, project resources impose limits, so when an assessment team identifies *too many* focal resources, it can undermine the entire assessment.

Similarly, identifying *too few* focal resources results in different challenges that are no less significant. Upon recognizing that one cannot plan for the conservation of dozens of species, natural communities and ecosystems simultaneously, teams often swing to the opposite extreme. Typically, they identify a very small number of generalized focal resources by selecting resources that are so

poorly defined and diffuse as to be unmanageable for planning. For example, a planning team might recognize it is impossible to plan for each of the dozens of native fish species and so choose to define the "native fish assemblage" as a single, all-encompassing focal ecological resource. However, where there is a wide diversity of habitat requirements among native fish species, this aggregation precludes a rigorous analysis of current conditions, and therefore provides little help in developing effective management strategies.

For this assessment, we applied what is commonly referred to as the "coarse filter / fine filter approach" to aid in selection of focal resources. Where the goal is addressing a wide spectrum of characteristic ecological processes, selection of characteristic ecosystem or natural community types provides a useful starting point. From there, some individual species will require attention where there are inherent vulnerabilities (e.g., often already endangered or otherwise considered of conservation concern).

Between these two scales of resource selection, one can consider where multiple species exhibit ecological requirements in common that would allow for their efficient treatment as a "vulnerable species assemblage." One might be able to select individual species from a given assemblage that would serve as useful surrogate foci, the management of which might address the needs of several additional species with very similar requirements.

We used the results of the initial overlay analysis and a review of high-priority resources documented by GRBA staff to identify a set of fourteen focal resources for the present assessment, shown in Table 4.

We selected seven ecosystem types to characterize the transition from GRBA into the surrounding lands likely to be affected by energy development. Among these are "wind erodible soils," which are characteristic within the surrounding basins and form the primary source of particulates that affect visibility within GRBA. We selected three ecologically-based species assemblages to address issues of migratory waterfowl and shorebirds that concentrate in limited open waters and wetlands; tree-roosting bats (represented by the Hoary bat); and cave-dwelling bats with riparian foraging habitat (represented by the Brazilian free-tailed bat). Finally, we selected four individual species for their importance to the Park and likely interactions with surrounding energy development.

Table 4. Focal resources selected for assessment *(data source: Comer et al. 2013).*

Resource Category	Focal Resources	Mapped Extent in Study Area (hectares)	Data Source
Representative Ecosystem Type	Inter-Mountain Basins Big Sagebrush Shrubland	201,900	SW ReGAP (NatureServe updated)
	Wind Erodible Soil (medium and high)	347,917	SSURGO
	Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream	7,919	SW ReGAP (NatureServe updated)
	Great Basin Springs and Seeps	1,779	–
	Inter-Mountain Basins Greasewood Flat	39,463	SW ReGAP (NatureServe updated)
	Inter-Mountain Basins Playa	11,719	SW ReGAP (NatureServe updated)
	Inter-Mountain Basins Wash	44,090	SW ReGAP (NatureServe updated)
Species Assemblages of Concern	Migratory Waterfowl & Shorebirds	572	SW ReGAP (NatureServe updated)
	Tree-Roosting Bats (represented by Hoary Bat, *Lasiurus cinereus*)	42,379	Updated model
	Cave-Roosting, Riparian Foraging Bats (represented by Brazilian Free-tailed Bat, *Tadarida brasiliensis*)	7,919	Updated model
Species Assemblages of Concern	Bighorn Sheep (*Ovis canadensis* ssp. *canadensis*)	142,782	AFWA, NDOW
	Golden Eagle (*Aquila chrysaetos*)	1,006	AFWA and NV NHP
	Greater Sage Grouse (*Centrocercus urophasianus*)	431,643 (20 leks)	Occupied Habitat (buffered lek locations)
	Pygmy Rabbit (*Brachylagus idahoensis*)	242,220	SW ReGAP range

Conceptual Models for Selected Focal Resources

A conceptual model brings together current knowledge of a given focal resource, particularly knowledge of natural dynamics and potential stressors. Once assembled, the conceptual model for each focal resource forms the foundation for identifying key ecological attributes (KEAs) and their indicators, estimating reference ranges of variation for these indicators, and building spatial models to characterize the location and condition of the resource based on these indicators. Appendix B presents conceptual models for all fourteen focal resources identified for the present assessment. The following paragraphs present, for illustration, summaries of four of these focal resource models – the Inter-Mountain Basins Big Sagebrush Shrubland, Wind Erodible Soils, Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream, and Bighorn Sheep. Each summary addresses the following information:

1) The name of the focal resource;
2) A short narrative description of the resource;
3) A summary of the key ecological attributes (KEAs) identified for the resource; and
4) A summary of key vulnerabilities of these KEAs to energy development.

Inter-Mountain Basins Big Sagebrush Shrubland

This ecological system occurs throughout much of the western U.S., typically in broad basins between mountain ranges, plains and foothills between 1,493 and 2,499 m. elevation. Adjacent ecological systems include Great Basin Pinyon-Juniper Woodland and Great Basin Xeric Mixed Sagebrush Shrubland above and at lower elevations Inter-Mountain Basins Mixed Salt Desert Scrub and Inter-Mountain Basins Greasewood Flat. The climate where this system occurs is semi-arid with annual precipitation ranging from 18-41 cm and high inter-annual variation. Much of the precipitation falls as snow, and growing-season drought is characteristic. Temperatures are continental with large annual and diurnal variation. In drier regions, these shrublands are usually associated with perennial or ephemeral stream drainages with water tables less than 3 m from the soil surface. Sites supporting this system include sloping fans, footslopes, rolling hills, swales, draws, and deep, well-drained alluvial bottomlands. Substrates are typically deep, well-drained and non-saline, fine- to medium-textured alluvial soils with some source of subirrigation during the summer season, but moderately deep upland soils with ample moisture storage also support these shrublands. Some stands occur on deep, sandy soils, or soils that are highly calcareous (Hironaka et al. 1983). Although this system may grade into sites with alkaline soils at the edge of internally drained basins, big sagebrush (*Artemisia tridentate)* is a non-halophyte and requires low salinity for optimum growth. The importance of perennial bunch grasses, the most typical herbaceous associates, is favored with greater spring and summer rain, which increases northward and eastward. The environmental description is based on several references, including Brown (1982), West (1983a), Barbour and Billings (1988), Knight (1994), Shiflet (1994), Holland and Keil (1995), Reid et al. (1999), West and Young (2000), Barbour et al. (2007), Sawyer et al. (2009), and NatureServe Explorer (2011).

These shrublands are dominated by *Artemisia tridentata ssp. tridentata*. Scattered juniper (*Juniperus* spp.), greasewood (*Sarcobatus vermiculatus)*, and saltbush (*Atriplex* spp.) may be present in some stands. Rubber rabbitbrush (*Ericameria nauseosa),* Truckee rabbitbrush *(Chrysothamnus*

viscidiflorus), antelope bitterbrush *(Purshia tridentata)*, or mountain bitterbrush (*Symphoricarpos oreophilus)* may codominate disturbed stands (e.g., in burned stands, these may become more predominant). Perennial herbaceous components typically contribute less than 25% vegetative cover. Common graminoid species can include Indian ricegrass (*Achnatherum hymenoides),* blue grama *(Bouteloua gracilis), thickspike wheatgrass (Elymus lanceolatus),* Idaho fescue *(Festuca idahoensis)*, needle and thread (*Hesperostipa comate),* basin wildrye *(Leymus cinereus),* James galleta *(Pleuraphis jamesii)*, western wheatgrass, (*Pascopyrum smithii),* Sandburg bluegrass *(Poa secunda)*, or bluebunch wheatgrass (*Pseudoroegneria spicata)*. Some semi-natural communities are included that often originate on abandoned agricultural land or on other disturbed sites. In these locations, cheatgrass (*Bromus tectorum)* or other annual bromes and invasive weeds can be abundant.

Key Ecological Attributes and Indicators

Sagebrush-dominated ecosystems are well studied, and many have identified key attributes associated with their function and integrity (e.g, Quigley et al. 2001, Davies et al. 2011, Comer et al. 2013). Biotic composition of sagebrush ecosystems is frequently altered by livestock overgrazing and introduction of invasive annual grasses, such as cheatgrass. In a cool desert landscape, such as occurs surrounding GRBA, cryptobiotic soil crusts are characteristic and provide the primary mechanism for maintaining soil stability where vegetation cover is sparse. With physical disturbance of these crusts, and soil compaction, invasive plants can easiliy become established, displacing other native species. Their accumulation as fine fuel results in increased frequency of wildfire. At the extreme, frequent wildfire and complete replacement of native vegetation by cheatgrass can result (Knapp 1996).

Practical indicators addressing the condition of sagebrush ecosystems can include direct estimates of area converted for infrastructure and measures of wildfire regime departure (Menakis et al. 2002). An indirect measure of landscape surface disturbance, as depicted in the Landscape Condition Model, as well as a model of invasive annual grass risk, are also important indicators (see Appendix B for methods). All of these are stressor-based measures, and so comparison of current scores (i.e., 0.0-1.0 for a given area) are in fact compared against a score of 1.0 (i.e., the lack of the given stressor).

Key Vulnerabilities to Energy Development

Big sagebrush shrublands are vulnerable to most forms of habitat conversion, surface disturbance, and disruption of landscape-level dynamics processes. This could result anywhere across these basins where energy-related infrastructure is installed and maintained. Perhaps more commonly, new infrastructure increases the potential for introduction of invasive annual grasses and related disruption of natural surface wildfire regimes. Likewise, the potential for surface disturbance increases wherever infrastructure development increases the accessibility of an area to motorized and non-motorized vehicles.

Wind Erodible Soils

The NRCS classifies the sensitivity of soils to wind erosion on the basis of the properties of the soil surface layer. There is a close correlation between soil blowing and the size and durability of surface clodiness, fragments, organic matter, and the calcareous reaction. The approach for the BLM REA in the Great Basin was to identify sensitive soil characteristics given the best available data at any given location. Wind Erodibility Groups (WEGs) 1 and 2 define high wind erodiblity. WEG 3, 4, and 4l

indicate moderate wind erodibility. These two categories were treated together for this assessment. Where available, the NRCS SSURGO 1:24,000 dataset provided one of the best means for identifying these soils. In portions of the study area for which SSURGO was unavailable, 1:250,000 scale STATSGO data were utilized when finer-scale draft soil survey data could not be obtained. Figure 5 shows the mapped result for moderate and high wind-erodible soils within the project assessment area.

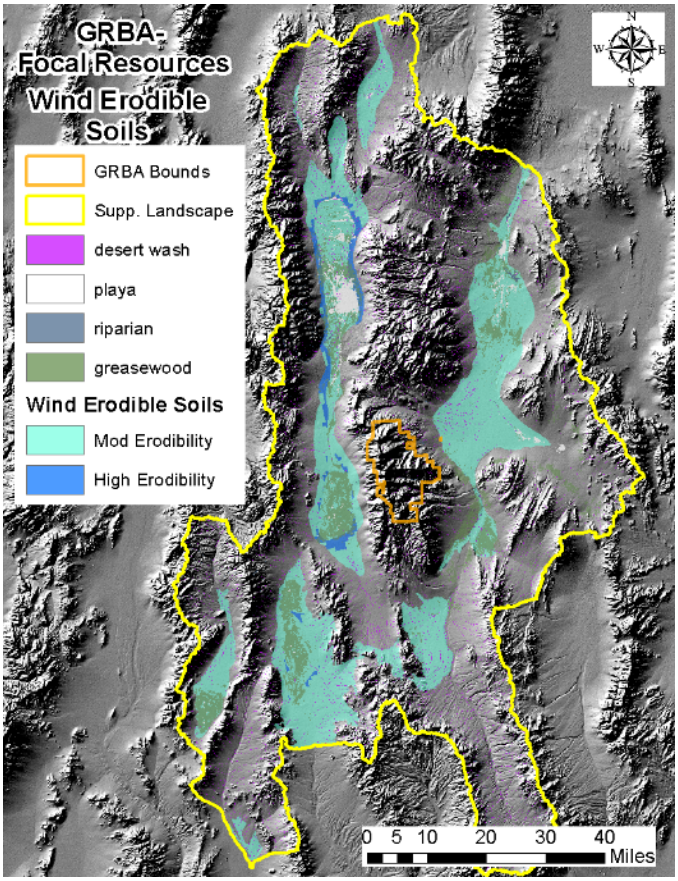

Figure 5. Map of known location of wind-erodible soils within the assessment area.

Within the vicinity of GRBA, the spatial distribution of moderate and high wind-erodible soils encompasses several basin bottoms, including area currently dominated by greasewood flat, playa, and desert wash.

Key Ecological Attributes and Indicators

In evaluation of wind erodibility across the southwest, Zobeck (1991) identified key factors for gauging wind-erodiblity. These factors provide a close parallel to the concept of key ecological attributes for measuring ecological integrity. Factors include soil surface wetness, soil surface roughness, soil-inherent wind erodibility, including aggregate size distribution and aggregate stability, and soil crust thickness. These factors are considered in wind erosion hazard scores for identification and mapping of these soil types. In a cool desert landscape, cryptobiotic soil crusts are

characteristic and provide the primary mechanism for maintaining soil stability where vegetation cover is sparse. With physical disturbance of these crusts, loose soil can then be carried by wind gusts, ultimately affecting visibility. With the removal of surface disturbance, and considerable time, soil crusts can recover and re-stabilize surface soil patches. Therefore, the presence and relative cover of soil crusts provides one focus for evaluating the integrity of wind-erodible soils.

Practical indicators addressing the condition of wind-erodible soils can include an indirect measure of landscape surface disturbance, as depicted in the Landscape Condition Model (see Appendix B). Two additional indicators, derived from field observation would include direct measurement of % cover of soil crust, and changes in ambient air visibility. Where feasible, a characterization of the expected range of variation for values from each of these indicators would be desirable. Landscape condition is a stressor-based measure, and so comparison of current scores (i.e., 0.0-1.0 for a given area) are in fact compared against a score of 1.0 (i.e., the lack of surface disturbance). However, for the indicators of % cover of soil crust, and ambient air visibility, one could characterize an expected range of variation suitable for the assessment area. This task was beyond the scope of this effort, but could be prioritized for future research.

Key Vulnerabilities to Energy Development

Wind erodible soils are vulnerable to most forms of surface disturbance. This could result anywhere across these basins where cattle are concentrated, causing compaction and breakdown of soil crust. Perhaps more commonly, where physical infrastructure results in direct soil crust removal and is not followed by measures for restabilization, there is an increased potential for wind erosion. Likewise, the potential for surface disturbance increases wherever infrastructure development increases the accessibility of an area to motorized and non-motorized vehicles.

Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream

This focal resource consists of riparian woodlands and shrublands and their associated stream reaches with at least seasonal flow. They may originate as high as 2,134 m elevation, and extend outward across valley floors as far as seasonal flows can reach (as low as 1.128 m elevation). Some occurrences originate as, or receive flow from, headwater streams supported by surface runoff, shallow groundwater seepage, and springs. Other occurrences sustain perennial flows only along distinct “gaining” reaches supported by basin-fill groundwater forced to the surface by a localized bedrock sill; and others originate at springs along basin margins. Where supported by springs or bedrock sills, the occurrences maintain perennial cold-water flow and have unique fauna and flora associated with these regionally rare hydrologic conditions. Where supported by headwater stream outflow from higher elevations, this system type sustains species adapted to variable wetting and variable depth to groundwater. Under natural conditions and regardless of the source type, surface flow either disappears at lower elevations through the combined effects of evapotranspiration and groundwater infiltration, or terminates in a playa/saline lake. Where the drainage lines extend into a terminal basin, they may become connected to each other during very infrequent periods of widespread wet weather (Abell et al. 2000).

The vegetation of this system often occurs as a mosaic of multiple assemblages that are tree- or shrub-dominated with a diverse shrub and herb component. These are disturbance-driven plant

communities that require flooding, scour and deposition of sands and gravel for germination and maintenance. Community composition varies with elevation, stream gradient, floodplain width, and flooding events. Dominant trees may include white fir (*Abies concolor),* James narrowleaf cottonwood *(Populus angustifolia),* black cottonwood *(Populus balsamifera ssp. trichocarpa),* Freemont cottonwood *(Populus fremontii),* red willow *(Salix laevigata),* Goodings willow *(Salix gooddingii)*, and Douglas-fir (*Pseudotsuga menziesii)*. Dominant shrubs may include gray alder (*Alnus incana),* silver sagebrush *(Artemisia cana),* water birch *(Betula occidentalis),* redosier dogwood *(Cornus sericea),* narrowleaf willow *(Salix exigua),* arroyo willow *(Salix lasiolepis),* Lemmon's willow *(Salix lemmonii),* or yellow willow *(Salix lutea)*. Herbaceous layers are often dominated by species of sedges (*Carex)* and reeds (*Juncus)*, and by perennial grasses and mesic forbs such as tufted hairgrass (*Deschampsia caespitosa),* slender wheatgrass *(Elymus trachycaulus),* fowl mannagrass *(Glyceria striata),* Rocky Mountain iris *(Iris missouriensis),* starry false lily of the valley *(Maianthemum stellatum),* or Fendler's meadow-rue *(Thalictrum fendleri)*. Introduced forage species such as creeping bentgrass (*Agrostis stolonifera),* Kentucky bluegrass *(Poa pratensis),* timothy *(Phleum pretense),* and the weedy annual cheatgrass *(Bromus tectorum)* are often present in disturbed stands; and livestock grazing historically has brought other alterations to the riparian vegetation.

The productivity and composition of the aquatic community, in turn, vary with several factors, including: the frequency, intensity, duration and timing of flow (including its often extreme inter-annual variability); the relative contributions of rainfall, snowmelt, and diffuse groundwater and spring discharges to flow); water temperature and chemistry; channel substrate and form; the extent of the hyporheic zone; and drainage network connectivity. The condition of these factors, in turn, varies with elevation, latitude and longitude, channel gradient, floodplain width (a function of topography and geology), surrounding geology and land cover, and connection of the flow to groundwater sources. Beaver (*Castor canadensis*) may occur in upper watershed reaches, where they may alter the hydrologic regime through construction of dams. Perennial and even frequently wetted reaches are often isolated from each other by dry reaches across the rest of the drainage network. Both the dry reaches and saline termini present barriers to movement of freshwater fauna between drainages, except during extremely rare wet hydroclimatic episodes. This lack of connectivity between adjacent drainage networks limits the mobility of aquatic faunal species on a regional scale, resulting in genetic isolation, a limited ability of populations to recover through immigration following major flood or drought disturbances, and a high degree of endemism among aquatic biota, including species adapted to using the hyporheic zone as their main habitat or as a refuge during periods with intermittent or no flow (e.g., Ward and Associates 1973, Louw and Seely 1982, Abell et al. 2000, Hilderbrand and Kershner 2000, Neville et al. 2006, Williams 2006, Levick et al. 2008, Miller et al. 2010a).

Key Ecological Attributes and Indicators

Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Streams are characterized by six key ecological attributes: (1) Native species assemblage; (2) Hydrologic regime; (3) Water quality; (4) Riparian corridor connectivity; (5) Flow network connectivity; and (6) Surrounding landscape condition. "Native species assemblage" addresses the taxonomic and

functional composition of the native biotic assemblage, and the presence/dominance of non-native species. Native species assemblage condition typically is assessed separately for riparian vegetation and stream fauna. “Hydrologic regime” addresses the pattern of variation in the frequency, magnitude, duration, and timing of surface and groundwater availability, and the similarity of this pattern to the known or estimated natural pattern of variation. The flow components driven by upstream watershed runoff and groundwater gain/loss (e.g., peak flow versus baseflow) may be addressed separately. Hydrologic regime condition also addresses the impacts of surface diversions and groundwater withdrawals. “Water quality” addresses the natural range of variation in discharge temperature, turbidity/sediment load, and chemical composition; impacts of livestock trampling and wastes; and impacts of storm runoff pollution, including from excessive watershed and channel erosion. “Riparian corridor connectivity” addresses the connectivity of riparian vegetation corridors, which may be naturally patchy. The The riparian corridor is here assumed to include a 100 m impact zone parallel to each side of the immediate corridor of the stream channel and adjacent riparian vegetation. Inclusion of this area of analysis a standard practice in the assessment and management of riparian corridors, because many ecological dynamics associated with the corridor involve interactions between the corridor core and its immediate surroundings (ELI 2008, Faber-Langendoen et al. 2012). “Flow network connectivity” similarly addresses the connectivity among perennial and seasonally wetted reaches within the local drainage network. Flow network and riparian vegetation connectivity are ecologically distinct, although in natural systems they are highly correlated. “Surrounding landscape condition” addresses characteristics of the surrounding landscape surface beyond the riparian area of analysisthat affect surface runoff, soil erosion, and recharge to both upland and basin-fill aquifers crucial to stream flow.

Key Vulnerabilities to Energy Development

The Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream ecological system is vulnerable to the impacts of energy development in the following ways:

- Increased vehicle and foot traffic across the drainage network on the valley floor surrounding the Park could result in a higher rate of introduction of non-native species into the portions of these drainage networks that extend upward into the Park.
- Surface development activities outside the Park boundaries, affecting the valley floor and other mountain ranges surrounding the Park, would not directly affect ecological conditions in the riparian/stream courses within the Park. However, damage to the drainage network and its area of analysisoutside the Park could prevent ecologically important episodic connections among watercourses within the Park. Damage could arise from vehicle traffic, foot traffic, or construction activities that fragment the riparian corridor and its buffer zone, interrupt flow lines, or degrade watershed runoff rates.
- Groundwater withdrawals outside the Park could lower storage in aquifers that support perennial flow along lower-elevation stream courses within the Park, if these local aquifers are connected to the aquifers being exploited outside the Park. This could occur even if the gaining reaches within the Park lie at higher elevations than the sites of groundwater pumping, because such pumping could affect groundwater gradients in the regional aquifer system recently identified and mapped by the USGS (Heilweil and Brooks 2011).

Bighorn Sheep

Individual sheep found within Great Basin National Park are thought to be Rocky Mountain bighorn sheep (*Ovis canadensis canadensis* – Shaw 1804). However, due to environmental characteristics and proximity, the characterics of the Desert bighorn (*Ovis canadensis nelsoni*) provide the model here.

Within the study area, bighorn sheep occur within the Snake Range, and to the southwest of GRBA in the Schell Creek Range (Figure 6).

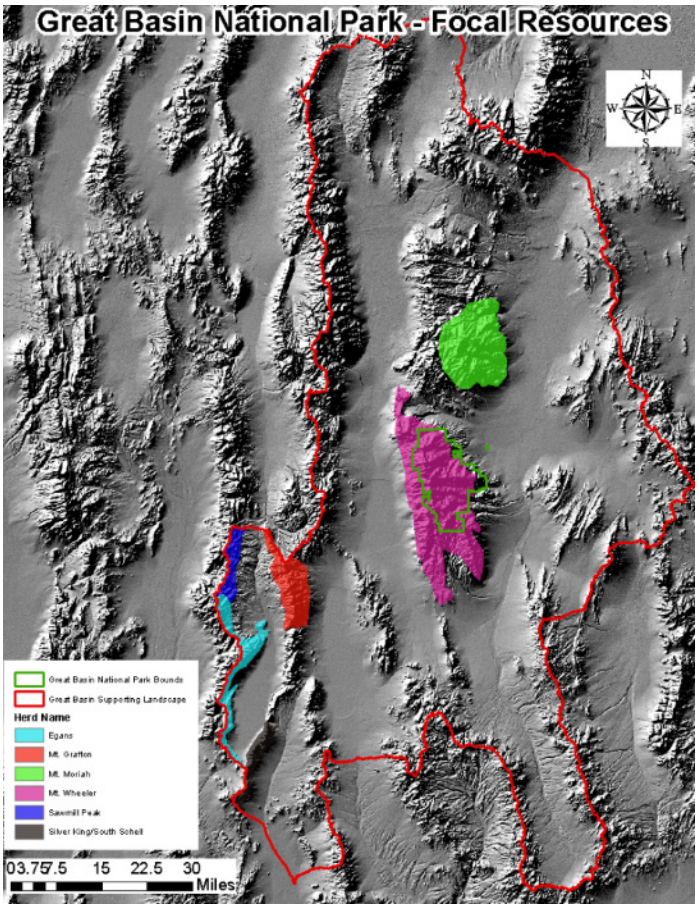

Figure 6. Current distribution of Bighorn sheep within the assessment area.

Bighorn sheep in this area tend to occur in alpine to shrub-steppe in mountains, foothills, or river canyons. Suitable escape terrain (cliffs, talus slopes, etc.) is an important feature of the habitat. In winter, Rocky Mountain bighorns spend as much of their time within 300 ft. of escape terrain (Oldemayer et al. 1971, Erickson 1972), and usually stay within one half mile of escape terrain throughout the year (Pallister 1974). The solar heat on south aspects also reduces cold stress on sheep (Shackleton et al. 1999). While gregarious, for most of the year adult males live apart from females and young (Shackleton et al. 1999, Krausman et al. 1999). Among mature males, older males (up to an age of not more than 10 years) generally dominate younger males during the breeding season; males older than 10 years decline rapidly in condition. Male annual home ranges are up to 37 km^2 in

Nevada (Leslie and Douglas 1979). Carrying capacity for bighorn can be reduced through grazing by other ungulates (cattle, burros, etc.). In some areas, lungworm infections may predispose bighorn to respiratory infection by opportunistic bacteria; lungworm life cycle involves gastropod intermediate host.

Bighorns probably live in groups primarily to reduce predation (Shackleton et al. 1999). Coyotes may be a significant predator on young in some areas, killing up to 80% of the year's lambs (Hebert and Harrison 1988, Harper 1984, Hass 1989). Mountain lions can be important predators as well (Harrison and Hebert 1988, Krausman et al. 1999), and can have significant impacts on remnant or transplant herds (Krausman et al. 1999). Direct losses to predation are not generally as important as the fact that threats of predation force females and young to use less productive habitats in and near escape terrain (Festa-Bianchet 1988, Demarchi et al. 1999a).

Populations other than those in low deserts typically migrate between an alpine or montane summer range and a lower elevation winter range (Shackleton et al. 1999). Some groups may occupy as many as five separate ranges during a year (Geist 1971). This vertical migration is probably a response to the increasing abundance of nutritious, new vegetative growth at higher elevations as spring and summer progress (Shackleton et al. 1999). The downward migration is motivated by snow accumulation in the high elevation summer ranges (Shackleton et al. 1999).

Bighorns in southwestern deserts have an extended mating season encompassing several months (Krausman et al. 1999), but the season is relatively later and shorter elsewhere, generally November in the northern part of the range (Shackleton et al. 1999). Litter size is 1, rarely 2 (Geist 1971, Turner and Hansen 1980). Young are weaned in 4-6 months. Females first breed usually in second year in south, third year in north; occasionally in first year in some areas (Krausman et al. 1999, Shackleton et al. 1999); fecundity generally declines only slightly after eight years of age (Caughley 1977).

Key Ecological Attributes and Indicators

The key ecological attribute driving the integrity of bighorn sheep populations is the maintenance of interacting healthy individuals. Therefore, local access to escape terrain (cliffs, talus slopes, etc.) is an important feature to maintain each interacting population. Bighorn sheep experience stress when faced with change agents, such as development, including mines that directly remove habitat. Roads and other transportation corridors (railroads, power lines), solar arrays, industrial wind facilitys, or oil/gas platforms, fragment habitat distribution (Debinski and Holt 2001). More dispersed human activities, such as recreation, hunting, logging, or ORV activities result in increases in road densities or disturbance via disrupted breeding, foraging, soil surface disturbance that affects biological soil crusts or uprooting or damage to plants. Any of these stressors can result in responses, such as decreased dispersal or reproductive success, and increases in direct mortality.

Key Vulnerabilities to Energy Development

Large historic declines in bighorn sheep populations were primarily the result of competition with domestic stock (e.g., cattle, domestic sheep, burros), diseases and parasites introduced by domestic sheep, overhunting, and habitat loss (Cowan 1940, Buechner 1960, Sugden 1961, Stelfox 1971, Goodson 1982, Boyce et al. 1990, Valdez and Krausman 1999). Decline of desert populations has

been attributed to destruction of habitat and competition with domestic livestock and other native and domestic species (e.g., may be limited through resource competition with burros) (Seegmiller and Ohmart 1981). Psoroptic scabies from domestic sheep devastated bighorn populations in the first half of the twentieth century (Boyce et al. 1990). Many dieoffs (greater than 50% mortality over a few months) of herds have been reported over the last century; these are poorly understood, but seem to result from stress, which interacts with endemic lungworm infestations and lowers the animals' resistance to organisms such as *Pasteurella* bacteria. The animals subsequently die from acute bronchopneumonia (Ryder et al. 1992, Dunbar 1992, Schwantje 1988). Loss and degradation of habitat, especially key winter forage sites, is a key threat (Valdez and Krausman 1999, Shackleton et al. 1999, Krausman et al. 1999). Habitat degradation can occur through overgrazing by domestic stock, competition with exotic ungulates (e.g., Aoudad or Barbary, *Ammotragus lervia*), excessive off-road vehicle use, spread of rangeland weeds, and the usurpation of water sources (Simpson 1980, Valdez and Krausman 1999, Krausman et al. 1999). Fire suppression and resulting vegetation succession (encroachment of tall dense shrubland and forest) have been a major cause of habitat loss in Colorado and British Columbia (Davidson 1991, Cannings et al. 1999, Wakelyn 1987). Fragmentation of habitat reduces or eliminates genetic interchange among populations (Ramey 2000) and reduces the probability of recolonization following local extirpation; both these effects are especially of concern in small populations (fewer than 100 individuals), which are especially vulnerable to extirpation (Berger 1990).

Potential Impacts of Energy Development on Focal Resource Ecological Integrity

The conceptual model for each focal resource documents current assumptions about the effects of stressors on the ecological integrity of the resource. In turn, spatial models express these assumptions visually and quantitatively. For this assessment, we used spatial models developed for the BLM Central Basin and Range REA (Comer et al. 2013), for current (2012) and future (2025) conditions. Appendix C provides additional select information on the technical steps involved in developing these spatial models; The REA report provides full details.

The assessment of ecological integrity uses indicators that can be assessed consistently across an entire study area for key ecological attributes for each focal resource. The indicator values are scaled in such a way that they provide an index of condition. Here, as in the REA, we scaled the indicators values so that they range from a value of 1.0 indicating near-natural or reference condition, to a value of 0.0 indicating extreme to complete alteration from reference conditions. We then overlaid a spatial model for each index on the distribution of each associated focal resource, to calculate a weighted average index score for each resource by spatial reporting units. For species resources, we used spatial reporting units consisting of 4 km^2 grid cells. For wind-erodible soils, we used a 1 km^2 grid. For ecosystem-scale resources, we used fifth level watersheds.

Table 5 summarizes the indicators used in the ecological integrity assessment of focal resources in this study and also summarizes the method of calculation of individual indicators.

The Landscape Condition Model (see Appendix C and Comer et al. 2013) expresses the primary effects of infrastructure development that fragment natural habitats. The Invasive Species Index is a spatial model designed to describe the potential shifts in native species composition through

displacement by invasive annual grasses. The Fire Regime index applies the output of state-and-transition models that establish expected combinations of succession classes (SClass) and their spatial distributions for different vegetation types under different conditions of fire regime alteration. By comparing observed with expected SClass combinations, an index of fire regime departure is calculated for each vegetation type within the reporting unit. Table 5 describes the methods of calculation for several other indicators, as well.

Table 5. Indicators used for ecological integrity scoring for both BLM REA and for GRBA analysis (*italics* indicate applicable resource categories).

Risk Factor	Key Ecological Attribute	Indicator	Definition (all scaled to 0-1 score)	KEA & Indicator Justification
Landscape Context	Landscape Condition (all resource types)	Landscape Condition Index (LCI)	This indicator is measured by intersecting the mapped area or habitat distribution map of the resource with the LCM layer and reporting the average LC index value for the resource or habitat within each 5th level watershed, or 4x4 km^2 units for species. Landscape Condition Index is a 90x90 m^2 unit resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. The results are a score for landscape condition from 0 to 1 with 1 being very high landscape condition and values close to 0 likely having very poor condition.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by fragmenting effects of land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance.
	Surrounding Watershed Land Use Context *(Aquatic resources only)*:*	Perennial Flow Network Fragmentation by Dams	Number of intersections with NHD perennial streams. The total number of intersections per watershed defines the index score.	The degree of fragmentation of continuous aquatic habitat directly affects processes and populations for aquatic species (Allan 2004, Ward and Stanford 1989).
Relative Extent	Extent / Size *(riparian/riverine aquatic resources and cave-roosting bats)**	Riparian Corridor Continuity	Indicates the degree to which the riparian areas (buffered by 200 m) exhibit an uninterrupted corridor. A measure of the linear, continuous unfragmented riparian corridor based on LCI, to measure how many fragments are created by the interruption of the natural riparian corridor by non-natural land use.	Unfragmented riparian corridors support individual animal movement, gene flow and natural flooding and sediment deposition and scour processes upon which aquatic and wetland species depend (Belsky et al. 1999, Allan 2004, Hansen et al. 2005).
Condition	Fire Regime *(vegetated terrestrial coarse filter resources only)**	Fire Regime Departure Index	This indicator is assessed by calculating and summarizing the updated LANDFIRE Succession classes (SClass) layer which characterizes current vegetation succession classes for the distribution of each resource within each 5th-level watershed. The resulting proportional calculation for current conditions is compared to the expected proportions, as derived from the VDDT or Path-Tools model characterizing the expected natural range of variation (NRV). This comparison defines the degree of departure (%). The SClass Departure Index is calculated by subtracting the Departure percent from 1 to produce a normalized scale from 0 to 1 with 1 being no departure from NRV in distribution of succession classes and 0 being complete departure from NRV.	A mix of successional classes among patches of a given vegetation type results from fire and other natural disturbances. Through field observation and modeling, one can establish a working hypothesis for the expected proportional mix of successional classes where human alterations are limited. Departure from the mixture predicted under NRV indicates uncharacteristic disturbance regime and declining integrity.
	Stressors on Biotic Condition	Invasive Annual Grass Index *(selected terrestrial resources only)**	This indicator is measured using the mapped area or habitat distribution of the resource with an abundance map of introduced invasive annual grass species. The output is predicted percent cover of invasive annual grass species within each 5th level watershed. The Invasive Annual Grass Index is calculated by multiplying the invasive annual grass cover percent by 4 then subtracting the product from 1 to produce a normalized scale from 0 to 1 with 0 being 25% or greater cover of invasive annual grasses and 1 being invasive annual grasses absent.	Invasive annual grass species displace natural composition and provide fine fuels that significantly increase spread of catastrophic fire.

* Appliciple resource categories (also shown in italics).

Table 5 (continued). Indicators used for ecological integrity scoring for both BLM REA and for GRBA analysis (*italics* indicate applicable resource categories).

Risk Factor	Key Ecological Attribute	Indicator	Definition (all scaled to 0-1 score)	KEA & Indicator Justification
Condition (continued)	Stressors on Biotic Condition	Presence of Invasive Aquatic Animal Species *(Aquatic resources only)**	The number of invasive taxa (known status).	Invasive animal species displace natural composition and affect natural foodwebs (Vitousek et al. 1996, Harju 2007, Shigesada and Kawasaki 1997).
	Stressors on Biotic Condition	Presence of Invasive Plant Species *(Aquatic resources only)**	Number of known locations of non-native introduced tamarisk, Russian olive, and annual grasses.	Increased non-native plant species reduces habitat quality for numerous wildlife species, decreases forage for livestock, reduces ecosystem native species richness, increases soil erosion potential and decreases ecosystem resiliency and resistance to damage from impacts, including climate change.
	Stressors on Hydrologic Condition *(Aquatic resources only)**	Condition of Groundwater Recharge Zone	Measures the landscape condition of the likely groundwater recharge zone (areas above 2000 m within each 10 digit HUC (watershed)) by percent area in hard-surface development as determined in LCI.	Hard surface development within a groundwater recharge zone can divert and reduce the amount water entering the groundwater (Flint and Flint 2007, USEPA 2007).
	Stressors on Hydrologic Condition *(Aquatic resources only)**	Flow Modification by Dams	"F" Index (Theobald et al. 2010a) measures the number of dams and their storage capacity relative to annual stream discharge.	Higher storage capacity is an indicator of greater impact to natural flow regimes of the downstream river or stream segments (Graf 1999, Theobold et al. 2010a).
	Stressors on Hydrologic Condition *(Aquatic resources only)**	Groundwater Use	The ratio of groundwater use as reported by the USGS Southwest Principal Aquifer study (Anning et al. 2009) to the total natural surface runoff per watershed (calculated from NHD). This is not a quantitative groundwater budget; it merely “normalizes” groundwater use relative to the overall “wetness” of a watershed.	This indicates the degree to which groundwater is being consumed for human use relative to availability within each watershed. The greater the use, the less water is available to support aquatic species, specifically higher ground water use is likely to draw down water tables and therefore springs (Manning 1999, Patten et al. 2007).
	Stressors on Hydrologic Condition *(Aquatic resources only)**	Perennial Flow Modification by Diversion Structures	Number of aquaducts intersecting or branching from NHD perennial streams. Total per watershed.	This indicates the amount of flow modification and change in hydrologic regime. (Poff et al. 2010).
	Stressors on Hydrologic Condition *(Aquatic resources only)**	Surface Water Use	The ratio of surface water use as reported by the USGS Southwest Principal Aquifer study (Anning et al. 2009) to the total natural surface runoff per watershed (calculated from NHD). This is not a quantitative surface water budget; it merely “normalizes” surface water use relative to the overall “wetness” of a watershed.	The greater the use relative to supply, the less water is available to support aquatic species (Richter et al. 1997).
	Stressors on Hydrologic Condition *(Aquatic resources only)**	Hydrologic Condition Index	Average scaled integrity score (0.0-1.0) across all individual indicators for Hydrologic Condition.	This index summarizes the information contained in all individual indicators of Hydrologic Condition.
	Stressors on Water Quality *(Aquatic resources only)**	Atmospheric Deposition-Nitrate (NO_3) Loading	Rate of deposition of NO_3 per unit area within watershed.	This indicator is used a representative indicator of a nutrient loading pollutant. Increased nitrogen in aquatic systems can increase algal growth and decrease oxygen content (Fenn et al. 2003a, 2003b).
	Stressors on Water Quality *(Aquatic resources only)**	Atmospheric Deposition-Toxic Mercury (Hg) Loading	Rate of deposition of mercury (Hg) per unit area within watershed.	This indicator is used to represent the amount of toxic pollutants. Toxic pollutants affect reproduction, growth and neurologic functioning of aquatic animals. Mercury in particular accumulates up the food chain and can affect human health as well (Peterson et al. 2009, Ward et al. 2010).

* Appliciple resource categories (also shown in italics).

Table 5 (continued). Indicators used for ecological integrity scoring for both BLM REA and for GRBA analysis (*italics* indicate applicable resource categories).

Risk Factor	Key Ecological Attribute	Indicator	Definition (all scaled to 0-1 score)	KEA & Indicator Justification
Condition (continued)	Stressors on Water Quality *(Aquatic resources only)**	Sediment Loading Index	Index values of total suspended sediment (developed by NSPECT) which are based on percent of land uses (NLCD) that contribute excess sedimentation and suspended solids via surface water runoff and overland flow into a wetland, as measured within the 200 m buffer area.	Different surrounding land uses contributes to the sediment loading in adjacent waters. Increased sediment clogs fish gills, reduce successful spawning, decrease visibility and increase pollutant loadings, especially heavy metals (Salomons et al. 1987, Apitz et al. 2005).
	Stressors on Water Quality *(Aquatic resources only)**	State-Listed Water Quality Impairments	Measures the integrity of water quality conditions in individual water bodies based on the presence and severity of state listings of water quality impairments for State 303(d) reporting requirements under the federal Clean Water Act –excluding nutrient enrichment, which is addressed by a separate key ecological attribute.	This indicator is a direct measure of pollutants, turbidity and sediments that exceed state standards. Polluted water negatively affects aquatic species health and ability to successfully reproduce (USEPA 2004).
	Stressors on Water Quality *(Aquatic resources only)**	Water Quality Condition Index	Average scaled integrity score (0.0-1.0) across all individual indicators for stressors on Water Quality.	This index summarizes the information contained in all individual indicators of Water Quality.

* Appliciple resource categories (also shown in italics).

Results

Areas of Current and Potential Conflict

Table 6 presents the results of overlaying data on the present (2012) and potential future (2025) distributions of energy infrastructure with the known distributions of the focal resources. Specifically, Table 6 gives the proportional area of each focal resource distribution included within the area of present or potential energy development with 1 km, 5 km, and 10 km buffers.

Table 6. Summary of map overlays within the study area including utility rights-of-way as currently configured, and as forecasted for 2025.

Resource Category	Focal Resources	1 km Buffer (%) 2012	1 km Buffer (%) 2025	5 km Buffer (%) 2012	5 km Buffer (%) 2025	10 km Buffer (%) 2012	10 km Buffer (%) 2025
Ecosystem Type	Inter Mountain Basins Big Sagebrush Shrubland	1.1	3.4	2.8	12.6	5.5	19.1
	Wind Erodible Soil (medium and high)	6.6	9.0	17.6	24.6	28.4	34.8
	Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream	1.0	2.8	4.4	7.9	9.9	14.7
	Great Basin Springs and Seeps	1.9	2.2	6.8	7.2	11.4	14.0
	Inter-Mountain Basins Greasewood Flat	0.3	4.0	1.8	13.3	3.6	19.3
	Inter-Mountain Basins Playa	0.0	0.0	1.4	1.5	4.9	4.9
	Inter-Mountain Basins Wash	1.4	2.9	5.6	11.3	10.0	19.9
Species Assemblages of Concern	Migratory Waterfowl & Shorebirds	0.2	3.8	0.2	6.0	1.3	7.0
	Tree-Roosting Bats	0.0	0.0	3.8	3.8	9.3	10.2
	Cave-Roosting, Riparian- Foraging Bats	1.0	2.8	4.4	7.9	9.9	14.7
Species of Concern	Bighorn Sheep	0.6	0.9	4.1	5.9	11.0	16.6
	Golden Eagle	0.0	14.1	7.8	37.9	22.9	68.5
	Greater Sage Grouse – active lek sites	6.1	7.3	18.7	24.4	38.4	49.6
	Greater Sage Grouse – core occupied habitat	1.0	1.1	4.2	4.9	7.9	9.6
	Pygmy Rabbit	1.0	2.8	2.3	8.7	4.5	14.1

Potential Impacts of Energy Development on Focal Resource Ecological Integrity

Appendix D presents the maps of integrity index scores for all spatial reporting units 4x4 km grid cells or fifth level watersheds) for ten of the eighteen indicators listed in Table 5, for the fourteen focal resources across the entire study area. Appendix D does not include maps for eight indicators (see Table 5) that showed little or no variation among reporting units:

- Perennial Flow Network Fragmentation by Dams
- Presence of Invasive Aquatic Animal Species
- Presence of Invasive Plant Species
- Condition of Groundwater Recharge Zone
- Flow Modification by Dams
- Perennial Flow Modification by Diversion Structures
- Sediment Loading Index
- State-Listed Water Quality Impairments

Appendix D includes maps for the "Hydrologic Condition Index" and "Water Quality Condition Index" that summarize all indicators for hydrologic condition and water quality, respectively.

Table 7 summarizes the results of the analysis of integrity score distributions for all indicators shown in Appendix D, including the summary indexes for hydrologic condition and water quality. See Appendix C for detailed explanation of the Landscape Condition Index. Table 7 specifically shows the percentages of reporting units for each indicator or index that fall into which quartile of potential indicator/index values. Table 7 shows that only nine indicators or indexes among six focal resources show any forecasted change in the distribution of score values between the 2012 and 2025 periods of assessment: Landscape Condition and Fire Regime Departure Index scores for the Inter-Mountain Basin Big Sagebrush Shrubland ecosystem; Landscape Condition Index scores for Bighorn Sheep, Cave-Dwelling/Riparian-Foraging Bats, Greater Sage Grouse, and Pygmy Rabbit; and Fire Regime Departure Index scores for the three forested communities in which Tree-Roosting Bats (represented by the Hoary Bat) roost.

The Landscape Condition Index scores for the first five focal resources show an expectable shift between 2012 and 2025, with fewer reporting units falling into the uppermost, highest-integrity quartile; and more falling into the second, moderately-reduced integrity quartile. The Fire Regime Departure Index scores for the Inter-Mountain Basin Big Sagebrush Shrubland ecosystem also show an expectable shift between 2012 and 2025, but in this case with fewer reporting units falling into the lowermost, most-altered integrity quartile, and more falling into the next higher quartiles.

The Fire Regime Departure Index scores for the three woodland system types important to Tree-Roosting Bats – the Inter-Mountain Basins (IMB) Aspen-Mixed Conifer Forest & Woodland; Inter-Mountain Basins (IMB) Mountain-mahogany Woodland & Shrubland; and Inter-Mountain Basins (IMB) Subalpine Limber-Bristlecone Pine Woodland – all show shifts toward higher quartiles.

Table 7. Percent of reporting units with ecological integrity scores in each quartile of index values for current (2012) and estimated future (2025) status. Table excludes eight indicators with little or no variation among reporting units.

		Proportion 0.75 – 1.0		Proportion 0.50 – 0.74		Proportion 0.25 – 0.49		Proportion 0.00 – 0.25	
Focal Resource	**Indicator**	**2012**	**2025**	**2012**	**2025**	**2012**	**2025**	**2012**	**2025**
Inter Mountain Basins Big Sagebrush Shrubland	Landscape Condition Index	**55** [b]	**45** [b]	**45** [b]	**55** [b]	0	0	0	0
	Fire Regime Departure Index	0	0	4	25	63	71	33	4
	Invasive Annual Grasses Index	10	NA	38	NA	52	NA	0	NA
Wind Erodible Soils	Landscape Condition Index	30	30	56	56	13	13	1	1
Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream	Landscape Condition Index	70	70	30	30	0	0	0	0
	Riparian Corridor Continuity Index	76	76	24	24	0	0	0	0
	Surface Water Use	3	NA	45	NA	52	NA	0	NA
	Groundwater Use	7	NA	55	NA	38	NA	0	NA
	Hydrologic Condition Index	3	NA	97	NA	0	NA	0	NA
	NO_3	0	NA	0	NA	0	NA	100	NA
	Hg	93	NA	7	NA	0	NA	0	NA
	Water Quality Index	0	NA	100	NA	0	NA	0	NA
Great Basin Springs and Seeps	Landscape Condition Index	68	68	32	32	0	0	0	0
	Surface Water Use	4	NA	43	NA	53	NA	0	NA
	Groundwater Use	7	NA	54	NA	39	NA	0	NA
	Hydrologic Condition Index	0	NA	4	NA	89	NA	7	NA
	Water Quality Index	50	NA	46	NA	4	NA	0	NA

[a] NA = Not Assessed.

[b] Indicates instances of change between the two timeframes (also in bold font).

Table 7 (continued). Percent of reporting units with ecological integrity scores in each quartile of index values for current (2012) and estimated future (2025) status. Table excludes eight indicators with little or no variation among reporting units.

		Proportion 0.75 – 1.0		Proportion 0.50 – 0.74		Proportion 0.25 – 0.49		Proportion 0.00 – 0.25	
Focal Resource	**Indicator**	**2012**	**2025**	**2012**	**2025**	**2012**	**2025**	**2012**	**2025**
Inter-Mountain Basins Greasewood Flat	Landscape Condition Index	68	68	32	32	0	0	0	0
	Surface Water Use	4	NA	43	NA	53	NA	0	NA
	Groundwater Use	7	NA	54	NA	39	NA	0	NA
	Hydrologic Condition Index	4	NA	50	NA	46	NA	0	NA
	NO_3	0	NA	0	NA	0	NA	100	NA
	Hg	96	NA	4	NA	0	NA	0	NA
	Water Quality Index	0	NA	96	NA	4	NA	0	NA
Inter-Mountain Basins Playa	Landscape Condition Index	66	66	34	34	0	0	0	0
	Surface Water Use	5	NA	38	NA	57	NA	0	NA
	Groundwater Use	10	NA	52	NA	38	NA	0	NA
	Hydrologic Condition Index	5	NA	43	NA	52	NA	0	NA
	NO_3	0	NA	0	NA	0	NA	100	NA
	Hg	95	NA	5	NA	0	NA	0	NA
	Water Quality Index	0	NA	95	NA	5	NA	0	NA
Inter-Mountain Basins Wash	Landscape Condition Index	70	70	30	30	0	0	0	0
	Surface Water Use	3	NA	45	NA	52	NA	0	NA
	Groundwater Use	7	NA	55	NA	38	NA	0	NA

[a] NA = Not Assessed.

[b] Indicates instances of change between the two timeframes (also in bold font).

Table 7 (continued). Percent of reporting units with ecological integrity scores in each quartile of index values for current (2012) and estimated future (2025) status. Table excludes eight indicators with little or no variation among reporting units.

		Proportion 0.75 – 1.0		Proportion 0.50 – 0.74		Proportion 0.25 – 0.49		Proportion 0.00 – 0.25	
Focal Resource	**Indicator**	**2012**	**2025**	**2012**	**2025**	**2012**	**2025**	**2012**	**2025**
Inter-Mountain Basins Wash (continued)	Hydrologic Condition Index	3	NA	52	NA	45	NA	0	NA
	NO_3	0	NA	0	NA	0	NA	100	NA
	Hg	93	NA	7	NA	0	NA	0	NA
	Water Quality Index	0	NA	93	NA	7	NA	0	NA
Migratory Waterfowl & Shorebirds	Landscape Condition Index	8	8	66	66	26	26	0	0
Bighorn Sheep	Landscape Condition Index	**81** [b]	**80** [b]	**19** [b]	**20** [b]	0	0	0	0
Golden Eagle	Landscape Condition Index	0	0	83	83	17	17	0	0
Hoary Bat (surrogate for tree-roosting bats)	Fire Regime Departure Index								
	IMB Aspen-Mixed Conifer Forest & Woodland	0	100	92	0	8	0	0	0
	IMB Mountain-mahogany Woodland & Shrubland	0	0	87	100	13	0	0	0
	IMB Subalpine Limber-Bristlecone Pine Woodland	0	0	22	33	78	67	0	0
Brazilian Free-tailed Bat (surrogate for cave-roosting bats that forage in riparian habitat)	Landscape Condition Index	64	60	35	39	1	1	0	0
	Riparian Corridor Continuity Index	76	76	24	24	0	0	0	0
Greater Sage Grouse	Landscape Condition Index	**64** [b]	**62** [b]	**35** [b]	**37** [b]	1	1	0	0
	Invasive Annual Grasses Index	39	NA	18	NA	40	NA	3	NA

[a] NA = Not Assessed.

[b] Indicates instances of change between the two timeframes (also in bold font).

Table 7 (continued). Percent of reporting units with ecological integrity scores in each quartile of index values for current (2012) and estimated future (2025) status. Table excludes eight indicators with little or no variation among reporting units.

		Proportion 0.75 – 1.0		Proportion 0.50 – 0.74		Proportion 0.25 – 0.49		Proportion 0.00 – 0.25	
Focal Resource	**Indicator**	**2012**	**2025**	**2012**	**2025**	**2012**	**2025**	**2012**	**2025**
Pygmy Rabbit	Landscape Condition Index	**55** [b]	**54** [b]	**41** [b]	**42** [b]	4	4	0	0
	Invasive Annual Grasses Index	29	NA	17	NA	46	NA	8	NA

[a] NA = Not Assessed.

[b] Indicates instances of change between the two timeframes (also in bold font).

These latter results for the Fire Regime Departure Index scores indicate a potential for improved integrity to the fire regime. That is, the results indicate that conditions are forecasted to shift closer to expected proportions of natural successional classes, given fire frequency and intensity.

Table 7 also shows that the majority of Landscape Condition Index scores, across the reporting units for all fourteen focal resources across the entire study area, fall into the uppermost, highest-integrity quartile, followed in frequency by reporting units with scores in the second-highest quartile. Most other integrity index scores, for all fourteen focal resources, fall most heavily in the second and third quartiles. The only exception to this pattern is the Nitrate (NO_3) index, which shows poor conditions (lowest quartile) in all reporting units, indicating high rates of atmospheric nitrate deposition.

The results shown in Table 7 indicate that, as of 2012, the study area overall has sustained mostly minor to moderate reductions in ecological integrity, with a few indicators pointing to major reductions. The greatest impacts are associated with the areas affected by roads and utility corridors, mostly in the valleys surrounding GRBA, and with the widespread presence of invasive grasses. In addition, the results in Table 7 indicate that only five of the fourteen focal resources are forecasted to experience worsening conditions between 2012 and 2025, as measured by the Landscape Condition Index scores. The forecasted worsening conditions arise from road and utility corridor development. These latter results differ from those in Table 5 for two reasons. First, Table 5 looks at percentage of resource area included within area of analysis around the areas of utility development, while the Landscape Condition Model (the basis of the Landscape Condition Index) looks at a finer spatial scale before aggregating the results by spatial reporting unit. Second, Table 7 aggregates scores by quartile, and this causes some loss of detail.

Conclusions

Summary of Study Approach

This study used the Ecological Integrity Assessment Framework (Unnasch et al. 2018) to assess the sensitivity of ecological resources within Great Basin National Park to energy development on lands surrounding the Park. The assessment established a study area consisting of the Park and surrounding fifth level watersheds, extending outward to cover all surrounding valleys and uplands. Across this area, the study identified fourteen focal ecological resources that could be sensitive to the impacts of energy development within the study area. The fourteen focal resources include seven large-scale ecosystem types that overlap with the Park or interact strongly with the natural resources of the Park; three species assemblages; and four individual species for which both the Park and the surrounding landscape provide important habitat, including movement corridors. The fourteen focal ecological resources assessed are:

- Inter-Mountain Basins Big Sagebrush Shrubland
- Wind Erodible Soils
- Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream
- Great Basin Springs and Seeps
- Inter-Mountain Basins Greasewood Flat
- Inter-Mountain Basins Playa
- Inter-Mountain Basins Wash
- Migratory Waterfowl & Shorebirds Species Assemblage
- Tree-Roosting Bat Assemblage, represented by the Hoary Bat (*Lasiurus cinereus*)
- Cave-Roosting, Riparian-Foraging Bat Assemblage, represented by the Brazilian Free-Tailed Bat (*Tadarida brasiliensis*)
- Rocky Mountain Bighorn Sheep (*Ovis canadensis canadensis*)
- Golden Eagle (*Aquila chrysaetos*)
- Greater Sage Grouse (*Centrocercus urophasianus*) (active lek sites and core occupied habitat)
- Pygmy Rabbit (*Brachylagus idahoensis*)

The assessment developed or adapted a conceptual ecological model for each focal resource, to identify key ecological attributes and their indicators and document current understanding of the effects of stressors on the ecological integrity of the resource. The conceptual models identified eighteen indicators or indexes – composites of multiple indicators – for which data were available for evaluation among the several key ecological attributes. The study specifically used data from the Central Basin and Range Rapid Ecoregional Assessment recently completed for the U.S. Bureau of Land Management (Comer et al. 2013). Eight indicators/indexes generated values with little or no variation within the study area, while ten presented sufficient variation to support quantitative analysis:

- Landscape Condition Index
- Fire Regime Departure Index
- Riparian Corridor Continuity Index
- Invasive Annual Grasses Index
- Groundwater Use
- Surface Water Use
- Hydrologic Condition Index (a summary of all indicators of hydrologic condition)
- Hg Deposition
- NO_3 Deposition
- Water Quality Index (a summary of all indicators of water quality)

The study then analyzed the potential impact of energy development on each resource in two ways, in terms of: (1) the overlap between the areas of energy development and the spatial distribution of each focal ecological resource; and (2) the possible impacts of energy development on the ecological integrity of each focal resource across the entire study area.

Summary of Results

The assessment results identify two ways in which the ecological resources of Great Basin National Park may be sensitive to energy development on lands surrounding the Park:

1) Significant percentages of the current spatial distribution of several focal ecological resources appear to fall within the current (2012) footprint of energy development, and even larger percentages within the footprint forecasted for 2025. The inter mountain basins big sagebrush shrubland, inter-mountain basins greasewood flat, Great Basin foothill and lower montane riparian woodland and shrubland/stream, and inter-mountain basins wash system types; the migratory waterfowl & shorebird assemblage; the cave-roosting, riparian-foraging bat assemblage; and the golden eagle and pygmy rabbit are forecasted to experience the greatest increases in the percentages of their areas included within the footprint of energy development. Wind erodible soils, greater sage grouse lek sites, and bighorn sheep movement corridors may also be highly vulnerable, with large percentages of their areas falling within the footprint of energy development even in 2012.
2) Forecasted energy development will result in a shift toward more degraded conditions- i.e., toward lower ecological integrity – by 2025 for five focal ecological resources within their ranges across the entire study area, as measured by the quartile distributions of Landscape Condition Index scores: the inter-mountain basin big sagebrush shrubland ecosystem, the riparian-foraging bat assemblage, bighorn sheep, greater sage grouse, and pygmy rabbit. These "ecological integrity" results differ from the first set for two reasons. First, the "footprint" analysis looks at the percentage of the spatial distribution of each focal resource included within area of analysis around the areas of utility development, while the Landscape Condition Model looks at a finer spatial scale before aggregating the results by spatial reporting unit. Second, the

analysis of Landscape Condition Index scores aggregates these scores by quartile, which results in some loss of detail.

Recommendations

The results have two important limitations. First, they rely on datasets compiled for the Central Basin and Range REA, and use the same spatial reporting units as the REA. Using datasets more specific to the immediate Park area, and finer-scale spatial reporting units, would produce more refined results. Nevertheless, the REA datasets and spatial reporting units permit an initial, rapid assessment to help managers consider whether any more refined analyses are warranted. Second, the actual pattern of energy development in the areas surrounding GRBA may evolve in ways other than as forecasted today; and the forecasts themselves may change. The assessment reported here can be updated as data, knowledge of energy impacts, and forecasts of energy development improve.

Finally, the methodology implemented here – particularly the assessment of multiple focal ecological resources across a large study area encompassing the Park and the surrounding ecosystems with which it interacts – encourages an awareness of the wide spectrum of stressors that can affect the ecological integrity of a Park unit at different spatial scales. Such awareness is crucial for safeguarding Park ecological resources and other natural resource values against the numerous large and small insults that can threaten any protected area surrounded by areas with fewer or no protections.

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Note: Additional references for selected focal resources can be found in Appendix B.

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Appendix A: Glossary and Measurement Unit Conversions

The terms and acronyms listed here cover not only the material in the present document, but ones that may be found in ecological integrity assessments and BLM rapid ecoregional assessments.

Glossary

Table A-1. Glossary of terms used in this document and their definitions.

Term	Definition
Areas of Critical Environmental Concern (AresourceC)	Areas within the public lands where special management attention is required to protect and prevent irreparable damage to important historic, cultural, or scenic values, fish and wildlife resources or other natural systems or processes, or to protect life and safety from natural hazards (FLPMA 1976).
Aridisols	The central concept of Aridisols is that of soils that are too dry for mesophytic plants to grow. They have either: 1) An aridic moisture regime and an ochric or anthropic epipedon and one or more of the following with an upper boundry within 100 cm of the soil surface: a calcic, cambic, gypsic, natric, petrocalcic petrogypsic, or a salic horizon or a duripan or an argillic horizon, or 2) A salic horizon and saturation with water within 100 cm of the soil surface for one month or more in normal years. An aridic moisture regime is one that in normal years has no water available for plants for more than half the cumulative time that the soil temperature at 50 cm below the surface is >5° C. and has no period as long as 90 consecutive days when there is water available for plants while the soil temperature at 50 cm is continuously >8° C.
Biophysical Setting (BpS)	As developed for LANDFIRE, this aims to depict the potential distribution of the ecosystem, given natural landscape disturbance regimes like wildfire. As used by LANDFIRE, the biophysical setting equates to the historic distribution of the ecosystem type, prior to alterations by European settlement and more recent human activities.
Change Agent	An environmental phenomenon or human activity that can alter/influence the future status of resource condition. Some change agents (e.g., roads) are the result of direct human actions or influence. Others (e.g., climate change, wildland fire, and invasive species) may involve natural phenomena or be partially or indirectly related to human activities.
Coarse Filter	A focus of analysis in biodiversity conservation that is based on conserving resources that occur at coarse scales of ecological organization than individual species, such as ecological system or natural community types. The concept behind a coarse filter approach is that assessment and conservation of coarse-scale focal resources will address major ecological processes that support relatively common species.
Deductive models	Using existing mapped information, and then recombine them according to a set of rules determined by the modeler; typically working within ArcGIS, ModelBuilder™ was used to describe interactions among spatial datasets.

Table A-1 (continued). Glossary of terms used in this document and their definitions.

Term	Definition
Development	A type of change (change agent) resulting from urbanization, industrialization, transportation, mineral extraction, water development, or other non-agricultural/silvicultural human activities that occupy or fragment the landscape or that develops renewable or non-renewable resources.
Distribution (as in *species distribution*)	In this REA the spatial methods employed was mapping of actual distribution as best possible, whether current known occupied habitat or predicted habitat. (see *Range Mapping*)
Ecological Integrity	The ability of an ecological system to support and maintain a community of organisms that have the species composition, diversity, and functional organization comparable to those of natural habitats within the ecoregion.
Ecological Integrity Status	The result of measuring a given criterion (biological or socio-economic resource values or conditions) within a geographic area (e.g., watershed, grid). A rating (e.g., low, medium, or high) or ranking (numeric) is assigned to specific criteria to describe status. The rating or ranking will be relative, either to the historical range of variability for that criterion (e.g., a wildland fire regime criterion) or relative to a time period when the criterion did not exist (e.g., an external partnerships/collaboration criterion).
Ecoregion	An ecological region or ecoregion is defined as an area with relative homogeneity in ecosystems. Ecoregions depict areas within which the mosaic of ecosystem components (biotic and abiotic as well as terrestrial and aquatic) differs from those of adjacent regions (Omernik and Bailey 1997).
Element Occurrence	A term used by NatureServe and Natural Heritage Programs. An element occurrence delineates the location and extent of a species population or ecological community type, and represents the geo-referenced location of that biological feature.
Fine Filter	A focus of analyses in biodiversity conservation that is based upon conserving resource elements that occur at lower ecological levels, such as individual species or subpopulations. A fine-filter approach is often used in conjunction with a coarse-filter approach (i.e., a coarse-filter/fine-filter approach) because coarse filters would be unlikely to capture all habitat requirements for e.g., rare and vulnerable species.
Fire Regime	Description of the patterns of fire occurrences, frequency, size, severity, and sometimes vegetation and fire effects as well, in a given area or ecosystem. A fire regime is a generalization based on fire histories at individual sites. Fire regimes can often be described as cycles because some parts of the histories usually get repeated, and the repetitions can be counted and measured, such as fire return interval (NWCG 2006).
Focal Resource	A resource of high conservation interest consisting of types or categories of resources, such as species, ecological communities, or larger ecological assemblages.
Fragmentation	The process of dividing habitats into smaller and smaller units until their utility as habitat is lost (BLM 1997).
Geographic Information System (GIS)	A computer system designed to collect, manage, manipulate, analyze, and display spatially referenced data and associated attributes.

Table A-1 (continued). Glossary of terms used in this document and their definitions.

Term	Definition
Grain	Grain is the spatial unit of analysis for assessment and is the smallest area analyzed and used for planning purposes. The many data and model outputs incorporated into an analysis are usually upscaled or downscaled to grain scale. The grain for analysis may be a regular size and shape (e.g., square, hexagon) but also may be defined by a particular level of hydrologic unit or similar geographic feature.
Grid Cell	When used in reference to raster data, a grid cell is equivalent to a pixel (also see *pixel*). When a raster data layer is converted to a vector format, the pixels may instead be referred to as grid cells.
Habitat	A place where an animal or plant normally lives for a substantial part of its life, often characterized by dominant plant forms and/or physical characteristics.
Hydrologic Unit	An identified area of surface drainage within the U.S. system for cataloging drainage areas, which was developed in the mid-1970s under the sponsorship of the Water Resources Council and includes drainage-basin boundaries, codes, and names. The drainage areas are delineated to nest in a multilevel, hierarchical arrangement. The hydrologic unit hierarchical system has four levels and is the theoretical basis for further subdivisions that form the *watershed boundary dataset* 5th and 6th levels.
Indicator	A characteristic or combination of characteristics of a resource (e.g., presence or absence, quantity, distribution) that can be measured directly to provide critical information on the condition of that resource; or an alternative condition (e.g., land development) that may be measured to provide indirect information on a component of a resource when direct measurement is too difficult, inconvenient, or expensive.
Inductive models	Geo-referenced observations (e.g., known observations of a given species) are combined with maps of potential explanatory variables (climate, elevation, landform, soil variables, etc.). Statistical relationships between dependent variables (observations) and independent explanatory variables are used to inductively derive a new spatial model.
Invasive Species	Species that are not part of (if exotic non-natives), or are a minor component of (if native), an original community that have the potential to become a dominant or co-dominant species if their future establishment and growth are not actively controlled by management interventions, or that are classified as exotic or noxious under state or federal law. Species that become dominant for only one to several years (e.g., short-term response to drought or wildfire) are not termed “invasive”
Key Ecological Attribute	An attribute, feature, or process that determines or constrains the occurrence of a focal resource; in conjunction with other key ecological attributes, the condition or function of this attribute or process is considered critical to the integrity of the focal resource in question.
Land Health	Degree to which the integrity of the soil and the ecological processes of ecosystems are sustained (BLM Handbook H-4180-1).

Table A-1 (continued). Glossary of terms used in this document and their definitions.

Term	Definition
Landscape Species	Biological species that use large, ecologically diverse areas and often have significant impacts on the structure and function of natural ecosystems.
Land-Use Plan (LUP)	A set of decisions that establishes management direction for land within an administrative area, as prescribed under the planning provisions of FLPMA; an assimilation of land-use-plan-level decisions developed through the planning process outlined in 43 CFR 1600, regardless of the scale at which the decisions were developed. The term includes both resource management plans and management framework plans (BLM 2007).
Management Questions	Questions from decision-makers that usually identify problems and request how to fix or solve those problems.
Metadata	The description and documentation of the content, quality, condition, and other characteristics of geospatial data.
Model	Any representation, whether verbal, diagrammatic, or mathematical, of an object or phenomenon. Natural resource models typically characterize resource systems in terms of their status and change through time. Models imbed hypotheses about resource structures and functions, and they generate predictions about the effects of management actions.
Native Plant and Animal Populations and Communities	Populations and communities of all species of plants and animals naturally occurring, other than as a result of an introduction, either presently or historically in an ecosystem.
Native Species	Species that historically occurred or currently occur in a particular ecosystem and were not introduced.
Natural Community	An assemblage of organisms indigenous to an area that is characterized by distinct combinations of species occupying a common ecological zone and interacting with one another.
Natural Heritage Program	An agency or organization, usually based within a state or provincial natural resource agency, whose mission is to collect, document, and analyze data on the location and condition of biological and other natural features (such as geologic or aquatic features) of the state or province. These programs typically have particular responsibility for documenting at-risk species and threatened ecosystems. (See natureserve.org/ for additional information on these programs.)
Pixel	A pixel is a cell or spatial unit comprising a raster data layer; within a single raster data layer, the pixels are consistently sized; a common pixel size is 30 x 30 meters square. Pixels are usually referenced in relation to spatial data that are in raster format. In this REA, some pixels sizes included 90 x 90 m, 4 x 4 km, and 15 x 15 km (also see *Grid Cell*).
Population	Individuals of the same species that live, interact, and migrate through the same niche and habitat.
Range Mapping (as in *Species Range*)	A spatially coarse depiction; the generalized area of possible occurrence of a species or ecosystem, such as one might find in a wildlife field guide.

Table A-1 (continued). Glossary of terms used in this document and their definitions.

Term	Definition
Rapid Ecoregional Assessment (REA)	The methodology used by the BLM to assemble and synthesize that regional-scale resource information, which provides the fundamental knowledge base for devising regional resource goals, priorities, and focal areas, on a relatively short time frame (e.g., 2 years).
Regionally-Significant Resource	A native plant, wildlife, or fish resource or other ecosystem resource or service that has more than locally significant qualities, which give it special worth, consequence, meaning, distinctiveness, or cause for concern, especially compared to other similar resources. Generally, regionally-significant resources within a specific ecoregion occur in two or more field offices.
Resource Value	An ecological value, as opposed to a cultural value. Examples of resource values are those species, habitats, communities, features, functions, or services associated with areas with abundant native species and few non-natives, having intact, connected habitats, and that help maintain landscape hydrologic function.
Scale	Refers to the characteristic time or length of a process, observation, model, or analysis. *Intrinsic scale* refers to the scale at which a pattern or process actually operates. Because nature phenomena range over at least nine orders of magnitude, the intrinsic scale has wide variation. This is significant for ecoregional assessment, where multiple resources and their phenomena are being assessed. *Observation scale*, often referred to as sampling or measurement scale, is the scale at which sampling is undertaken. Note that once data are observed at a particular scale, that scale becomes the limit of analysis, not the phenomenon scale. *Analysis* or *modeling scale* refers to the resolution and extent in space and time of statistical analyses or simulation modeling. *Policy scale* is the scale at which policies are implemented and is influenced by social, political, and economic policies.
Scaling	The transfer of information across spatial scales. *Upscaling* is the process of transferring information from a smaller to a larger scale. *Downscaling* is the process of transferring information to a smaller scale.
Special Status Species (SSS)	Plant and animal species that are federally listed as threatened or endangered; proposed threatened or endangered; candidate species; state listed as threatened or endangered or listed by a resource manager (e.g., a BLM state director) as sensitive (BLM 2001b).
Stressor	A factor causing negative impacts to the biological health or ecological integrity of a focal resource. Factors causing such impacts may or may not have anthropogenic origins.
Subwatershed	A subdivision of a *watershed*. A *subwatershed* is the 6th-level, 12-digit unit and smallest of the hydrologic unit hierarchy. Subwatersheds generally range in size from 10,000 to 40,000 acres. (USGS 2009).
Watershed	A watershed is the 5th-level, 10-digit unit of the hydrologic unit hierarchy. Watersheds range in size from 40,000 to 250,000 acres. Also used as a generic term representing a drainage basin or combination of hydrologic units of any size (USGS 2009).

Table A-1 (continued). Glossary of terms used in this document and their definitions.

Term	Definition
Watershed Boundary Dataset (WBD)	A National geospatial database of drainage areas consisting of the 1st through 6th hierarchical hydrologic unit levels. The WBD is an ongoing multiagency effort to create hierarchical, and integrated hydrologic units across the Nation (USGS 2009).
Wildland Fire	Any non-structure fire that occurs in the wildland. Three distinct types of wildland fire have been defined and include wildfire, wildland fire use, and prescribed fire (NWCG 2006).

Measurement Unit Conversions

1.000 inches (in) = 2.54 centimeters (cm)

1 centimeter (cm) = 0.3937 inches (in)

1.000 foot (ft) = 0.3048 meters (m) = 0.0003048 kilometers (km)

1.000 meter (m) = 3.2808 feet (ft)

1.000 mile (mi) = 1.609 kilometers (km)

1.000 kilometer (km) = 0.62137 miles (mi)

1.000 acre (ac) = 0.40469 hectares (ha) = 0.0040469 square kilometers (km2)

1.000 square mile (mi2) = 640 acres (ac) = 259 hectares (ha) = 2.59 square kilometers (km2)

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Introduction to Conceptual Models

The conceptual models presented in this Appendix combine text, causal diagrams, and tabular summaries for each focal resource used to characterize its ecological composition, structure, processes, and interactions with major change agents within the ecoregion. These conceptual models in turn are used to identify indicators of the relative ecological status of each resource at one or more spatial scales. The Appendix discusses Terrestrial and Aquatic Focal Resources separately; the latter includes wetland and aquatic ecological system types.

All Tables and Figures are numbered sequentially within the section for each resource, not sequentially through the entire Appendix.

Terrestrial Coarse-Filter Focal Resource Conceptual Models

The conceptual models for terrestrial ecological systems build upon the descriptions of terrestrial ecological system types that NatureServe has been developing since 2003, when the ecological systems classification was first developed (see http://www.natureserve.org/explorer/index.htm to search and download existing descriptions). The versions presented here include additional material for each coarse-filter resource, describing natural and altered vegetation dynamics, as well as threats and stressors to the system. The information presented covers the full geographic range of distribution of each resource type, which can extend beyond the ecological sub-region immediately including and surrounding Great Basin National Park, and does not specifically focus on characteristics or dynamics of each resource that are unique to this immediate sub-region.

The resource descriptions include many names of plant species that are characteristic of each ecological system type. Vascular plant species nomenclature follows the nationally standardized list of Kartesz (1999), with very few exceptions. Nomenclature for nonvascular plants follows Anderson

(1990) and Anderson et al. (1990) for mosses, Egan (1987, 1989, 1990, and 1991) and Esslinger and Egan (1995) for lichens, and Stotler and Crandall-Stotler (1977) for liverworts/hornworts.

The conceptual model for each resource type begins by characterizing the resource and its place within a broader conceptual model and classification of terrestrial ecological system types for the ecoregion. Table B-1 presents this broader ecoregional model. Each resource is placed within one of the "Level 1" components of the ecoregional model, and within one of the "Level 2" categories that further characterize each Level-1 component.

Table B-1. Ecoregional conceptual model, terrestrial coarse-filter conservation elements, Central Basin and Range ecoregion.

Level 1	Level 2	Coarse-filter Element Name
Montane Dry Land System	Alpine Uplands	Rocky Mountain Alpine Turf
	Montane Canyons	Inter-Mountain Basins Cliff and Canyon
	Montane Shrublands	Great Basin Semi-Desert Chaparral
	Montane Shrublands	Inter-Mountain Basins Montane Sagebrush Steppe
	Montane Shrublands	Inter-Mountain Basins Curl-leaf Mountain-mahogany Woodland and Shrubland
	Subalpine/Montane Forests & Woodlands	Great Basin Pinyon-Juniper Woodland
	Subalpine/Montane Forests & Woodlands	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland
	Subalpine/Montane Forests & Woodlands	Inter-Mountain Basins Subalpine Limber-Bristlecone Pine Woodland
	Subalpine/Montane Forests & Woodlands	Rocky Mountain Aspen Forest and Woodland
Basin Dry Land System	Desert Scrub	Inter-Mountain Basins Mixed Salt Desert Scrub
	Desert Scrub	Mojave Mid-Elevation Mixed Desert Scrub
	Dunes	Inter-Mountain Basins Active and Stabilized Dune
	Semi-desert Shrub & Steppe	Colorado Plateau Mixed Low Sagebrush Shrubland
	Semi-desert Shrub & Steppe	Great Basin Xeric Mixed Sagebrush Shrubland
	Semi-desert Shrub & Steppe	Inter-Mountain Basins Big Sagebrush Shrubland*
	Semi-desert Shrub & Steppe	Inter-Mountain Basins Big Sagebrush Steppe
	Semi-desert Shrub & Steppe	Inter-Mountain Basins Semi-Desert Grassland
	Semi-desert Shrub & Steppe	Inter-Mountain Basins Semi-Desert Shrub-Steppe

* Indicates types addressed for this GRBA assessment (also shown in bold font)

The identification of each coarse-filter resource further clarifies relevant taxonomic relationships using the standard NatureServe element code for each ecological system type (e.g., "(resourceS304.773)"), and LANDFIRE Biophysical Settings codes where appropriate.

Each conceptual model presentation includes sections on "Focal Resource Characterization," "Change Agent Effects," "Ecological Integrity Criteria and Indicators," and "References."

The section on "Focal Resource Characterization" includes a narrative of the resource distribution, biophysical setting, and floristic composition. For terrestrial ecological systems, the description also provides a direct crosswalk between the resource concept and Ecological Site Descriptions (ESDs) applicable to the ecoregion. Crosswalks are provided only for ESDs approved for the USDA Natural Resources Conservation Service (NRCS) Multiple Resource Land Area (MLRA) that overlap the CBR ecoregion. The NRCS Site ID in the crosswalk table identifies each type as determined by NRCS. This list is not a complete crosswalk, as some MLRAs do not have approved ESDs. Additionally, the user should consider that ESDs are based on landform/soil concepts. Consequently, the match between these concepts and ecological system concepts – which integrate information on both biophysical conditions and natural floristic composition – will be imperfect and may vary from type to type. The section on "Focal Resource Characterization" also includes a narrative description of vegetation dynamics, both natural and altered, with supporting literature cited. Again, this information is developed across the range-wide distribution of the ecological system type.

The section on "Change Agent Effects" characterizes the primary change agents and current knowledge of their effects on this resource. Some CAs have specific effects on each resource such as the alteration of expected fire regimes and the interacting effects of introduced weed infestations. This section provides a narrative on the effects of CAs on the individual resource, in an "altered dynamics" sub-section. Wildfire and invasive plant CAs are described and modeled within the context of their effects on coarse filter resources.

The impacts of wildfire and invasive plants are modeled through the use of the Vegetation Dynamics Development Tool (VDDT). The simulations were run in the Path Landscape Model (ESSA Technologies). The models are modified for this assessment from ones developed by the Nevada chapter of The Nature Conservancy. VDDT is a state-and-transition modeling platform that simulates vegetation dynamics based on user-defined states and transitions. States (boxes) represent a vegetation community defined by a cover type and structural stage. Transitions link states through processes such as succession, disturbance, and management, and can be either deterministic or probabilistic. Deterministic transitions usually simulate successional changes by defining the number of years until a transition occurs from one successional stage to the next, in the absence of disturbance. Probabilistic transitions specify an annual transition probability of moving from one state to another. Probabilistic transitions represent disturbances (e.g., fire and drought), ecological processes (e.g. tree encroachment and natural recovery), and land management activities (e.g., seeding and prescribed fire).

Each VDDT simulation partitions the landscape into a number of cells or simulation units, allocated among state classes in the model. At each time step, deterministic transitions occur based on the age

of the cell and probabilistic transitions may occur based on the specified transition probability. VDDT is a nonspatial model, and all cells are simulated independently of other cells. The Path model uses VDDT as a simulation engine but allows users to organize model runs, run many models simultaneously, and view output across all model runs simultaneously. Each coarse-filter resource was described using two VDDT models – one describing the natural range of variation (NRV) under historic conditions, and one describing contemporary dynamics and including uncharacteristic states such as annual grass or depleted shrub. The contemporary model includes all states and transitions from the NRV model in addition to a set of uncharacteristic states and transitions.

The section on "Ecological Integrity Criteria and Indicators" describes the methods and data used to assess ecological status, following NatureServe's ecological integrity framework (Faber-Langendoen et al. 2006, Unnasch et al. 2018). Implementation of this framework results in a scorecard for reporting on the ecological status of a given resource within a given location, and facilitates the aggregation and synthesis of the component results for broader measures of ecological integrity at landscape and ecoregional scales. Using this framework, indicators are chosen to provide a measurement for a limited set of key ecological attributes, or ecological drivers for each resource. Key ecological attributes may include natural characteristics, such as native species composition, or stressors such as effects of relevant change agents, that are well known to affect the natural function and integrity of the resource.

Conceptual or "causal" diagrams are a crucial component of the presentation of the conceptual model of Change Agent effects and the ecological status criteria and indicators. Each diagram consists of three sub-figures, conceptualizing the relationships between Change Agents, the stresses they induce in the resource, the response of the resource to those stressors, and indicators with which to measure either the stress or the resource response with indicators. The diagrams do not show all possible Change Agents, stresses, responses, or indicators – only those relevant to the present assessment.

In part because of project constraints, indicators identified for this assessment emphasize ecosystem stressors that can be more readily measured using available remotely sensed data. Spatial models that reflect these indicators serve as the link between the conceptual models and the spatial representation of ecological status. For each resource, the text provides the definitions and justifications for each of the indicators for that resource, organized in an Ecological Status Scorecard table. Each indicator is scored according to criteria described in the table and is calculated between 0 and 1, with 1 indicating highest ecological status and 0 indicating lowest status (and presumably transitional to a wholly different ecological state).

The section on "References" for each resource lists literature pertaining to the classification, distribution, floristic composition, ecological processes, threats, stressors, or management of the resource, in some cases from portions of its range outside of the ecoregion. These are not exhaustive bibliographies. Some documents may be listed that are not cited in the narrative text.

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Inter-Mountain Basins Big Sagebrush Shrubland

Code for Type: resourceS304.777)

Model Group: Basin Dry Land System > Semi-desert Shrub & Steppe

Biophysical Setting: 1080

Focal Resource Characterization

Summary

This ecological system occurs throughout much of the western U.S., typically in broad basins between mountain ranges, plains and foothills between 1500 and 2500 m elevation. Distribution within ecoregion is shown in Appendix D. Adjacent ecological systems include Great Basin Pinyon-

Juniper Woodland (resourceS304.773) and Great Basin Xeric Mixed Sagebrush Shrubland (resourceS304.774) above and at lower elevations Inter-Mountain Basins Mixed Salt Desert Scrub (resourceS304.784) and Inter-Mountain Basins Greasewood Flat (resourceS304.780). The climate where this system occurs is semi-arid with annual precipitation ranging from 18-40 cm and high inter-annual variation. Much of the precipitation falls as snow, and growing-season drought is characteristic. Temperatures are continental with large annual and diurnal variation. In drier regions, these shrublands are usually associated with perennial or ephemeral stream drainages with water tables less than 3 m from the soil surface. Sites supporting this system include sloping fans, footslopes, rolling hills, swales, draws, and deep, well-drained alluvial bottomlands. Substrates are typically deep, well-drained and non-saline, fine- to medium-textured alluvial soils with some source of sub-irrigation during the summer season, but moderately deep upland soils with ample moisture storage also support these shrublands (Table B-2). Some stands occur on deep, sandy soils, or soils that are highly calcareous (Hironaka et al. 1983). Although this system may grade into sites with alkaline soils at the edge of internally drained basins, *Artemisia tridentata* is a non-halophyte and requires low salinity for optimum growth. The importance of perennial bunch grasses, the most typical herbaceous associates, is favored with greater spring and summer rain, which increases northward and eastward. The environmental description is based on several references, including Brown (1982), West (1983a), Barbour and Billings (1988), Knight (1994), Shiflet (1994), Holland and Keil (1995), Reid et al. (1999), West and Young (2000), Barbour et al. (2007), Sawyer et al. (2009), and NatureServe Explorer (2011).

Table B-2. Inter-Mountain Basins Big Sagebrush Shrubland ecological system crosswalk with approved Ecological Site Descriptions

MLRA	Ecological Site Description Name	Site ID
024-Humboldt Area	Arid Fan 8-10 PZ / *Artemisia tridentata ssp. wyomingensis/Achnatherum hymenoides-Achnatherum thurberianum*	R024XY653OR
024-Humboldt Area	Clayey Playette / *Artemisia tridentata ssp. wyomingensis/Elymus elymoides-Poa secunda*	R024XY008OR
024-Humboldt Area	Loamy 8-10 PZ / *Artemisia tridentata ssp. wyomingensis/Achnatherum thurberianum-Achnatherum hymenoides*	R024XY016OR
024-Humboldt Area	Low Clayey Terrace 8-10 PZ / *Artemisia tridentata ssp. wyomingensis/Pseudoroegneria spicata ssp. spicata-Poa secunda*	R024XY123OR

Table B-2 (continued). Inter-Mountain Basins Big Sagebrush Shrubland ecological system crosswalk with approved Ecological Site Descriptions

MLRA	Ecological Site Description Name	Site ID
024-Humboldt Area	North Slopes 6-10 PZ / *Artemisia tridentata ssp. wyomingensis/Pseudoroegneria spicata ssp. spicata-Achnatherum thurberianum*	R024XY033OR
024-Humboldt Area	Shallow Loam 8-10 PZ / *Artemisia tridentata ssp. wyomingensis/Achnatherum thurberianum-Achnatherum hymenoides*	R024XY017OR
025-Owyhee High Plateau	Upland Loam (Basin Big Sagebrush) / *Artemisia tridentata*	R025XY310UT
025-Owyhee High Plateau	Upland Loam (Wyoming Big Sagebrush) / *Artemisia tridentata ssp. wyomingensis*	R025XY314UT
025-Owyhee High Plateau	Upland Shallow Gravelly Loam (Thurber Fescue) / *Artemisia tridentata ssp. wyomingensis*	R025XY315UT
028A-Great Salt Lake Area	Semidesert Bouldery Loam (Wyoming Big Sagebrush) / *Artemisia tridentata ssp. wyomingensis*	R028AY208UT
028A-Great Salt Lake Area	Semidesert Gravelly Loam (Wyoming Big Sagebrush) North / *Artemisia tridentata ssp. wyomingensis*	R028AY215UT
028A-Great Salt Lake Area	Semidesert Gravelly Loam (Wyoming Big Sagebrush) South / *Artemisia tridentata ssp. wyomingensis*	R028AY214UT
028A-Great Salt Lake Area	Semidesert Loam (Basin Big Sagebrush) / *Artemisia tridentata ssp. tridentata*	R028AY221UT
028A-Great Salt Lake Area	Semidesert Loam (Wyoming Big Sagebrush) / *Artemisia tridentata ssp. wyomingensis*	R028AY220UT
028A-Great Salt Lake Area	Semidesert Sandy Loam (Wyoming Big Sagebrush) / *Artemisia tridentata ssp. wyomingensis*	R028AY226UT
028A-Great Salt Lake Area	Semidesert Shallow Loam (Wyoming Big Sagebrush) / *Artemisia tridentata ssp. wyomingensis*	R028AY243UT
028A-Great Salt Lake Area	Upland Gravelly Loam (Bonneville Big Sagebrush) / *Artemisia tridentata ssp. wyomingensis-Purshia tridentata-Pseudoroegneria spicata*	R028AY306UT
028A-Great Salt Lake Area	Upland Gravelly Loam (Wyoming Big Sagebrush) / *Artemisia tridentata ssp. wyomingensis-Purshia tridentata/Pseudoroegneria spicata-Elymus trachycaulus*	R028AY307UT
047-Wasatch and Uinta Mountains	Upland Loam (Basin Big Sagebrush)	R047XA308UT
047-Wasatch and Uinta Mountains	Upland Loam (Basin Big Sagebrush) / *Artemisia tridentata ssp. tridentata/Pseudoroegneria spicata*	R047XA308UT
047-Wasatch and Uinta Mountains	Upland Stony Loam (Wyoming Big Sagebrush) / *Artemisia tridentata ssp. wyomingensis/Pseudoroegneria spicata*	R047XA338UT

These shrublands are dominated by *Artemisia tridentata ssp. tridentata* (not as common in Wyoming or Montana but possibly on the stabilized part of Killpecker Dunes in Wyoming) and/or *Artemisia tridentata ssp. wyomingensis* (predominant in Wyoming and Montana). Scattered *Juniperus* spp., *Sarcobatus vermiculatus*, and *Atriplex* spp. may be present in some stands. *Ericameria nauseosa, Chrysothamnus viscidiflorus, Purshia tridentata* (not commonly in Montana or Wyoming), or *Symphoricarpos oreophilus* may codominate disturbed stands (e.g., in burned stands, these may become more predominant). Perennial herbaceous components typically contribute less than 25% vegetative cover. Common graminoid species can include *Achnatherum hymenoides, Bouteloua gracilis, Elymus lanceolatus, Festuca idahoensis* (not in Montana or Wyoming), *Hesperostipa comata, Leymus cinereus, Pleuraphis jamesii* (not present in northeastern portions of the range), *Pascopyrum smithii, Poa secunda*, or *Pseudoroegneria spicata* (not in Wyoming). Some semi-natural communities are included that often originate on abandoned agricultural land or on other disturbed sites. In these locations, *Bromus tectorum* or other annual bromes and invasive weeds can be abundant. Most *Artemisia tridentata ssp. wyomingensis* communities in Wyoming are placed in Inter-Mountain Basins Big Sagebrush Steppe (resourceS304.778); the shrubland system is more restricted in environmental setting than the steppe. Dunes in the Red Desert have areas of large basin big sagebrush with very dense canopies. In Wyoming, this system is likely to only contain *Artemisia tridentata ssp. tridentata*. The vegetation description is based on several references, including Brown (1982), West (1983a), Barbour and Billings (1988), Knight (1994), Shiflet (1994), Holland and Keil (1995), Reid et al. (1999), West and Young (2000), Barbour et al. (2007), Sawyer et al. (2009), and NatureServe Explorer (2011).

Species of Conservation or Management Concern

The Central Basin and Range Rapid Ecoregional Assessment (Comer et al. 2013) developed and applied criteria to identify species to be targeted for focused assessment. These species are of conservation or management concern due primarily to their relative vulnerability to extinction. These vulnerabilities stem from their sensitivity to past or current land/water uses, natural rarity, or forecasted vulnerabilities to climate change effects.

Listed below are species of conservation or management concern that are very strongly associated with this ecosystem type. This close connection facilitates our analysis in that the ecosystem type provides a practical "coarse filter" for analysis, and documentation of ecological status for locations of this ecosystem type should provide a reliable indication of the ecological status for each of these species. Therefore, these species of conservation or management concern were not assessed and reported on individually.

Birds: Gray Flycatcher (*Empidonax wrightii*), Green-tailed Towhee (*Pipilo chlorurus*), White-crowned Sparrow (*Zonotrichia leucophrys*)

Flowering Plants: Margaret's Rushy Milkvetch (*Astragalus convallarius var. margaretiae*) [NatureServe ranked G5T2 – Globally secure as a species, Imperiled at the level of variety]

Natural Dynamics

Complex ecological interactions of fire regimes, grazing history, and climate patterns result in equally complex patterns of species structure and composition in *Artemisia tridentata* stands. Prolonged drought on the more xeric sites may reduce shrub cover. Flooding may also cause mortality if the soil remains saturated for an extended period of time. The Aroga moth is capable of defoliating large acreages (i.e., > 10 ha., but usually 4-40 ha. Heavy grazing by wildlife can remove the fine fuels that support mixed-severity fires and result in woody fuel buildup that leads to severe, stand-replacement fires (LandFire BpS 1210800).

Big sagebrush stands are inhibited by fire as *Artemisia tridentata* does not sprout after burning (Tirmenstein 1999c). Excessive grazing may decrease fire frequency due to consumption of herbaceous forage (fine fuels) resulting in increased shrub density. Conversely, increasing fire frequency significantly will eliminate the shrubs from the stands (Daubenmire 1970, Tirmenstein 1999c). With a change in fire frequency, species composition will be altered as well (West 1983a). With a high fire frequency (every 2-5 years), perennial grasses and shrubs are eliminated and non-native annual grasses dominate. At fire-return intervals of 10-30 years, short-lived resprouting shrubs such as *Chrysothamnus* or *Tetradymia* spp. dominate. At fire-return intervals of 30-70 years, a mixture of perennial bunch grasses and non-sprouting shrubs is maintained (Johnson 2000b). Finally, in the complete absence of fire, deep-rooted shrubs such as *Artemisia tridentata* become dominant. At higher-elevation sites with absence of fire (gt; 100 years), *Pinus monophylla* and *Juniperus osteosperma* trees may invade and eventually dominate sites (Tirmenstein 1999c).

Insects are an important component of many shrub-steppe and grassland systems. Mormon crickets and grasshoppers are natural components of many rangeland systems (USDA-APHIS 2003, 2010). There are almost 400 species of grasshoppers that inhabit the western United States with 15-45 species occurring in a given rangeland system (USDA-APHIS 2003). Mormon crickets are also present in many western rangelands and, although flightless, are highly mobile and can migrate large distances consuming much of the forage while travelling in wide bands (USDA-APHIS 2010). Following a high population year for grasshoppers or Mormon crickets and under relatively warm dry spring environmental conditions that favor egg hatching and grasshopper and Mormon cricket survival, there may be large population outbreaks that can utilize 80% or more of the forage in areas as large as 2,000 mi^2. Conversely, relatively cool and wet spring weather can limit the potential for outbreaks. These outbreaks are naturally occurring cycles and, especially during drought, can denude an area of vegetation leaving it exposed to increased erosion rates from wind and water (USDA-APHIS 2003).

Model Description

For each coarse-filter resource, a state-and-transition model was developed using the Vegetation Dynamics Development Tool (VDDT) and simulations were run in the Path Landscape Model (ESSA Technologies). Models were developed by the Nevada chapter of The Nature Conservancy. VDDT is a state-and-transition modeling platform that simulates vegetation dynamics based on user-defined states and transitions. States (boxes) represent a vegetation community defined by a cover type and structural stage (Figure B-1). Transitions link states through processes such as succession,

disturbance, and management, and can be either deterministic or probabilistic. Deterministic transitions usually simulate successional changes by defining the number of years until a transition occurs from one successional stage to the next, in the absence of disturbance. Probabilistic transitions specify an annual transition probability of moving from one state to another. Probabilistic transitions represent disturbances (e.g. fire and drought), ecological processes (e.g. tree encroachment and natural recovery), and land management activities (e.g. seeding and prescribed fire).

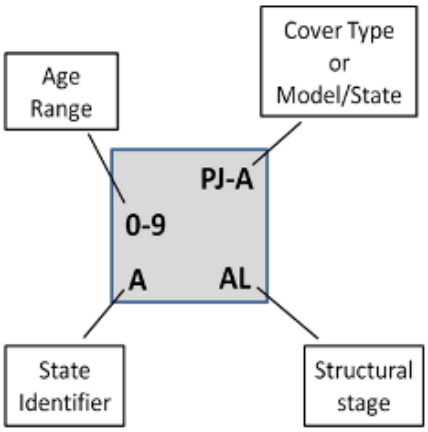

Figure B-1. State classes in VDDT describe a plant community type by defining the cover type, age range, structural stage and identifier of each of its vegetative state classes.

For each simulation, the landscape is partitioned into a number of cells or simulation units and allocated among state classes in the model. At each time step, deterministic transitions occur based on the age of the cell and probabilistic transitions may occur based on the specified transition probability. VDDT is a nonspatial model, and all cells are simulated independently of other cells. The Path model uses VDDT as a simulation engine but allows users to organize model runs, run many models simultaneously, and view output across all model runs simultaneously. Each coarse-filter resource was described using two VDDT models – one describing the natural range of variation (NRV) under historic conditions, and one describing contemporary dynamics and including uncharacteristic states such as annual grass or depleted shrub. The contemporary model includes all states and transitions from the NRV model in addition to a set of uncharacteristic states and transitions.

The historic (NRV) model contains state classes that characterize natural vegetation conditions and transitions that describe vegetation dynamics (Figure B-2).

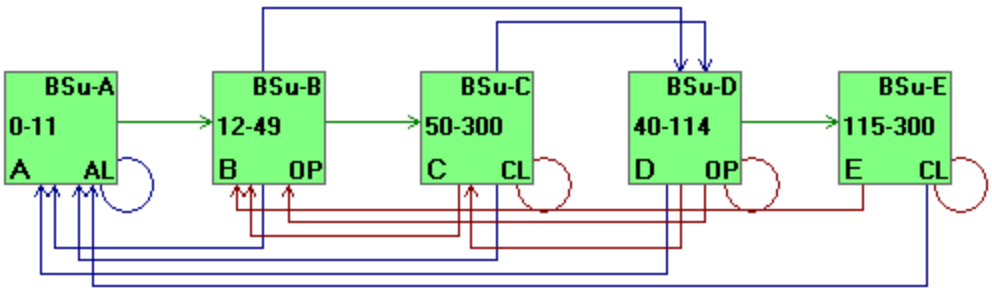

Figure B-2 (Upland). VDDT model for historic (NRV) conditions of the Upland variant of Inter-Mountain Basins Big Sagebrush Shrubland. Green arrows show deterministic succession and other arrows represent all other probabilistic transitions.

The historic (NRV) VDDT model for the Upland variant of Inter-Mountain Basins Big Sagebrush Shrubland contains the following state classes (Table B-3):

- *Class A (Early):* 10-80% grass/forb cover; 0-10% cover of big sagebrush (mountain and Wyoming)/mountain brush. Age range is 0-11 years.
- *Class B (Mid-Open):* 11-30% cover of big sagebrush (mountain and Wyoming)/mountain shrub; >50% herbaceous cover. Age range is 12-49 years.
- *Class C (Mid-Closed):* 31-50% cover of big sagebrush (mountain and Wyoming)/mountain brush; 25-50% herbaceous cover, <10% conifer sapling cover. Age range is 50-300 years.
- *Class D (Late-Open):* 10-30% cover conifer <5m for PJ and <10m for mixed conifers. Age range is 40-114 years.
- *Class E (Late-Closed):* 31-80% conifer cover (lower for PJ, greater for mixed conifers) 10-25m; 6-20% shrub cover; <20% herbaceous cover. Age range is 115-300 years.

Table B-3 (Upland). Transition probabilities and return intervals for the Inter-Mountain Basins Big Sagebrush Shrubland ecological system (Upland variant) under NRV. These probabilities are used in the VDDT model to estimate the relative abundance of each class over time.

From Class	To Class	Transition Type	Probability	Return Interval (years)
C	B	Drought	0.00060	1,667
C	C	Drought	0.00500	198
D	B	Drought	0.00170	585
D	C	Drought	0.00340	292
D	D	Drought	0.00060	1,667
E	B	Drought	0.00060	1,667
E	E	Drought	0.00500	198
A	A	Replacement Fire	0.01250	80

Table B-3 (Upland) (continued). Transition probabilities and return intervals for the Inter-Mountain Basins Big Sagebrush Shrubland ecological system (Upland variant) under NRV. These probabilities are used in the VDDT model to estimate the relative abundance of each class over time.

From Class	To Class	Transition Type	Probability	Return Interval (years)
B	A	Replacement Fire	0.02500	40
C	A	Replacement Fire	0.02000	50
D	A	Replacement Fire	0.02000	50
E	A	Replacement Fire	0.01300	77
B	D	Tree Invasion	0.01000	100
C	D	Tree Invasion	0.01000	100

Change Agent Effects

Altered Dynamics

The primary land uses that alter the natural processes of this system are associated with livestock practices, annual exotic species, fire regime alteration, direct soil surface disturbance, and fragmentation. Excessive grazing stresses the system through soil disturbance, diminishing or eliminating the biological soil crust, altering the composition of perennial species, and increasing the establishment of native disturbance-increasers and annual grasses, particularly *Bromus tectorum* and other exotic annual bromes. If soil moisture is present and sagebrush seeds are available, grazing can result in increased shrub density. There are strong links between foliose lichens and ecosystem health. Severe trampling breaks lichens into fragments too small to re-establish and eventually leads to foliose lichen elimination (Rosentreter and Eldridge 2002).

Fire further stresses livestock-altered vegetation by increasing exposure of bare ground and consequently increases exotic annuals and decreases perennial bunchgrass and sagebrush abundance. Fire suppression, even in the absence of livestock grazing impacts, can increase shrub density that in turn reduces bunchgrass cover or results in increased grass litter and fire fuel. Both conditions increase the probability of fire and vegetation responses that increase annual grass abundance following fire (Davies et al. 2009). Any soil and bunchgrass layer disturbances, such as vehicle tracks or chaining shrubs, will increase the probability of alteration of vegetation structure and composition, and response to fire as discussed above. Loss of shrub density and degradation of the bunchgrass layer's native diversity decreases obligate shrub-steppe birds (Vander Haegen et al. 2000). Fragmentation of shrub-steppe by agriculture increases cover of annual grasses, total annual/biennial forbs, and bare ground, and decreases cover of perennial forbs and biological soil crusts, and reduces obligate insects (Quinn 2004) and obligate birds and small mammals (Vander Haegen et al. 2001).

Fine fuel adjacency from alien annual grasses, such as Bromus madritensis, Bromus tectorum, and Schismus spp., currently represents the most important fuelbed component in the system, and can substantially increase the fire frequency. With a high fire frequency (every 2-5 years), perennial

grasses and shrubs are eliminated and non-native annual grasses dominate. At fire-return intervals of 10-30 years, short-lived resprouting shrubs such as Chrysothamnus or Tetradymia spp. dominate. This expansion of pinyon and juniper trees into Artemisia tridentata-dominated ecosystems has many effects on the ecology of the site, including reduction of understory cover and species, increased fuel load as trees grow and expand, resulting eventually in large, high-severity fires with high tree and shrub mortality (Miller et al. 2011). These severely burned areas are highly susceptible to invasion by annual grasses, often resulting in conversion to Bromus tectorum-dominated stands (Chambers et al. 2007, Condon et al. 2011).

Domestic livestock grazing is a widespread disturbance factor in sagebrush systems and can affect ecosystem condition and trend (Veblen et al. 2011). Inappropriate livestock grazing, in terms of numbers of animals or season of use, can alter species composition, ecosystem function and structure (Dyksterhuis 1949, as cited by Veblen et al. 2011). An assessment was conducted by Veblen et al. (2011) to evaluate rangewide impacts of livestock grazing across the sagebrush biome. Most information on range condition is at the local scale and not consistently collected for regional or rangewide assessment; however, the study was able to compile and utilize available data. Using LHS data and sagebrush vegetation characteristics, the study compared LHS across a subset of allotments within the sagebrush biome. Results showed 798 allotments (70%) that met and 333 allotments that did not meet LHS. Livestock grazing was identified as the reason for unmet standards for 132 (approximately 15%) of the 333 allotments that did not meet standards. Therefore, across the sagebrush biome, a relatively small percentage of allotments are being significantly impacted by livestock grazing. The study was able to compile and utilize additional spatial data to test whether remotely-sensed vegetation characteristics could be used to predict which allotments met or did not meet LHS. Preliminary results suggest that method might be used to create an "at risk map" to help prioritize monitoring efforts. The study also made recommendations on future BLM grazing allotment monitoring and assessment work.

Conversion of *Artemisia tridentata* ecosystems to invasive, non-native annual grasses causes habitat degradation, fragmentation and loss for several species, including sage-grouse (*Centrocercus* spp.) which is now at risk for federal listing (Knick et al. 2003). Urgent action is needed to develop and execute management solutions to maintain and restore *Artemisia tridentata* communities (Knick et al. 2003). In 2004, the BLM released Bureau of Land Management National Sage Grouse Habitat Conservation Strategy, U.S. Department of the Interior to address these issues and "calls for managing public lands in a manner that will maintain, enhance and restore sage-grouse and sagebrush habitats while continuing to provide for multiple uses of lands under BLM stewardship" (BLM 2004).

When grasshopper and Mormon cricket populations reach outbreak levels, they cause significant economic losses for ranchers and livestock producers, especially when accompanied by a drought (USDA-APHIS 2003, 2010). Both rangeland forage and cultivated crops can be consumed by grasshoppers. The U.S. Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS) is the Federal agency responsible for controlling economic infestations of grasshoppers on western rangelands with a cooperative suppression program. They work with federal

land managing agencies to conduct grasshopper suppression. The goal of APHIS's grasshopper program is not to eradicate them but to reduce outbreak populations to less economically damaging levels (USDA-APHIS 2003). This APHIS effort dampens the natural ecological outbreak cycles of grasshoppers and Mormon crickets, but does not eradicate the species.

Altered Model Description

The VDDT model for current conditions (Figure B-3) contains all states and transitions in the historic (NRV) model (Figure B-2; Table B-2) and contains additional uncharacteristic states and transitions that represent contemporary vegetation dynamics.

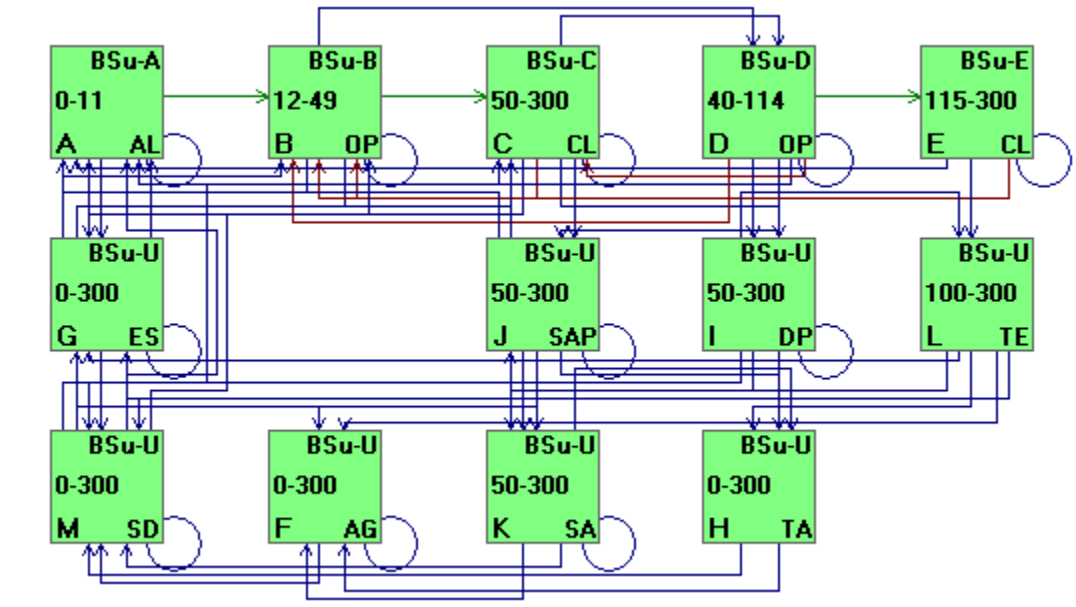

Figure B-3 (Upland). VDDT model for current conditions of the Upland variant of Inter-Mountain Basins Big Sagebrush Shrubland. Uncharacteristic state classes are denoted with a U in the top-right corner of the box. Green arrows show deterministic succession and other arrows represent all other probabilistic transitions.

The current conditions VDDT model for the Upland variant of Inter-Mountain Basins Big Sagebrush Shrubland contains all of the states found in the historic model (Figure 2) in addition to the following uncharacteristic state classes (Table B-3):

- *Class F (Annual Grass):* 10-30% cover of cheatgrass; <10% shrub cover. Age range is 0-300 years.
- *Class G (Early Shrub):* 20-50% cover rabbitbrush species. Age range is 0-300 years.
- *Class H (Tree-Annual Grass):* 31-80% conifer cover 10-25m; <5% shrub cover; <5% herbaceous cover, ≥5% cheatgrass cover. Age range is 0-300 years.
- *Class I (Depleted):* 20-50% cover of big sagebrush (mountain and Wyoming)/mountain brush; <5% herbaceous cover; <5% cheatgrass cover; <10% conifer sapling cover. Age range is 50-300 years.

- *Class J (Shrub-Annual Grass/Perennial Grass):* 21-50% cover of big sagebrush (mountain and Wyoming)/mountain brush; ≥5% cover of native grass; 5-10% cheatgrass cover; <10% conifer sapling cover. Age range is 50-300 years.
- *Class K (Shrub-Annual Grass):* 21-50% cover of big sagebrush (mountain and Wyoming)/mountain brush; <5% cover of native grass; 5-10% cheatgrass cover; <10% conifer sapling cover. Age range is 50-300 years.
- *Class L (Tree-Encroached):* 31-80% conifer cover 10-25m; <5% shrub cover; <5% herbaceous cover, <5% cheatgrass cover. Age range is 100-300 years.
- *Class M (Seeded):* >10% cover of seeded herbaceous and/or shrub species, either native, introduced, and mixed native and introduced; <5% cheatgrass cover. Age range is 0-300 years.

Table B-3. Upland transition probabilities and return intervals for the Inter-Mountain Basins Big Sagebrush Shrubland ecological system (Upland variant) under current conditions. These transition probabilities were used in the VDDT model illustrated in Figure 3 to calculate departure estimates.

From Class	To Class	Transition Type	Probability	Return Interval (years)
C	J	Annual Grass Invasion	0.00500	200
D	J	Annual Grass Invasion	0.00500	200
I	K	Annual Grass Invasion	0.00500	200
L	H	Annual Grass Invasion	0.00500	200
M	J	Annual Grass Invasion	0.00100	1,000
C	B	Drought	0.00060	1,667
C	C	Drought	0.00500	198
D	B	Drought	0.00170	588
D	C	Drought	0.00340	294
D	D	Drought	0.00060	1,667
E	B	Drought	0.00060	1,667
E	E	Drought	0.00500	200
I	G	Drought	0.00060	1,667
I	I	Drought	0.00500	198
J	A	Drought	0.00010	10,000
J	F	Drought	0.00050	2,000

Table B-3 (continued). Upland transition probabilities and return intervals for the Inter-Mountain Basins Big Sagebrush Shrubland ecological system (Upland variant) under current conditions. These transition probabilities were used in the VDDT model illustrated in Figure 3 to calculate departure estimates.

From Class	To Class	Transition Type	Probability	Return Interval (years)
J	J	Drought	0.00500	200
K	F	Drought	0.00060	1,667
K	K	Drought	0.00500	200
L	G	Drought	0.00280	357
L	K	Drought	0.00280	357
A	G	Excessive Herbivory	0.00100	1,000
B	G	Excessive Herbivory	0.00100	1,000
C	I	Excessive Herbivory	0.00100	1,000
D	D	Excessive Herbivory	0.00080	1,250
D	I	Excessive Herbivory	0.00030	3,333
J	K	Excessive Herbivory	0.00100	1,000
M	G	Excessive Herbivory	0.00100	1,000
A	A	Managed Herbivory	0.00050	2,000
B	B	Managed Herbivory	0.05000	20
C	C	Managed Herbivory	0.05000	20
D	D	Managed Herbivory	0.05000	20
E	E	Managed Herbivory	0.05000	20
J	J	Managed Herbivory	0.05000	20
J	K	Managed Herbivory	0.05000	20
M	M	Managed Herbivory	0.05000	20
G	B	Natural Recovery	0.00100	1,000
G	C	Natural Recovery	0.00100	1,000
J	C	Natural Recovery	0.00100	1,000

Table B-3 (continued). Upland transition probabilities and return intervals for the Inter-Mountain Basins Big Sagebrush Shrubland ecological system (Upland variant) under current conditions. These transition probabilities were used in the VDDT model illustrated in Figure 3 to calculate departure estimates.

From Class	To Class	Transition Type	Probability	Return Interval (years)
M	A	Natural Recovery	0.00100	1,000
M	B	Natural Recovery	0.01000	100
M	C	Natural Recovery	0.05000	20
A	A	Replacement Fire	0.01250	80
B	A	Replacement Fire	0.02500	40
C	A	Replacement Fire	0.02000	50
D	A	Replacement Fire	0.02000	50
E	A	Replacement Fire	0.01300	77
F	F	Replacement Fire	0.10000	10
G	A	Replacement Fire	0.00130	769
G	G	Replacement Fire	0.01200	84
H	F	Replacement Fire	0.01300	77
I	G	Replacement Fire	0.01330	75
J	A	Replacement Fire	0.01440	69
J	F	Replacement Fire	0.01440	69
K	F	Replacement Fire	0.02870	35
L	F	Replacement Fire	0.00380	263
L	G	Replacement Fire	0.00380	263
L	K	Replacement Fire	0.00080	1,250
M	M	Replacement Fire	0.00500	200
E	L	Tree Encroachment	0.02000	50
B	D	Tree Invasion	0.01000	100
C	D	Tree Invasion	0.01000	100
I	L	Tree Invasion	0.01000	100
J	H	Tree Invasion	0.01000	100
K	H	Tree Invasion	0.01000	100

Development Impacts

Human development has impacted many locations throughout the ecoregion. High- and low-density urban and industrial developments also have large impacts. For example, residential development has

significantly impacted locations within commuting distance to urban areas. Impacts may be direct as vegetation is removed for building sites or more indirectly through natural fire regime alteration, and/or the introduction of invasive species. Mining operations can drastically impact natural vegetation. Road building and power transmission lines continue to fragment vegetation and provide vectors for invasive species.

Major impacts of development and management actions were captured in the Landscape Condition Index (LCI) developed for this ecoregion (see below). The LCI uses spatial layers of transportation, urban and industrial development, and managed and modified land cover layers. This spatial model incorporates documented knowledge and expert judgment to reflect the relative impact of different land uses on ecological processes.

Conceptual Diagram

Terrestrial Course Filter Conservation Elements experience stress when faced with Change Agents. Some change agents directly remove the element, such as new rural or urban development including mines and landfills. Other change agents such as roads and transportation corridors (railroads, power lines, solar arrays, oil pumping platforms and the like) fragment its distribution (Debinski and Holt 2000). Irrigated agriculture, in addition to complete replacement of resource distribution, can have an effect of increased pollution through fertilizers or heavy metal-laden sedimentation runoff (Boody and DeVore 2006, Chipps et al. 2006, Pimentel et al. 2004). Water development projects have a double effect on aquatic resources, as they both change the amount and timing of flow, but also fragment the network of flow (Poff et al. 2010). Aquatic invasive species can have profound effect on the amount of oxygen available, can directly compete with native species, and have been shown to completely remove the native ecosystem habitat (e.g. tamarisk) (Brussard et al. 2000; USGS 2011). These stressors result in different levels of response depending on the degree of impact and how many stressors are acting on the same resource simultaneously. Responses include a reduction in species diversity and species genetic diversity with the fragmentation and loss of habitat (Vryanckx et al. 2011). Species can become less abundant as their habitats become fragmented or continually disturbed such that reproduction is less successful (Brussard et al. 2000). As native species become stressed, other more tolerant and opportunistic species may increase in abundance, further tipping the balance of food webs in aquatic systems and preditor/prey dynamics. Shifts in species abundance and presence results in a change in species composition changing the vegetative community of stream banks or the riverine aquatic community. Lastly the indicator metrics we have chosen allows us to measure the amount of stress or response within each resource. See the Ecological Status Scorecard section for full explanation of each indicator (Figure B-4).

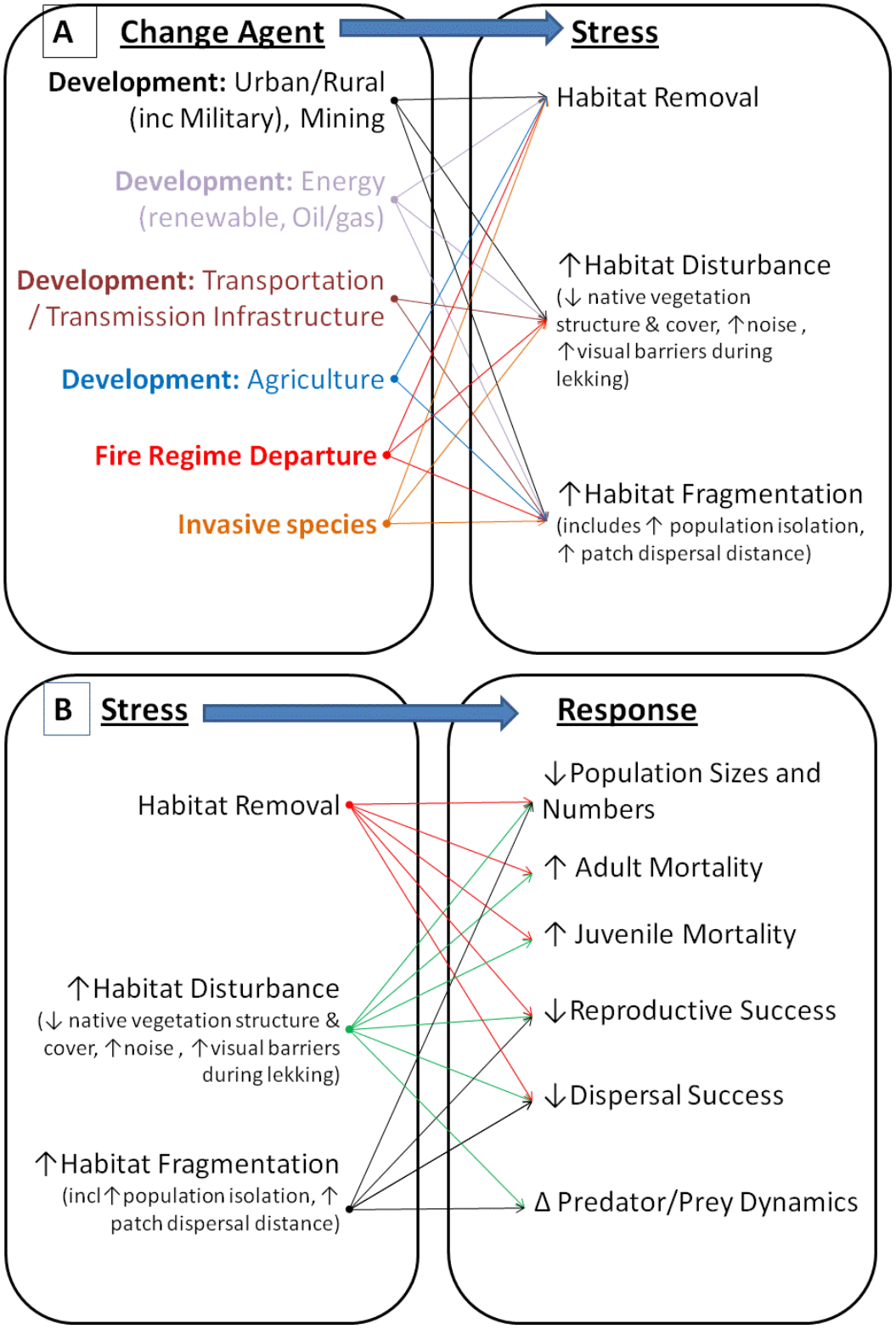

Figure B-4 (A and B). The conceptual model for Inter-Mountain Basins Big sagebrush Shrubland illustrates the effect of each Change Agent on the resource's ecological integrity. A. Change Agents are a source of different types of stressors. B. Different types of stressors invoke different responses.

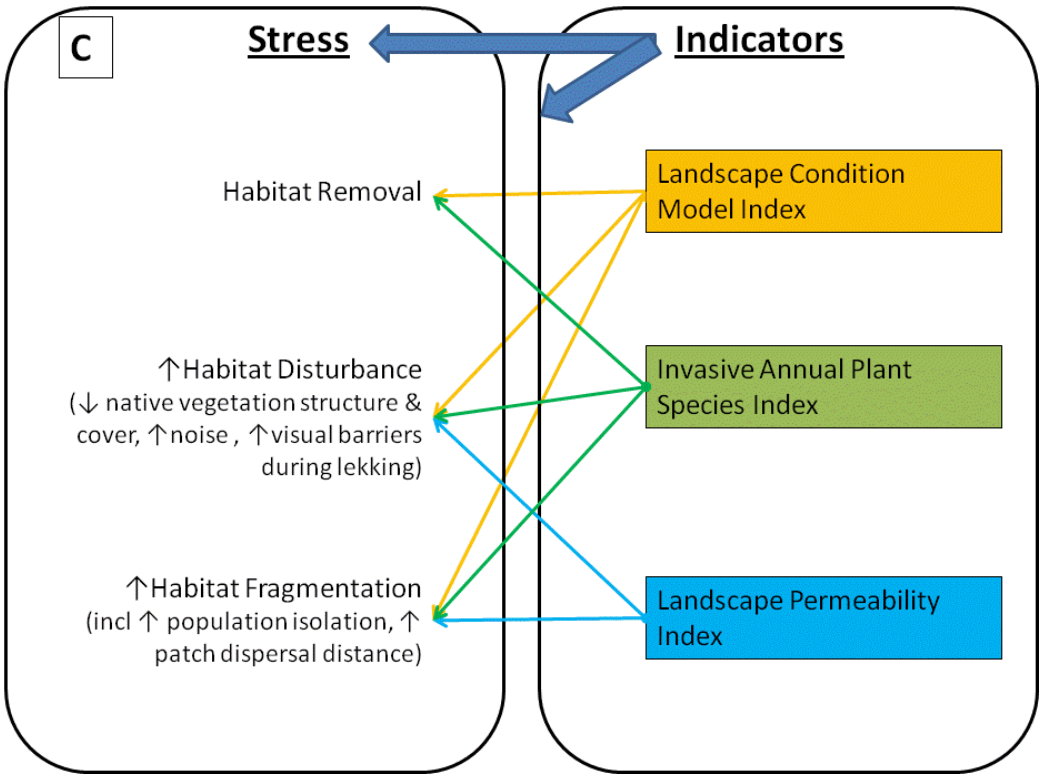

Figure B-4 (C). The conceptual model for Inter-Mountain Basins Big sagebrush Shrubland illustrates the effect of each Change Agent on the resource's ecological integrity. C. Indicators are metrics by which we can directly measure the amount of stress or response within each type of resource.

Ecological Integrity Criteria and Indicators

The conceptual model diagrams presented above in the discussion of Change Agent Effects indicate the stresses and responses expected. These stresses and responses were identified based on an assessment of the key ecological attributes for this resource type, based on the information presented in the Focal Resource Characterization section. Panel C of these diagrams, and Table B-4, identify a suite of indicators for assessing levels of stress and response. The indicators are organized by key ecological attributes (KEAs), which are pivotal ecological characteristics and primary ecological drivers. KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For coarse-filter conservation elements the reporting unit for the present assessment is at the 5th Level Watershed (10-digit hydrologic catalog units, or HUC10).

Table B-4. Indicators used for ecological status assessment of Inter-Mountain Basins Big Sagebrush Shrubland.

Key Ecological Attribute	Indicator	Definition	Justification
Landscape Condition	Landscape Condition Index	This indicator is measured by intersecting the mapped area or habitat distribution map of the resource with the LCM layer and reporting the average LCM index value for the resource or habitat within each 5th level watershed, or 4x4 km square units for species. Landscape Condition Index is a 90x90m square unit resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. The results are a score for landscape condition from 0 to 1 with 1 being very high landscape condition and values close to 0 likely having very poor condition.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance.
Relative Extent	Change in extent	This indicator is assessed by comparing the mapped current extent (circa early 2000s) of the resource, per 5th level watershed, with the mapped extent of the biophysical setting (BpS) layer for the same resource, reporting the percent change between the two extents (positive or negative).	The proportion of change due either to conversion to other land cover or land use, or potentially its expansion due to alterations to natural disturbance processes, decreases ecological integrity for the resource.
Fire Regime	Fire Regime Departure Index	This indicator is assessed by calculating and summarizing the updated LandFire Succession classes (SClass) layer which characterizes current vegetation succession classes for the distribution of each resource within each 5th-level HUC. The resulting proportional calculation for current conditions is compared to the expected proportions, as derived from the VDDT or Path-Tools model characterizing the expected natural range of variation (NRV). This comparison defines the degree of departure (%). The SClass Departure Index is calculated by subtracting the Departure percent from 1 to produce a normalized scale from 0 to 1 with 1 being no departure from NRV in distribution of succession classes and 0 being complete departure from NRV.	A mix of successional classes among patches of a given vegetation type results from fire and other natural disturbances. Through field observation and modeling, one can establish a working hypothesis for the expected proportional mix of successional classes where human alterations are limited. Departure from the mixture predicted under NRV indicates uncharacteristic disturbance regime and declining integrity.

Table B-4. Indicators used for ecological status assessment of Inter-Mountain Basins Big Sagebrush Shrubland.

Key Ecological Attribute	Indicator	Definition	Justification
Biotic Condition	Invasive Annual Grass Index	This indicator is measured using the mapped area or habitat distribution of the resource with an abundance map of introduced invasive annual plant species. The output is predicted percent cover of invasive annual species within each 5th level HUC. The Invasive Annual Grass Index is calculated by multiplying the invasive annual cover percent by 4 then subtracting the product from 1 to produce a normalized scale from 0 to 1 with 0 being 25% or greater cover of invasive annuals and 1 being invasive annuals absent.	Invasive annual plant species displace natural composition and provide fine fuels that significantly increase spread of catastrophic fire.

Ecological Status Scorecard

Each indicator is measured and scored as described in Table B-4. The score is normalized between 0 and 1 with 1 being highest ecological status and 0 being lowest. The mean index scores of these indicators may then be averaged by each Key Ecological Attribute. Displaying the indicators with individual scores allows the user to interpret which particular ecological attributes in a reporting area is driving the ecological status of the resource.

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Wind Erodible Soils

Focal Resource Characterization

The Bureau of Land Management defines a number of sensitive soil types as those soils which are extremely susceptible to impact and difficult to restore and reclaim, including those with high erosion potential (from water and wind), high salinity (excess salt and excess sodium), high gypsum content, low water-holding capacity (droughty), restricted rooting depth, or hydric qualities. The NRCS classifies the sensitivity of soils to wind erosion on the basis of the properties of the soil surface

layer. There is a close correlation between soil blowing and the size and durability of surface clodiness, fragments, organic matter, and the calcareous reaction. (NSSH, part 618.72).

The approach for BLM REA in the Great Basin was to identify sensitive soil characteristics given the best available data at any given location. BLM provided a list of vulnerable soil properties (Table B-5). Wind Erodibility Groups (WEGs) 1 and 2 define high wind erodiblity. WEG 3, 4, and 4l indicate moderate wind erodibility. These two categories were treated together for this assessment.

Where available, the SSURGO 1:24,000 dataset provided by NRCS provided one of the best means for identifying these soils. In portions of the study area for which SSURGO was unavailable, 1:250,000 scale STATSGO data were utilized when finer-scale draft soil survey data could not be obtained.

Table B-5. Sensitive soils groups and criteria for definition (from Comer et al. 2013).

Properties	Low	Moderate	High	Restrictive Feature / Vulnerability Category [a]
Kw < 0.20 [a, b] (by percent slope)	<20	20 – 40	>40	
Kw 0.20 – 0.36 [b, c] (by percent slope)	<15	15 – 35	>35	
Kw >0.36 [b, c] (by percent slope)	<10	10 – 25	>25	Steep Slopes Water Erosion
Wind Erodibility Group (Surface Layer)	5, 6, 7, 8	3,4, 4l	1, 2	Wind Erosion Hazard
Available Water Capacity [c] (Average To 40 Inches Or Limiting Layer) (In/In)	>0.10	0.05 – 0.10	<0.05	Droughty Soils
Salinity (Mmhos/Cm) (Surface Layer)	<8	8 – 15.9	≥16	Excess Salt [note: this was combined with Sodium Adsorption Ratio]
Sodium Adsorption Ratio [c] (Surface Layer)	<8	8 – 12.9	≥13	Excess Sodium
Gypsum > 10% (% by weight of hydrated calcium sulfates in the fraction of soil less than 20mm in size)	< 10%	–	>10%	Gypsum Soils

[a] Table content, with the exception of gypsum and hydric soils, is based on values developed by BLM Soil Specialist Bill Ypsilantis (Bryant, L. BLM internal communication).

[b] K Factor of surface layer adjusted for the effect of rock fragments (Kw).

[c] The representative value for the range in soil properties

[d] For Central Basin and Range, include soils in WEG 3 that have formed from volcanic parent materials or Bonneville Lake Sediments in the “high” category, based on experience in NV and UT in which soils from these parent materials have high potential to blow following wildfire or other vegetation loss, even with the finer surface textures characteristic of WEG.

[f] Food and Agriculture Organization of the United Nations (FAO) 1990

Table B-5 (continued). Sensitive soils groups and criteria for definition (from Comer et al. 2013).

Properties	Low	Moderate	High	Restrictive Feature / Vulnerability Category [a]
Soils with Hydric Properties	Field: hydclprs value = “All Hydric”	Field: Hydric Rating Value = Yes Land Cover Type = not upland	[Many Factors; see below spatial Model]	Hydric Soils

[a] Table content, with the exception of gypsum and hydric soils, is based on values developed by BLM Soil Specialist Bill Ypsilantis (Bryant, L. BLM internal communication).

[b] K Factor of surface layer adjusted for the effect of rock fragments (Kw).

[c] The representative value for the range in soil properties

[d] For Central Basin and Range, include soils in WEG 3 that have formed from volcanic parent materials or Bonneville Lake Sediments in the “high” category, based on experience in NV and UT in which soils from these parent materials have high potential to blow following wildfire or other vegetation loss, even with the finer surface textures characteristic of WEG.

[f] Food and Agriculture Organization of the United Nations (FAO) 1990.

Figures B-5 and B-6 indicate the mapped result for moderate and high wind-erodible soils within the ecoregion as a whole and within the project assessment area. Within the vicinity of GRBA, their distribution encompasses several basin bottoms, including area currently dominated by greasewood flat, playa, and desert wash.

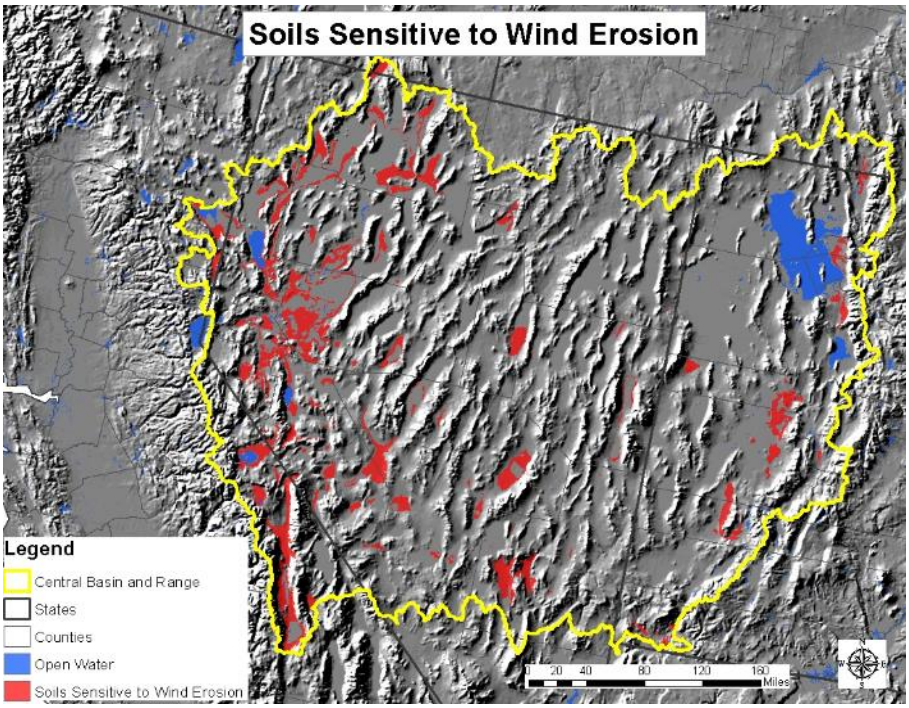

Figure B-5. Distribution of soils vulnerable to moderate or high wind erosion across the Central Basin and Range ecoregion.

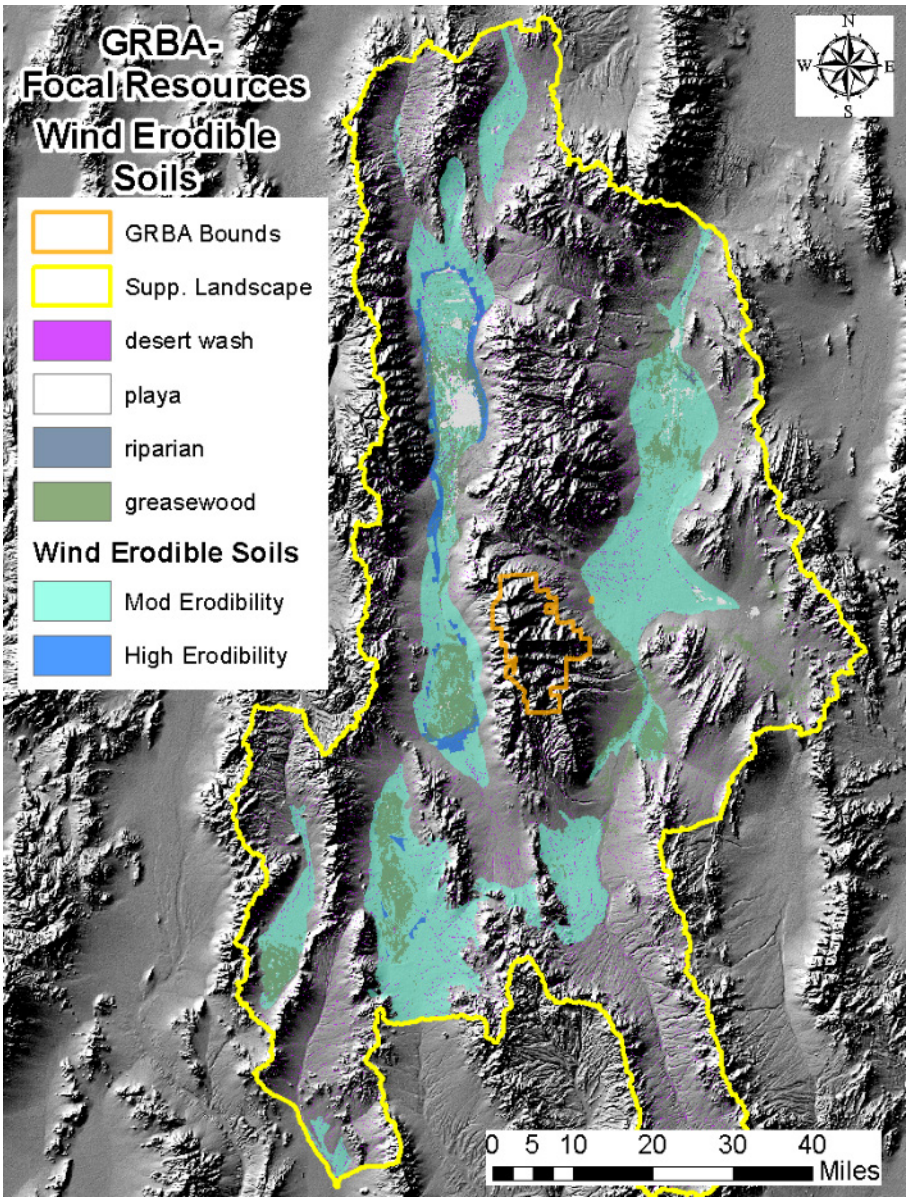

Figure B-6. Map of known location of wind-erodible soils within the assessment area.

Data Limitations and Uncertainty

SSURGO provides an acceptable means for identifying sensitive soils in those locations where it is available. It was beyond the scope of this REA to incorporate landscape context (e.g., wind pattern) into the calculation of wind erosion potential. There is undoubtedly some error introduced by the use of these spatial inputs of distinct spatial and thematic resolutions. While these are issues, for project purposes, the results provide moderately certain predictions of where these vulnerable soils types occur

Given their widespread distribution throughout basins surrounding GRBA, wind-erodible soils tend to occur where infrastructure is concentrated in the study area. Figure B-7 shows the overlay of the landscape condition model, thresholded at four levels of intensity, with wind-erodible soils in the

study area. Areas of highest intensity impact (due to proximity) are located both to the east and west of GRBA. While this map does not directly indicate disturbance to wind-erodible soils, it suggests areas where concentrated development, and accessibility from current infrastructure rights-of-way, might be causing surface disturbance.

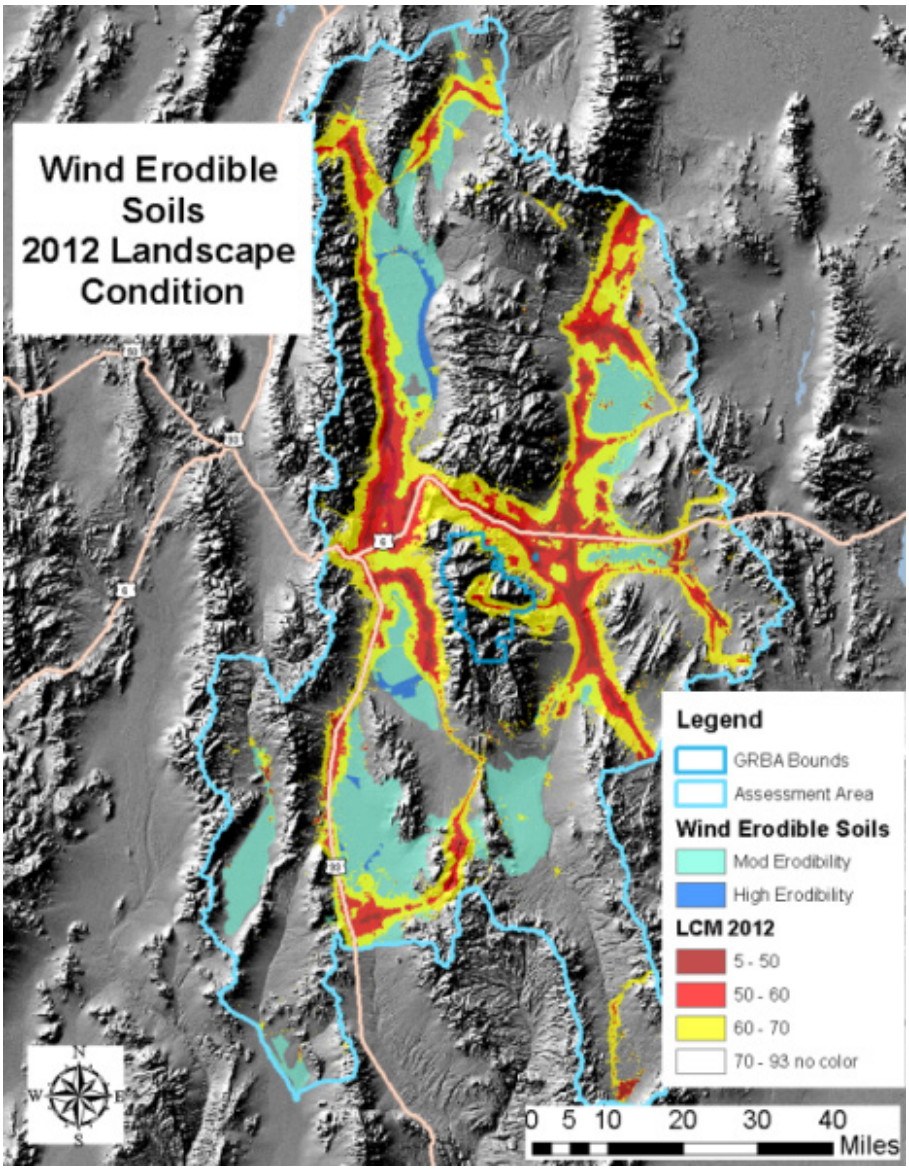

Figure B-7 Landscape condition model, thresholded to define four classes of potential landscape disturbance, overlain on the local distribution of wind-erodible soils.

Change Agent Effects

From the NPS Solar PEIS, soils that are less resistant to blowing wind are more likely to contribute to airborne particulate loading, and the cumulative increased disturbance of these soils is likely to

produce increased local and regional windblown dust[2]. Increased windblown dust from disturbed arid soils is an air quality concern in terms of the PM2.5 and PM10 health-based standards, as well as its contribution to regional visibility impairment. Cumulative windblown dust, both local and regional, has been found to be a significant contributor to visibility impairment on the 20% worst visibility days in Class I areas in the six state southwest study area (reference is in specific Air Quality comments). The cumulative disturbance of soils susceptible to wind erosion could increase downwind particulate concentrations and contribute to visibility impairment in Class I areas, including national parks in the six state study area.

The NPS is concerned with the development of variance lands for energy development because:

1) site controls may be successful at the project level, but less than fully successful for cumulative dust minimization over broad geographic areas;
2) there will be increased surface disturbance and dust emissions due to expansion into roadless, pristine areas; and
3) projects located in high wind areas will exacerbate a growing problem of airborne particulate pollution in protected airsheds of downwind national parks.

Table B-6 provides a tabular summary of the map overlay from Figure B-7. While approximately 50% of the total are of medium to highly erodible soils occurs with sufficient distance from infrastructure to be tentatively indicated as "intact" (landscape condition scores >0.7), a high proportion of the total area of these soils within the study area co-occur, or occur quite close to potentially impacting infrastructure. Table B-6 indicates that as much as 37 to 47% of the aerial extent of wind-erodible soils occurs in areas with a landscape condition value between 0.5 and 7.0.

Table B-6. Tabular summary of overlay from thresholded landscape condition model on sensitive soils within the study area.

	Medium Wind Erodibility		High Wind Erodibility	
Landscape Condition Class	**Hectares**	**% Impacted**	**Hectares**	**% Impacted**
<0.50 severe	24,423	7	2,295	12
0.51 – 0.60	54,785	17	5,420	29
0.61 – 7.0	81,0001	24	1,491	8
>0.70 ~ intact	170,549	52	9,346	50

Key Ecological Attributes and Indicators

In evaluating wind erodibility across the southwest, Zobeck (1991) identified key factors for gauging wind-erodiblity. These factors provide a close parallel to the concept of key ecological attributes for

[2] *Partially excerpted from the NPS PEIS: Solar Energy Development in Six Southwestern States* http://solareis.anl.gov/

measuring ecological integrity. Factors include soil surface wetness, soil surface roughness, soil-inherent wind erodibility, including aggregate size distribution and aggregate stability, and soil crust thickness. These factors are considered in wind erosion hazard scores for identification and mapping of these soil types (Table B-5 above). Figure B-8 depicts linkages between change agents, stress, response, and practical indicators of integrity. This conceptual diagram describes the main dynamic as related to wind-erodible soils in a cool desert landscape, where cryptobiotic soil crusts are characteristic and provide the primary mechanism for maintaining soil stability where vegetation cover is sparse. With physical disturbance of these crusts, loose soil can then be carried by wind gusts, ultimately influencing local visibility. With the removal of surface disturbance, and considerable time, soil crusts can recover and re-stabilize surface soil patches. Therefore, the presence and relative cover of soil crusts provides one primary focus for evaluating the integrity of wind-erodible soils. Practical indicators addressing the condition of wind-erodible soils can include an indirect measure of landscape surface disturbance, as depicted in the landscape condition model. Two additional indicators, derived from field observation would include direct measurement of % cover of soil crust, and changes in ambient air visibility (Figure B-8).

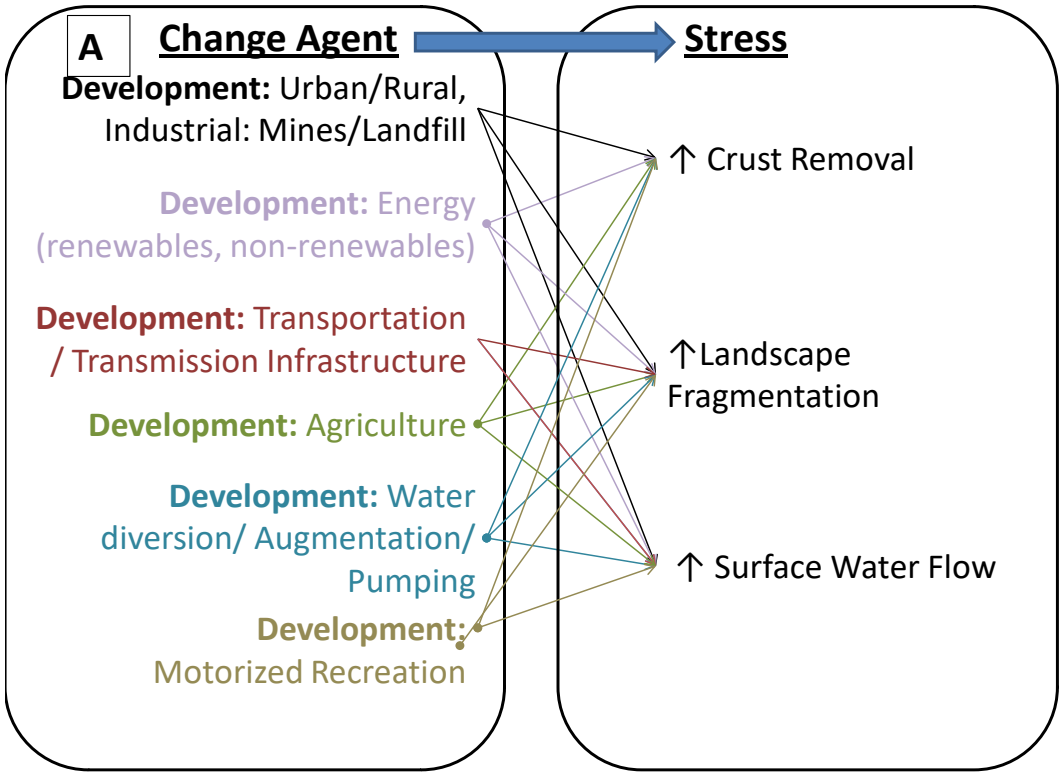

Figure B-8 (A). The conceptual diagram linking change agents to stressors, response, and indicators of integrity. A. Change Agents are a source of different types of stressors.

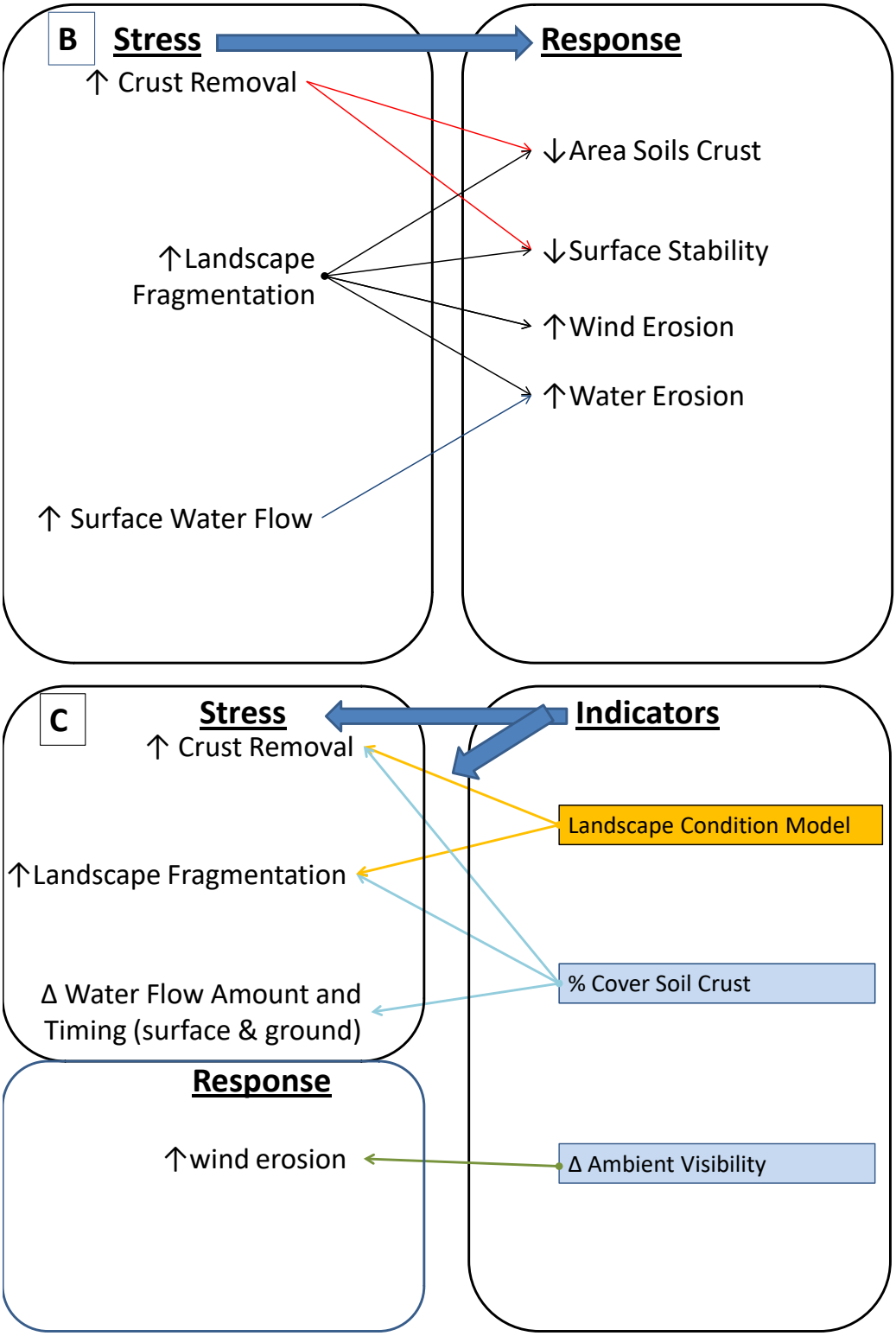

Figure B-8 (B and C). The conceptual diagram linking change agents to stressors, response, and indicators of integrity. B. Different types of stressors invoke different responses. C. Indicators are metrics by which we can directly measure the amount of stress or response within each type of resource.

Where feasible, a characterization of the expected range of variation for values from each of these indicators would be desirable. Landscape condition is a stressor-based measure, and so comparison of current scores (i.e., 0.0-1.0 for a given area) are in fact compared against a score of 1.0 (i.e. the lack of surface disturbance). However, for the indicators of % cover of soil crust, and ambient air visibility, one could characterize an expected range of variation suitable for the assessment area. This task was beyond the scope of this effort, but could be prioritized for future research.

Ecological Integrity Scorecard

The Ecological Integrity Scorecard links conceptual diagrams that describe the relationships between change agents, stress, response, and indicators, to spatial models that provide practical measures across the landscape. The primary indicator of integrity for wind-erodible soil is scored as described in Table B-7. The landscape condition model is used here as a level 1 indicator for the key attribute of surface stability of wind-erodible soil, that is measured in the field as the percent area of intact cryptobiotic soil crust. The score using the landscape condition model (LCM) is normalized between 0 and 1 with 1 being most intact habitat status and 0 being least.

Table B-7. Level 1 indicator used for measuring integrity of wind-erodible soils.

Key Ecological Attribute	Indicator	Definition	Justification
Surface Stability Provided By Intact cryptobiotic Soil Crust	Landscape Condition Index	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance.	This indicator is measured by intersecting the mapped area of medium-high win-erodible soil with the LCM layer and reporting the average LCM index value for the soil distribution by 1x1 km square units. Landscape Condition Index is a 90x90m square unit resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing impact with distance from the source. The results are a score for landscape condition from 0 to 1 with 1 being very high landscape condition and values close to 0 likely having very poor condition.

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Aquatic Coarse-Filter Conservation Element Characterization and Conceptual Models

The conceptual models for aquatic ecological systems build upon the descriptions of wetland (including riparian) ecological system types that NatureServe has been developing since 2003, when the ecological systems classification was first developed (to search and download existing descriptions, see http://www.natureserve.org/explorer/index.htm). The version presented here includes additional material focusing on aquatic components, and natural and altered aquatic dynamics, as well as threats and stressors to the aquatic components of each system.The information presented covers the full geographic range of distribution of each resource type, which can extend beyond the ecological sub-region immediately including and surrounding Great Basin National Park, and does not specifically focus on characteristics or dynamics of each resource that are unique to this immediate sub-region.

The resource descriptions include many names of plant species that are characteristic of each coarse-filter ecological system type. In the text sections these names are provided as scientific names. Vascular plant species nomenclature follows the nationally standardized list of Kartesz (1999), with very few exceptions. Nomenclature for nonvascular plants follows Anderson (1990) and Anderson et al. (1990) for mosses, Egan (1987, 1989, 1990, 1991) and Esslinger and Egan (1995) for lichens, and Stotler and Crandall-Stotler (1977) for liverworts/hornworts.

The conceptual model for each resource type begins by characterizing the resource and its place within a broader conceptual model and classification of aquatic ecological system types for the ecoregion. Table B-8 presents this broader ecoregional model. Each resource is placed within one of the “Level 1” components of the ecoregional model, and within one of the ”Level 2” categories that further characterize each Level-1 component.

Each conceptual model presentation again includes sections on “Focal Resource Characterization,” “Change Agent Effects,” “Ecological Integrity Criteria and Indicators,” and “References.”

Table B-8. Ecoregional Conceptual Model, Aquatic Coarse-filter Conservation Elements, Central Basin and Range Ecoregion.

Level 1	Level 2	Coarse-filter Element Name
Montane Wet System	Montane Streams & Riparian	Rocky Mountain Subalpine-Montane Riparian Woodland and Shrubland / Stream
	Montane Streams & Riparian	Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland / Stream
Basin Wet System	Playa, Greasewood Flats, Washes	Inter-Mountain Basins Greasewood Flat
	Playa, Greasewood Flats, Washes	Inter-Mountain Basins Wash
	Playa, Greasewood Flats, Washes	Inter-Mountain Basins Playa
	Basin and Foothill Streams & Riparian	Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland / Stream
	Basin Lake/Reservoir	Great Basin Lake / Reservoir
	Desert Springs, Seeps	Great Basin Springs and Seeps

The section on "Focal Resource Characterization" includes a narrative of the resource distribution, its biophysical and hydrologic setting, and floristic composition. For the Inter-Mountain Basins Greasewood Flat coarse-filter resource, we also provide a direct linkage between the resource concept and Ecological Site Descriptions (ESDs) applicable to the ecoregion. Crosswalks are provided only for ESDs approved for the USDA Natural Resources Conservation Service (NRCS) Multiple Resource Land Area (MLRA) that overlap the ecoregion. However, ESDs are based on landform/soil concepts. Consequently, the match between these concepts and ecological system concepts – which integrate information on both biophysical conditions and natural floristic composition – will be imperfect and may vary from type to type. The section on "Conservation Element Characterization" also includes a narrative description of vegetation dynamics, both natural and altered, with supporting literature cited. A portion of each conceptual model is devoted to the aquatic habitat component of the resource. Again, this information is developed across the range-wide distribution of the ecological system type.

The section on "Change Agent Effects" characterizes the primary change agents and current knowledge of their effects on this resource. Some CAs have specific effects on each resource such as the alteration of hydrologic regimes and the interacting effects of introduced weed infestations. We provide narrative on the effects of CAs on the individual resource, in an "altered dynamics" section. Invasive aquatic and terrestrial plant species CAs are described and modeled within the context of their effects on coarse filter resources.

The Inter-Mountain Basins Greasewood Flat coarse-filter resource is unique in our conceptual models for the aquatic resources, in that we have also modeled the impacts of wildfire and invasive

plants through the use of the Vegetation Dynamics Development Tool (VDDT) and simulations run in the Path Landscape Model (ESSA Technologies). These models, originally developed by the Nevada chapter of The Nature Conservancy, were modified for use in this REA. Further details about the VDDT modeling are provided in the discussion of the conceptual model for the Inter-Mountain Basins Greasewood Flat coarse-filter resource.

The section on "Ecological Integrity Criteria and Indicators" describes the methods and data used to assess ecological status, following NatureServe's ecological integrity framework (Faber-Langendoen et al. 2006, Unnasch et al. 2018). Implementation of this framework results in a scorecard for reporting on the ecological status of a given resource within a given location, and facilitates the aggregation and synthesis of the component results for broader measures of ecological integrity at landscape and ecoregional scales. Using this framework, indicators are chosen to provide a measurement for a limited set of key ecological attributes, or ecological drivers for each resource. Ecological attributes may include natural characteristics, such as native species composition, or stressors such as effects of relevant change agents, that are well known to affect the natural function and integrity of the resource

Conceptual or "causal" diagrams are a crucial component of the presentation of the conceptual model of Change Agent effects and the ecological status criteria and indicators. Each diagram consists of three sub-figures, conceptualizing the relationships between Change Agents, the stresses they induce in the resource, the response of the resource to those stressors, and indicators with which to measure either the stress or the resource response with indicators. The diagrams do not show all possible Change Agents, stresses, responses, or indicators – only those relevant to the present assessment.

In part because of project constraints, indicators identified for this assessment emphasize ecosystem stressors that can be more readily measured using available remotely sensed data. Spatial models that reflect these indicators serve as the link between the conceptual models and the spatial representation of ecological status. For each resource, the text provides the definitions and justifications for each of the indicators for that resource, organized in an Ecological Status Scorecard table. Each indicator is scored according to criteria described in the table and is calculated between 0 and 1, with 1 indicating highest ecological status and 0 indicating lowest status (and presumably transitional to a wholly different ecological state).

The section on "References" for each resource lists literature pertaining to the classification, distribution, floristic composition, ecological processes, threats, stressors, or management of the resource, in some cases from portions of its range outside of the ecoregion. These are not exhaustive bibliographies. Some documents may be listed that are not cited in the narrative text.

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Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream

Model Group: Montane Wet System > Montane Streams & Riparian

Focal Resource Characterization

Summary

This ecological system occurs on the lower slopes, foothills and valleys between mountain ranges of the Great Basin and along the eastern slope of the Sierra Nevada within a broad elevational range from about 1128 m to over 2135 m. The system consists of riparian woodlands and shrublands and their associated streams or rivers as they descend in elevation for as far as there is at least regular seasonal flow in the stream channel. Some occurrences originate as, or receive flow from, headwater streams supported by surface runoff and shallow groundwater seepage; others originate at springs along montane canyon bottoms or from bedrock aquifers along valley margins. The terrestrial vegetation of this system often occurs as a mosaic of multiple communities that are tree- or shrub-dominated with a diverse shrub and herb component. The plant communities connected to this

system vary with elevation, stream gradient, floodplain width, and flooding events. Dominant trees may include *Abies concolor, Populus angustifolia, Populus balsamifera ssp. trichocarpa, Populus fremontii, Salix laevigata, Salix gooddingii*, and *Pseudotsuga menziesii*. Dominant shrubs include *Alnus incana, Artemisia cana, Betula occidentalis, Cornus sericea, Salix exigua, Salix lasiolepis, Salix lemmonii*, or *Salix lutea*. Herbaceous layers are often dominated by species of *Carex* and *Juncus*, and perennial grasses and mesic forbs such *Deschampsia caespitosa, Elymus trachycaulus, Glyceria striata, Iris missouriensis, Maianthemum stellatum*, or *Thalictrum fendleri*. Introduced forage species such as *Agrostis stolonifera, Poa pratensis, Phleum pratense*, and the weedy annual *Bromus tectorum* are often present in disturbed stands.

The plant communities of this resource require flooding, scour and deposition of sands and gravel for germination and maintenance. Livestock grazing is a major influence in altering structure, composition, and function of the plant community. The composition of the aquatic communities, in turn, varies with the frequency, intensity, duration and timing of flow (including its often-extreme inter-annual variability); the relative contributions of rainfall, snowmelt, and diffuse groundwater and spring discharges to flow; water temperature (and related ice dynamics) and chemistry; channel substrate and form; the extent of the hyporheic zone; and drainage network connectivity. These latter conditions, in turn, vary with elevation and aspect, latitude and longitude, channel gradient, floodplain width (a function of topography and geology), and surrounding geology and land cover.

Aquatic Ecology/Habitat

The streams and rivers in this system, as with all cold desert streams and rivers, support a unique range of species adapted to the overall scarcity and irregular availability of water over space and time, and the frequent isolation of perennial reaches by dry conditions across the rest of the drainage network. These factors result in a high degree of endemism among aquatic biota, including species adapted to using the hyporheic zone as their main habitat or as a refuge during periods with intermittent or no flow (Ward and Associates 1973, Louw and Seely 1982, Abell et al. 2000, Williams 2006, Levick et al. 2008, Miller et al. 2010a). As in all fluvial ecosystems (Poff et al. 1997, 2010), the flow regime is the master variable for this system. That is, the pattern of variation in the timing, duration, and spatial extent of flow pulses and baseflow determines the kinds of aquatic species that can live in this system, where they can live, and how they can persist during periods of no flow or floods. The timing, duration, temperature range and spatial extent of flow pulses and baseflow in turn are shaped by the ecoregion's severely arid climate and the distribution of springs with sufficient discharge to support streamflow.

The limited precipitation across the Great Basin is concentrated at higher elevations as either rainfall or snow, and varies greatly in magnitude and spatial distribution from season to season, year to year, and decade to decade (Miller et al. 2010a). Overall precipitation is also slightly higher toward the eastern half of the Great Basin, due to the stronger rainshadow effects of the Sierra Nevada and Cascade Range across the western portions of the ecoregion and due to the influence of summer "monsoonal" storms across the eastern portions (Miller et al. 2010a). Among occurrences of this system with headwaters at higher elevations, variation in both precipitation and snowmelt timing, intensity, and spatial distribution affect flow patterns and their variation with elevation, including

intense flow pulses triggered by episodes of abrupt rainfall or snowmelt. In turn, recharge to underlying aquifers and losses to evapotranspiration almost always result in the disappearance of flow at lower elevations except during extremely infrequent wet conditions. Many streams of this system include both "gaining" and "losing" reaches, along which groundwater either flows into the stream (to support baseflow) or seeps back into underlying aquifers resulting in reduced baseflow or the complete cessation of flow. Groundwater discharge may be difuse from a surrounding hyporheic zone or concentrated at springs fed by basin-fill or bedrock aquifers, as in Ruby Valley or the upper White River basin [see Springs]. Alternating gaining and losing reaches may result in a patchy distribution of flow except during runoff-driven flow pulses (Levick et al. 2008).

Most examples of this resource type in the ecoregion flow into terminal basins, and are connected to each other only very rarely during periods of widespread wet weather (Abell et al. 2000). This lack of connectivity at the "bottoms" of these drainage networks occurs because the streams simply dry out or because they flow into playas/saline lakes that present barriers to movement of freshwater fauna between contributing drainages. This lack of connectivity limits mobility of species on a regional scale, resulting in genetic isolation and a limited ability of populations to recover through immigration following major flood or drought disturbances (e.g., Hilderbrand and Kershner 2000, Neville et al. 2006). This combination of conditions supports a unique aquatic assemblage of species adapted to the battery of stressful and isolating habitat conditions found across the ecoregion.

Stream biotic assemblage composition also tends to vary along an elevational gradient within occurrences of this system type, except when the stream originates at a lower-elevation spring emanating from a regional aquifer. At higher elevations, runoff-driven flow is often perennial, water temperatures are cool, and dissolved nutrients are scarce under natural conditions. The associated faunal communities are typical for high-gradient, cold-temperature, high current velocity streams, including a preponderance of shredder taxa in the benthic macroinvertebrate assemblage. In turn, assemblage composition at lower elevations is dominated by collector/gatherers and grazers in the larger streams that have increased within stream primary production due to more open canopies and solar radiation (Vannote et al. 1980). However, a lack of connectivity with nearby stream systems can result in a depletion of local populations of particular species and prevent their recolonization. Beaver (*Castor canadensis*) may occur in upper watershed reaches, where they may alter the hydrologic regime through construction of dams. Average water temperatures and concentrations of dissolved solids and particulate organic matter in runoff-driven streams are greater at lower elevations, as are within-stream primary productivity and concentrations of suspended and re-suspended sediment during runoff pulses. These factors select for a somewhat different spectrum of aquatic species at these lower elevations; for example, benthic macroinvertebrate assemblages generally consist of highly tolerant, short-lived, fast-reproducing individuals with broad ecological tolerances, with an emphasis on collector/gatherers and grazers. Vertebrate and invertebrate species able to use the hyporheic zone as a refuge during periods without flow also do well at lower elevations (e.g., Del Rosario and Resh 2000, Levick et al. 2008), as do species tolerant of higher temperatures and salinity. In fact, disturbances caused by intermittent flows may actually facilitate high food quality and consequently high levels of insect production (Fisher and Gray 1983, Jackson and Fisher 1986, Grimm and Fisher 1989, Huryn and Wallace 2000) and may facilitate reproduction

in some species (e.g., Erman and Hawthorne 1976). In addition, the greater diversity of macrohabitat settings at intermediate elevations – associated with the greater diversity of substrates and topography found here – supports a greater diversity of benthic fauna than found at higher or lower elevations (e.g., Pearsons et al. 1992, Levick et al. 2008).

Species of Conservation or Management Concern Assessed via Coarse-Filter

The Central Basin and Range Rapid Ecoregional Assessment (Comer et al. 2013) developed and applied criteria to identify species to be targeted for focused assessment. These species are of conservation or management concern due primarily to their relative vulnerability to extinction. These vulnerabilities stem from their sensitivity to past or current land/water uses, natural rarity, or forecasted vulnerabilities to climate change effects.

Listed below are species of conservation or management concern that are very strongly associated with this ecosystem type across the entire ecoregion. This close connection facilitates analysis in that the ecosystem type provides a practical "coarse filter" for analysis, and documentation of ecological status for locations of this ecosystem type should provide a reliable indication of the ecological status for each of these species. Therefore, these species of conservation or management concern were not assessed and reported on individually.

Amphibians: Columbia Spotted Frog (*Rana luteiventris*), Columbia Spotted Frog – Great Basin (*Rana luteiventris pop. 3*), Great Basin Spadefoot (*Spea intermontana*), Mount Lyell Salamander (*Hydromantes platycephalus*), Northern Leopard Frog (*Rana pipiens*), Owens Valley Web-toed Salamander (*Hydromantes sp. 1*), Pacific Chorus Frog (*Pseudacris regilla*), Western Toad (*Bufo boreas*)

Birds: A Willow Flycatcher (*Empidonax traillii adastus*), A Yellow Warbler (*Dendroica petechia brewsteri*), American Robin (*Turdus migratorius*), Black Phoebe (*Sayornis nigricans*), Black-crowned Night-Heron (*Nycticorax nycticorax*), Black-throated Gray Warbler (*Dendroica nigrescens*), Blue Grosbeak (*Passerina caerulea*), Downy Woodpecker (*Picoides pubescens*), Gray Flycatcher (*Empidonax wrightii*), Greater Sandhill Crane (*Grus canadensis tabida*), Green Heron (*Butorides virescens*), Least Bittern (*Ixobrychus exilis*), Lesser Goldfinch (*Spinus psaltria*), Lewis's Woodpecker (*Melanerpes lewis*), Long-billed Curlew (*Numenius americanus*), MacGillivray's Warbler (*Oporornis tolmiei*), Marsh Wren (*Cistothorus palustris*), Mountain Quail (*Oreortyx pictus*), Orange-crowned Warbler (*Vermivora celata*), Sharp-shinned Hawk (*Accipiter striatus*), Snowy Egret (*Egretta thula*), Tree Swallow (*Tachycineta bicolor*), Western Least Bittern (*Ixobrychus exilis hesperis*), Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*), White-crowned Sparrow (*Zonotrichia leucophrys*), Wilson's Phalarope (*Phalaropus tricolor*), Wilson's Snipe (*Gallinago delicata*), Wood Duck (*Aix sponsa*), Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*)

Butterflies and Skippers: Carson Valley Silverspot (*Speyeria nokomis carsonensis*)

Freshwater and Anadromous Fishes: Big Spring Spinedace (*Lepidomeda mollispinis pratensis*), Bluehead Sucker (*Catostomus discobolus*), Desert Sucker (*Catostomus clarkii*), Inland Redband Trout and Redband Steelhead (*Oncorhynchus mykiss gairdneri*), Lahontan Creek Tui Chub (*Gila bicolor obesa*), Lahontan Cutthroat Trout (*Oncorhynchus clarkii henshawi*), Lahontan Speckled Dace (*Rhinichthys osculus robustus*), Meadow Valley Wash Desert Sucker (*Catostomus clarkii ssp. 2*), Northern Leatherside Chub (*Lepidomeda copei*), Owens River Pupfish (*Cyprinodon radiosus*), Owens Speckled Dace (*Rhinichthys osculus ssp. 2*), Owens Sucker (*Catostomus fumeiventris*), Owens Tui Chub (*Gila bicolor snyderi*), Pahranagat Speckled Dace (*Rhinichthys osculus velifer*), Southern Leatherside Chub (*Lepidomeda aliciae*), Virgin River Spinedace (*Lepidomeda mollispinis mollispinis*), Virgin Spinedace (*Lepidomeda mollispinis*), Wall Canyon sucker (*Catostomus sp. 1*), White River Desert Sucker (*Catostomus clarkii intermedius*), White River Speckled Dace (*Rhinichthys osculus ssp. 7*)

Freshwater Mussels: California Floater (*Anodonta californiensis*), Western Pearlshell (*Margaritifera falcata*)

Freshwater Snails: Mountain Marshsnail (*Stagnicola montanensis*), Smooth Juga (*Juga interioris*)

Mammals: Broad-footed Mole (*Scapanus latimanus*), Montane Shrew (*Sorex monticolus*), Panamint Kangaroo Rat (*Dipodomys panamintinus*), Ringtail (*Bassariscus astutus*), Vagrant Shrew (*Sorex vagrans*), Western Red Bat (*Lasiurus blossevillii*)

Stoneflies: A Stonefly (*Capnia hornigi*)

Turtles: Northern Pacific Pond Turtle (*Actinemys marmorata marmorata*), Western Pond Turtle (*Actinemys marmorata*)

Flowering Plants: Hooded Ladies'-tresses (*Spiranthes romanzoffiana*), Tiny-flower Phacelia (*Phacelia minutissima*)

Natural Dynamics

The hydrologic regime is naturally highly variable temporally and spatially among the occurrences of this resource type. Where present, spring discharges from bedrock aquifers provide flows unaffected by rainfall and snowmelt. Otherwise, stream and river flows – where they occur, at what magnitudes, and when and how often – are subject to wide fluctuations as a result of the wide variation in where and when precipitation takes place, what form the precipitation takes (rain versus snow), and where and when snowmelt takes place (e.g., Abell et al. 2000, Levick et al. 2008, Miller et al. 2010a). Intense runoff associated with intense rainfall events are highly erosive, resulting in rapid reconfiguration of aquatic and riparian macrohabitats particularly along reaches with sand and gravel substrates. Fire disturbances occur in riparian zones, but are generally less severe and less often than in neighboring uplands (Reeves et al. 2005). The vegetation of this ecological system contains early-, mid- and late-seral riparian plant associations and non-obligate riparian species. Cottonwood communities are early-, mid- or late-seral, depending on the age-class of the trees and the associated

species of the occurrence (Kittel et al. 1999b). Cottonwoods, however, do not reach a climax stage as defined by Daubenmire (1952). Mature cottonwood occurrences do not regenerate in place, but regenerate by "moving" up and down a stream or river reach. Over time, a healthy riparian area supports all stages of cottonwood communities (Kittel et al. 1999b). Significant interactions may also take place between the immediate riparian corridor (extent of riparian vegetation and stream channel) and immediately adjacent uplands. This adjacent impact zonemay parallel both sides of the actual riparian corridor. This buffer zone, generally estimated at roughly 100m on both sides of the actual riparian corridor, supports important interactions between the corridor core and its immediate surroundings such as movements of birds, mammals, reptiles, amphibians, and insects between riparian and upland habitats; and movements of these species upward and downward in elevation along the corridor (ELI 2008, Faber-Langendoen et al. 2012).

Change Agent Effects

Riparian areas, their aquatic communities, and their area of analysis are directly affected by concentrated grazing, cutting of woody vegetation for timber and firewood, residential development, river channelization, regulation or diversion of flows, wildfire suppression, trapping (principally beaver), exotic species (both terrestrial and aquatic plants and animals), unregulated recreation (both motorized and nonmotorized), road building, mining, pollution, farming, channel dredging, bank armoring, and construction of dams and levees. These same communities are indirectly affected by human activities across their surrounding watersheds outside their impact zonethat alter watershed runoff and groundwater recharge and discharge via altered ground cover and water diversions and withdrawals, or cause pollution, including from atmospheric deposition.

Invasive plant species may be one of the strongest agents of change in occurrences of this resource type. Invasive plant species such as salt-cedar and Russian-olive have invaded nearly all riparian systems in the ecoregion to varying degrees and can convert many miles of riparian zone into undesirable monotypes. Invasive aquatic species such as common carp and American bullfrog can out-compete native aquatic species for space and nutrient resources. Several invasive taxa already occur and are highly likely to spread in this ecosystem, including didymo, New Zealand mudsnails, carp, crayfish, and frogs. Didymo will most likely continue to become a nuisance in the cooler headwaters and at the outflow of lakes or reservoirs (Spaulding and Elwell 2007). Didymo may become a nuisance in springs with adequate flows (Spaulding and Elwell 2007). It appears that extensive stalk generation in didymo blooms occurs when cell division rates are nutrient-limited, photosynthetic rates are high, water temperature is increased, or ultra-violet radiation is increased from loss of stratospheric ozone (Falkowski and LaRoche 1991, Bothwell et al. 2006, Marshal 2007). Didymo can cause major shifts in benthic macroinvertebrate density and composition, including reduction in grazers and increase in collector-gatherer densities (McLaughlin and McKnight 2010, Richards 2010, Taylor 2010). Like many algal blooms, didymo outbreaks may not continually occur, but may be cyclical or sporadic. New Zealand mudsnails thrive in these environs and are very likely to spread throughout these ecosystems (MSU 2011). Carp and crayfish also do relatively well in this resource type particularly in the slower warmer stretches. Invasive frogs, particularly the American bullfrog, survive in this resource type. Invasive aquatic macrophytes (Eurasian watermillfoil and

curly leaf pondweed) should only occur in the slower velocity sections such as pools and back eddies.

Conceptual Diagram

Aquatic Course Filter Conservation Elements experience stress when faced with Change Agents. Some change agents directly remove the element (including its buffer zone), such as new rural or urban development including mines and landfills. Other change agents such as roads and transportation corridors (railroads, power lines, solar arrays, oil pumping platforms and the like) fragment its distribution (Debinski and Holt 2001). Irrigated agriculture, in addition to complete replacement of aquatic resource distribution, can have an effect of increased pollution through fertilizers or heavy metal-laden sedimentation runoff (Boody and DeVore 2006, Chipps et al. 2006, Pimentel et al. 2004). Water development projects have a double effect on aquatic resources, as they change the amount and timing of flow, and also fragment the network of flow along reaches where groundwater withdrawals or surface diversions eliminate flow entirely (Poff et al. 2010). Aquatic invasive species can have profound effect on the amount of oxygen available, can directly compete with native species, and have been shown to completely remove the native ecosystem habitat (e.g. tamarisk) (Brussard et al. 2000; USGS 2011). These stressors result in different magnitudes of response along a response gradient (USEPA 2005, Davies and Jackson 2006) depending on the type and magnitude of impact and how many stressors are acting on the same resource simultaneously. Responses include a reduction in species diversity and species genetic diversity with the fragmentation and loss of habitat (Vryanckx et al. 2011). Species can become less abundant as their habitats become fragmented or continually disturbed such that reproduction is less successful (Brussard et al. 2000). As native species become stressed, other more tolerant and opportunistic species may increase in abundance, further tipping the balance of food webs in aquatic systems and preditor/prey dynamics. Shifts in species abundance and presence results in a change in species composition changing the vegetative community of stream banks or the riverine aquatic community. The indicators, shown in the causal diagrams below, measure the amount of stress or the type and magnitude of response to stress within each resource. See the Ecological Status Scorecard section for full explanation of each indicator (Figure B-9).

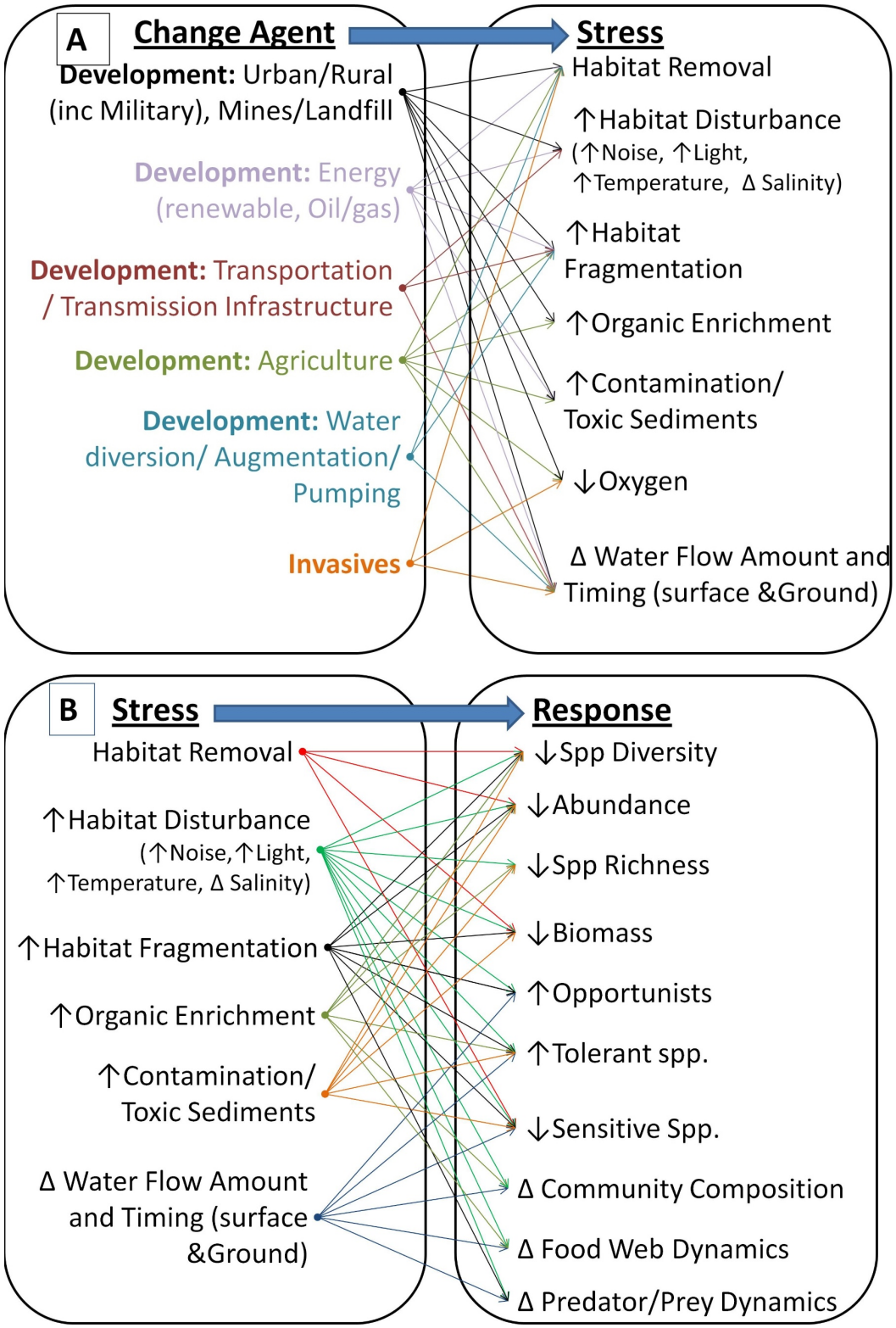

Figure B-9 (A and B). The conceptual model for Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland / Stream illustrates the effect of each Change Agent on the resource's ecological integrity. A. Change Agents are a source of different types of stressors. B. Different types of stressors invoke different responses

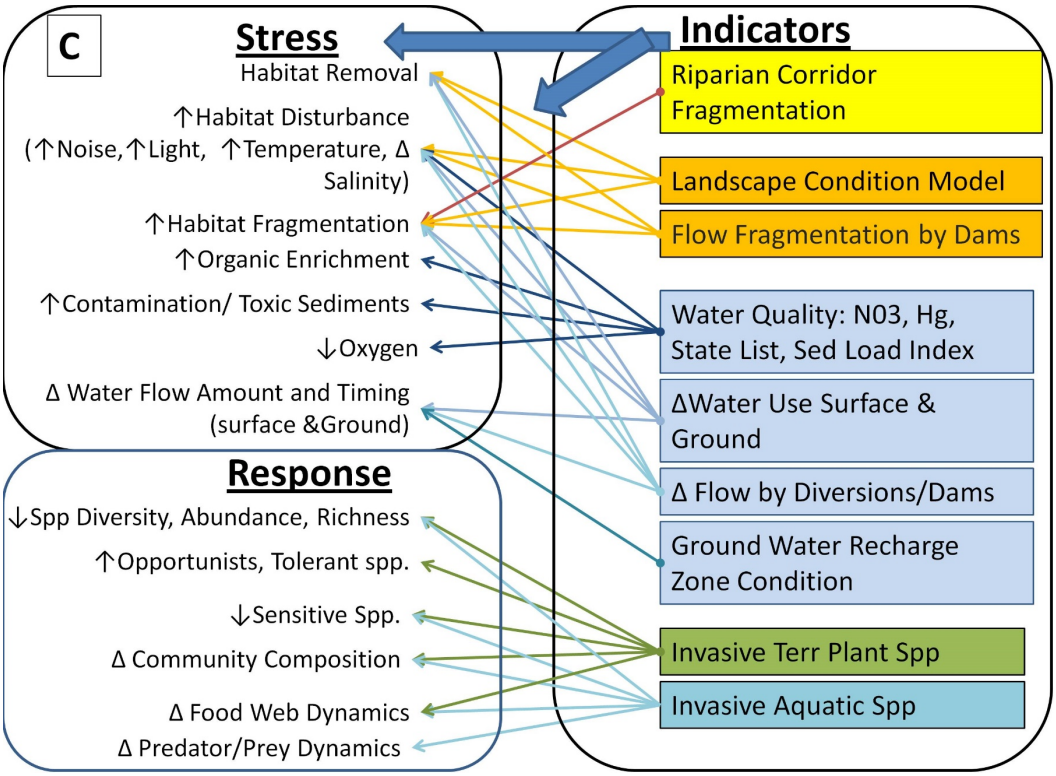

Figure B-9 (C). The conceptual model for Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland / Stream illustrates the effect of each Change Agent on the resource's ecological integrity. C. Indicators are metrics by which we can directly measure the amount of stress or response within each type of resource.

Ecological Integrity Criteria and Indicators

The conceptual model diagrams presented above in the discussion of Change Agent Effects indicate the stresses and responses expected. These stresses and responses were identified based on an assessment of the key ecological attributes for this resource type, based on the information presented in the Focal Resource Characterization section. Panel C of these diagrams, and Table B-9 below, identify a suite of indicators for assessing levels of stress and response. The indicators are organized by key ecological attributes (KEAs), which are pivotal ecological characteristics and primary ecological drivers. KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For coarse-filter conservation elements the reporting unit for the present assessment is at the 5th Level Watershed (10-digit hydrologic catalog units, or HUC10). The assessment indicators with justifications and definitions are presented in Table B-9, organized by Key Ecological Attributes.

Each indicator is normalized to produce a score between 0 and 1, with 1 being highest ecological status and 0 being lowest. The mean index scores of these indicators may then be averaged by each Key Ecological Attribute. Displaying the indicators with individual scores allows user to interpret which particular ecological attributes in a reporting area is driving the ecological status of the resource.

Table B-9. Indicators used for ecological status assessment of Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland / Stream.

Key Ecological Attribute	Indicator	Definition	Justification
Surrounding Landscape Condition	Landscape Condition Index	This indicator is measured by intersecting the mapped area or habitat distribution map of the resource with the Landscape Condition Model layer and reporting the average LCM value for the resource or habitat within each 5th level watershed, or 4x4 km square units for species. Landscape Condition Model is a 90x90m square unit resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance.
Flow Network Connectivity	Perennial Flow Network Fragmentation by Dams	Number of intersections with NHD perennial streams. Total per HUC.	Indicator of the degree of fragmentation of continuous aquatic habitat.
Riparian Corridor Connectivity	Riparian Corridor Fragmentation	Indicates the degree to which the riparian areas (buffered by 100 m on each side) exhibit an uninterrupted corridor. A measure of the linear, continuous unfragmented riparian corridor based on Landscape Condition Index (LCI), to measure how many fragments are created by the interruption of the natural riparian corridor by non-natural land use.	Unfragmented riparian corridors support individual animal movement, gene flow and natural flooding and sediment deposition and scour processes upon which aquatic and wetland species depend. Intact, unfragmented area of analysis support important interactions between the corridor core and its immediate surroundings such as movements of birds, mammals, reptiles, amphibians, and insects between riparian and upland habitats; and movements of these species upward and downward in elevation along the corridor (ELI 2008, Faber-Langendoen et al. 2012).
Native Species Assemblage	Invasive Aquatic Index	The number of invasive taxa known to be present.	Impacts from invasive species are considered to be of equal importance with habitat loss and global climate change as the primary causal factors responsible for the world’s rapidly decreasing biodiversity and altered ecosystem functioning.
Native Species Assemblage (continued)	Presence of Invasive Plant Species	Number of known locations of non-native introduced tamarisk, Russian olive, and annual grasses.	Increased non-native plant species reduces habitat quality for numerous wildlife species, decreases forage for livestock, reduces ecosystem native species richness, increases soil erosion potential and decreases ecosystem resiliency and resistance to damage from impacts, including climate change.

Table B-9 (continued). Indicators used for ecological status assessment of Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland / Stream.

Key Ecological Attribute	Indicator	Definition	Justification
Hydrologic Regime	Condition of Groundwater Recharge Zone	Measures the landscape condition of the likely groundwater recharge zone (areas above 2000 m within each 10 digit HUC) by percent area in hard-surface development as determined in LCI.	Hard surface development within a groundwater recharge zone can divert and reduce the amount water entering the groundwater.
	Flow Modification by Dams	"F" Index (Theobald et al. 2010)-- Dams and their storage capacity relative to annual stream discharge.	The greater the storage capacity is an indicator of greater the impact to natural flow regimes of the downstream river or stream segments.
	Ground Water Use	Ratio of ground water use as defined by USGS Southwest Principal Aquifer study (Anning 2009; McKinney and Anning 2009) to total flow per watershed (calculated from NHD).	Data show the degree to which surface water is being consumed for human use relative to availability within each watershed. The greater the use, the less water is available to support aquatic species, specifically higher ground water use is likely to draw down water tables and therefore springs.
	Perennial Flow Modification by Diversion Structures	Number of aquaducts intersecting or branching from NHD perennial streams. Total per HUC.	Indication of the amount of flow modification and change in hydrologic regime.
	Surface Water Use	Ratio of surface water use as defined by USGS Southwest Principal Aquifer study (Anning 2009; McKinney and Anning 2009) to total flow per watershed (calculated from NHD).	Data show the degree to which surface water is being consumed for human use relative to availability within each ten digit HUC. The greater the use, the less water is available to support aquatic species.
Water Quality	Atmospheric Deposition-Nitrate Loading (NO3)	Rate of total (dry + wet) deposition of Nitrate (NO3) as N per unit area within HUC.	Used a representative indicator of nutrient loading pollutant. Increased nitrogen in aquatic systems can increase algal growth and decrease oxygen content.
	Atmospheric Deposition-Toxic Mercury Loading (Hg)	Rate of wet deposition of Mercury (Hg) per unit area within HUC.	Used as a representative of the amount of toxic pollutants. Toxic pollutants affect reproduction, growth and neurologic functioning of aquatic animals. Mercury in particular accumulates up the food chain and can affect human health as well.
	Sediment Loading Index	Index values of total Suspended Sediment (developed by NSPECT) which are based on percent of land uses (NLCD) that contribute excess sedimentation and suspended solids via surface water runoff and overland flow into a wetland, as measured within the 200 m buffer area.	Different surrounding land uses contributes to the sediment loading in adjacent waters. Increased sediment clogs fish gills, reduce successful spawning, decrease visibility and increase pollutant loadings, especially heavy metals.

Table B-9 (continued). Indicators used for ecological status assessment of Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland / Stream.

Key Ecological Attribute	Indicator	Definition	Justification
Water Quality (continued)	State-Listed Water Quality Impairments	Measures the integrity of water quality conditions in individual water bodies based on the presence and severity of state listings of water quality impairments for State 303(d) reporting requirements under the federal Clean Water Act – excluding nutrient enrichment, which is addressed by a separate key ecological attribute.	This indicator is a direct measure of pollutants, turbidity and sediments that exceed state standards. Polluted water negatively affects aquatic species health and ability to successfully reproduce.

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Great Basin Springs and Seeps

Model Group: Basin Wet System > Desert Springs, Seeps

Focal Resource Characterization

Summary

Springs (e.g., rheocrenes) and seeps (e.g., limnocrenes, etc.) within the Great Basin are unique ecosystems where groundwater reaches the Earth's surface. Springs and seeps are very distinct from other aquatic, wetland, and riparian ecosystems (Stevens et al. 2005). The geomorphology of springs and seeps often creates numerous microhabitats. Some springs are very small and isolated, while others have large outflows creating large spring pools and outflow creeks (Williams et al. 1985, Abell et al. 2000). Highly endemic fauna occur in these springs, including species and subspecies of fish, and rare and uncommon described and undescribed springsnails, many of which only occur in a single spring system.

Aquatic Ecology/Habitat

Springs and seeps often occur in environments unconnected to other aquatic features and frequently support an extensive and often endemic aquatic flora and fauna. Physical, chemical, and disturbance patterns are the most dominant factors influencing spring communities (Levin and Flora 2008) and are strongly influenced by high elevations, rugged topography, and diverse lithology (Thomas et al. 1996, Hershey et al. 2010, Abele 2011). Springs are often characterized by extreme water quality conditions (e.g., temperatures, chemistry) but are predominantly governed by stable water discharge (Shepard 1993). Spring and seep waters are often chemically unique due to the hydrogeochemistry of the aquifers that support them and due to the effects of evaporation on non-flowing springs and seeps, which increases the concentrations and overall salinity of their unique chemical signatures. The resulting hydrochemical uniqueness of springs and seeps makes each a unique setting for biodiversity, further supporting the development of unique biotic assemblages. Springs can range in flows from *Phalaropus tricolor*), Wilson's Snipe (*Gallinago delicata*), Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*).

Species of Conservation or Management Concern Assessed via Coarse-Filter

The Central Basin and Range Rapid Ecoregional Assessment (Comer et al. 2013) developed and applied criteria to identify species to be targeted for focused assessment. These species are of conservation or management concern due primarily to their relative vulnerability to extinction. These vulnerabilities stem from their sensitivity to past or current land/water uses, natural rarity, or forecasted vulnerabilities to climate change effects.

Listed below are species of conservation or management concern that are very strongly associated with this ecosystem type across the entire ecoregion. This close connection facilitates analysis in that the ecosystem type provides a practical "coarse filter" for analysis, and documentation of ecological status for locations of this ecosystem type should provide a reliable indication of the ecological status for each of these species. Therefore, these species of conservation or management concern were not assessed and reported on individually.

Freshwater and Anadromous Fishes: A Roundtail Chub (*Gila robusta jordani*), Alvord Chub (*Gila alvordensis*), Big Smokey Valley Speckled Dace (*Rhinichthys osculus lariversi*), Big Smokey Valley Tui Chub (*Gila bicolor ssp. 8*), Clover Valley Speckled Dace (*Rhinichthys osculus oligoporus*), Desert Dace (*Eremichthys acros*), Diamond Valley Speckled Dace (*Rhinichthys osculus ssp. 10*), Fish Creek Springs Tui Chub (*Gila bicolor euchila*), Fish Lake Valley Tui Chub (*Gila bicolor ssp. 4*), Hiko White River Springfish (*Crenichthys baileyi grandis*), Hot Creek Valley Tui Chub (*Gila bicolor ssp. 5*), Independence Valley Speckled Dace (*Rhinichthys osculus lethoporus*), Independence Valley Tui Chub (*Gila bicolor isolata*), Least Chub (*Iotichthys phlegethontis*), Little Fish Lake Valley Tui Chub (*Gila bicolor ssp. 6*), Monitor Valley Speckled Dace (*Rhinichthys osculus ssp. 5*), Moorman White River Springfish (*Crenichthys baileyi thermophilus*), Newark Valley Tui Chub (*Gila bicolor newarkensis*), Oasis Valley Speckled Dace (*Rhinichthys osculus ssp. 6*), Owens River Pupfish (*Cyprinodon radiosus*), Owens Tui Chub (*Gila bicolor snyderi*), Pahrump Poolfish (*Empetrichthys latos latos*), Preston White River Springfish (*Crenichthys baileyi albivallis*), Railroad Valley Springfish (*Crenichthys nevadae*), Railroad Valley Tui Chub (*Gila bicolor ssp. 7*), Relict Dace (*Relictus solitarius*), White River Sculpin (*Cottus sp. 3*), White River Spinedace (*Lepidomeda albivallis*), White River Springfish (*Crenichthys baileyi baileyi*).

Freshwater Snails: Antelope Valley Pyrg (*Pyrgulopsis pellita*), Benton Valley Springsnail (*Pyrgulopsis aardahli*), Bifid Duct Pyrg (*Pyrgulopsis peculiaris*), Big Warm Spring Pyrg (*Pyrgulopsis papillata*), Butterfield Pyrg (*Pyrgulopsis lata*), Camp Valley Pyrg (*Pyrgulopsis montana*), Carinate Duckwater Pyrg (*Pyrgulopsis carinata*), Carinate Glenwood Pyrg (*Pyrgulopsis inopinata*), Cloaked Physa (*Physa megalochlamys*), Cortez Hills Pebblesnail (*Pyrgulopsis bryantwalkeri*), Crittenden Springsnail (*Pyrgulopsis lentiglans*), Desert Springsnail (*Pyrgulopsis deserta*), Desert Tryonia (*Tryonia porrecta*), Desert Valvata (*Valvata utahensis*), Dixie Valley Pyrg (*Pyrgulopsis dixensis*), Duckwater Pyrg (*Pyrgulopsis aloba*), Duckwater Warm Springs Pyrg (*Pyrgulopsis villacampae*), Elko Pyrg (*Pyrgulopsis leporina*), Elongate Cain Spring Pyrg (*Pyrgulopsis augustae*), Elongate Mud Meadows Pyrg (*Pyrgulopsis notidicola*), Emigrant Pyrg (*Pyrgulopsis gracilis*), Fat-whorled Pondsnail (*Stagnicola bonnevillensis*), Fish Lake Pyrg (*Pyrgulopsis ruinosa*), Fish Slough Springsnail (*Pyrgulopsis perturbata*), Flat Pyrg (*Pyrgulopsis breviloba*), Flat-topped Steptoe Pyrg (*Pyrgulopsis planulata*), Fly Ranch Pyrg (*Pyrgulopsis bruesi*), Grapevine Springs Elongate Tryonia (*Tryonia margae*), Grapevine Springs Squat Tryonia (*Tryonia rowlandsi*), Hamlin Valley Pyrg (*Pyrgulopsis hamlinensis*), Hardy Pyrg (*Pyrgulopsis marcida*), Hubbs Pyrg (*Pyrgulopsis hubbsi*), Humboldt Pyrg (*Pyrgulopsis humboldtensis*), Kings River Pyrg

(*Pyrgulopsis imperialis*), Lake Valley Pyrg (*Pyrgulopsis sublata*), Landyes Pyrg (*Pyrgulopsis landyei*), Large Gland Carico Pyrg (*Pyrgulopsis basiglans*), Lockes Pyrg (*Pyrgulopsis lockensis*), Long Valley Pyrg (*Pyrgulopsis longae*), Longitudinal Gland Pyrg (*Pyrgulopsis anguina*), Monitor Tryonia (*Tryonia monitorae*), Neritiform Steptoe Ranch Pyrg (*Pyrgulopsis neritella*), Ninemile Pyrg (*Pyrgulopsis nonaria*), Northern Soldier Meadow Pyrg (*Pyrgulopsis militaris*), Northern Steptoe Pyrg (*Pyrgulopsis serrata*), Northwest Bonneville Pyrg (*Pyrgulopsis variegata*), Oasis Valley Springsnail (*Pyrgulopsis micrococcus*), Otter Creek Pyrg (*Pyrgulopsis fusca*), Ovate Cain Spring Pyrg (*Pyrgulopsis pictilis*), Owens Valley Springsnail (*Pyrgulopsis owensensis*), Pahranagat Pebblesnail (*Pyrgulopsis merriami*), Pleasant Valley Pyrg (*Pyrgulopsis aurata*), Pyramid Lake Pebblesnail (*Fluminicola dalli*), Sada's Pyrg (*Pyrgulopsis sadai*), Small Gland Carico Pyrg (*Pyrgulopsis bifurcata*), Smoke Creek Pyrg (*Pyrgulopsis eremica*), Smooth Glenwood Pyrg (*Pyrgulopsis chamberlini*), Southern Bonneville Pyrg (*Pyrgulopsis transversa*), Southern Duckwater Pyrg (*Pyrgulopsis anatina*), Southern Soldier Meadow Pyrg (*Pyrgulopsis umbilicata*), Southern Steptoe Pyrg (*Pyrgulopsis sulcata*), Squat Mud Meadows Pyrg (*Pyrgulopsis limaria*), Steptoe Hydrobe (*Eremopyrgus eganensis*), Sterile Basin Pyrg (*Pyrgulopsis sterilis*), Sub-globose Snake Pyrg (*Pyrgulopsis saxatilis*), Sub-globose Steptoe Ranch Pyrg (*Pyrgulopsis orbiculata*), Toquerville Springsnail (*Pyrgulopsis kolobensis*), Transverse Gland Pyrg (*Pyrgulopsis cruciglans*), Twentyone Mile Pyrg (*Pyrgulopsis millenaria*), Upper Thousand Spring Pyrg (*Pyrgulopsis hovinghi*), Utah Physa (*Physa gyrina utahensis*), Vineyards Pyrg (*Pyrgulopsis vinyardi*), Virginia Mountains Pebblesnail (*Fluminicola virginius*), Western Lahontan Pyrg (*Pyrgulopsis longiglans*), White River Valley Pyrg (*Pyrgulopsis sathos*), Wong's Springsnail (*Pyrgulopsis wongi*)

Mammals: Vagrant Shrew (*Sorex vagrans*)

Other Beetles: Ash Springs riffle beetle (*Stenelmis lariversi*)

Other Insects: Pahranagat Naucorid Bug (*Pelocoris shoshone shoshone*)

Stoneflies: Utah Sallfly (*Sweltsa gaufini*)

Flowering Plants: Desert Allocarya (*Plagiobothrys salsus*), Fish Slough Milkvetch (*Astragalus lentiginosus var. piscinensis*), Mesic Milkvetch (*Astragalus diversifolius*), Mono Buckwheat (*Eriogonum ampullaceum*), Sodaville Milkvetch (*Astragalus lentiginosus var. sesquimetralis*), Tecopa Bird's-beak (*Cordylanthus tecopensis*), Ute Ladies'-tresses (*Spiranthes diluvialis*)

Change Agent Effects

Springs and seeps are threatened by channelization, overgrazing of neighboring riparian zones, diversions and groundwater withdrawal, and construction of aquaculture projects for channel catfish, as well as development for petroleum and agricultural expansion (Williams et al. 1985).

Because community structure in springs is mostly governed by biotic interactions (as opposed to environmental fluctuations) and because of the high rates of endemism, springs are highly

susceptible to invasions. The majority of invasive species in our list can invade spring ecosystems. All trophic levels in springs can be affected either through predation, direct and indirect competition, changes in primary and secondary productivity, altered food webs, and changes in community structure. Impacts from invasives in spring ecosystems can be greater than in any other aquatic ecosystem in this ecoregion. Predacious and omnivorous mollies and guppies, tilapia, carp, and frog taxa can proliferate in springs ecosystems and devastate native communities, including *Carassius aurartus* (gold fish), *Cyprinus carpio* (carp), *Ictalurus punctatus* (channel catfish), and *Poecilia reticulata* (guppies) that can cause extinctions due to predation and competition for limited resources.

Non-native snails also do extremely well in spring ecosystems and can directly compete with native endemic snails for resources including food and habitat. *Melanoides tuberculatus* is perhaps the most important invasive snail in springs in the region (Abele 2011), however, the New Zealand mudsnail can also invade spring habitats and has been reported to be a strong competitor with rare and threatened snails in spring habitats (Richards 2004). Invasive crayfish are extremely problematic, particularly those in the family Cambaridae. Non-native Cambaridae crayfish are highly invasive and, when established, can have far-reaching effects on biodiversity, community structure, energy transfer, food webs, effects on fisheries, and severe effects on the structure and functioning of spring ecosystems (Gutierrez-Yurrita et al. 1998, Lodge et al. 2000, Geiger et al. 2005, Crehuet et al. 2007, Larson and Olden 2011, Leib et al. 2011). Cambaridae crayfish are mostly omnivores that feed on large quantities of invertebrates, plants, and detritus (Feminella and Resh 1989, Huner and Barr 1991, Ilheu and Bernardo 1993, Correia 2002, Alcorlo et al. 2004, Rudnick and Resh 2005) and are prone to prey on slow-moving invertebrates, particularly snails and clams (Nystrom et al. 1999, Stenroth and Nystrom 2003).

Invasive macrophytes can proliferate in springs and exclude native species and alter habitat structure for fish and invertebrates (Eiswerth et al. 2000, Cheruvelil et al. 2002, Warfe and Barmuta 2004). Didymo may become a nuisance in springs that have adequate flows (Spaulding and Elwell 2007). It appears that extensive stalk generation in didymo blooms occurs when cell division rates are nutrient-limited, photosynthetic rates are high, water temperature is increased, or ultra-violet radiation is increased from loss of stratospheric ozone (Falkowski and LaRoche 1991, Bothwell et al. 2006, Marshal 2007). Didymo can cause major shifts in benthic macroinvertebrate density and composition, including reduction in grazers and increase in collector-gatherer densities (McLaughlin and McKnight 2010, Richards 2010, Taylor 2010). Like many algal blooms, didymo outbreaks may not continually occur, but may be cyclical or sporadic.

Conceptual Diagram

Some Change Agents, such as new rural or urban development including mines and landfills, directly remove an aquatic Conservation Element. Other Change Agents such as roads and transportation corridors (railroads, power lines, solar arrays, oil pumping platforms and the like) fragment the distribution or connectivity of the resource (Debinski and Holt 2001). Irrigated agriculture can completely remove aquatic resource occurrences or can cause increased pollution through runoff of fertilizers or metal-laden sediment (Boody and DeVore 2006, Chipps et al. 2006, Pimentel et al. 2004). Water development projects have a double effect on aquatic resources, as they both change

the amount and timing of flow, and also fragment the network of flow (Poff et al. 2010). Aquatic invasive species can have profound effects on the amount of oxygen available, can directly compete with native species, and have been shown to completely alter the native ecosystem habitat (e.g. tamarisk) (Brussard et al. 2000; USGS 2011). These stressors result in different levels of response depending on the degree of impact and how many stressors are acting on the same resource simultaneously. Responses include a reduction in species diversity and species genetic diversity with the fragmentation and loss of habitat (Vryanckx et al. 2011). Species can become less abundant as their habitats become fragmented or continually disturbed such that reproduction is less successful (Brussard et al. 2000). As native species become stressed, other more tolerant and opportunistic species may increase in abundance, further reshaping the food web. Shifts in species abundance and presence can result in changes in species composition in the vegetative community of stream banks or in the aquatic community. The indicators shown in the causal diagrams below measure the amount of stress or the type and magnitude of response to stress within each resource. See the Ecological Status Scorecard section for full explanation of each indicator (Figure B-10).

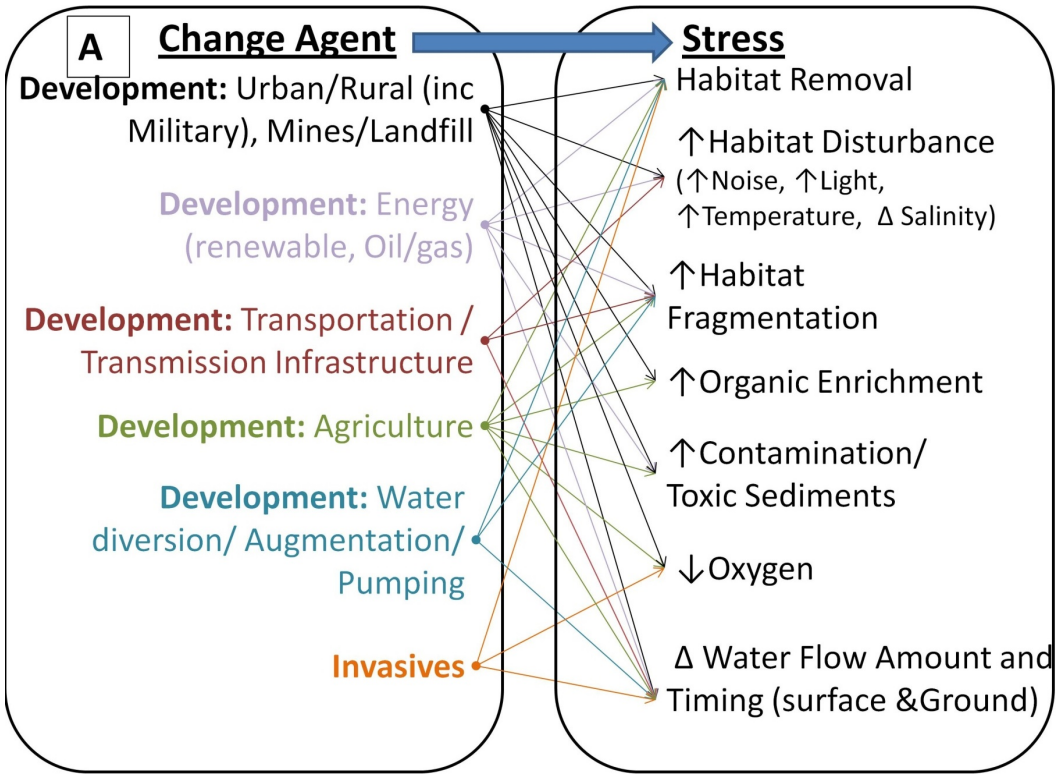

Figure B-10 (A). The conceptual model for Great Basin Springs and Seeps illustrates the effect of each Change Agent on the resource's ecological integrity. A. Change Agents are a source of different types of stressors.

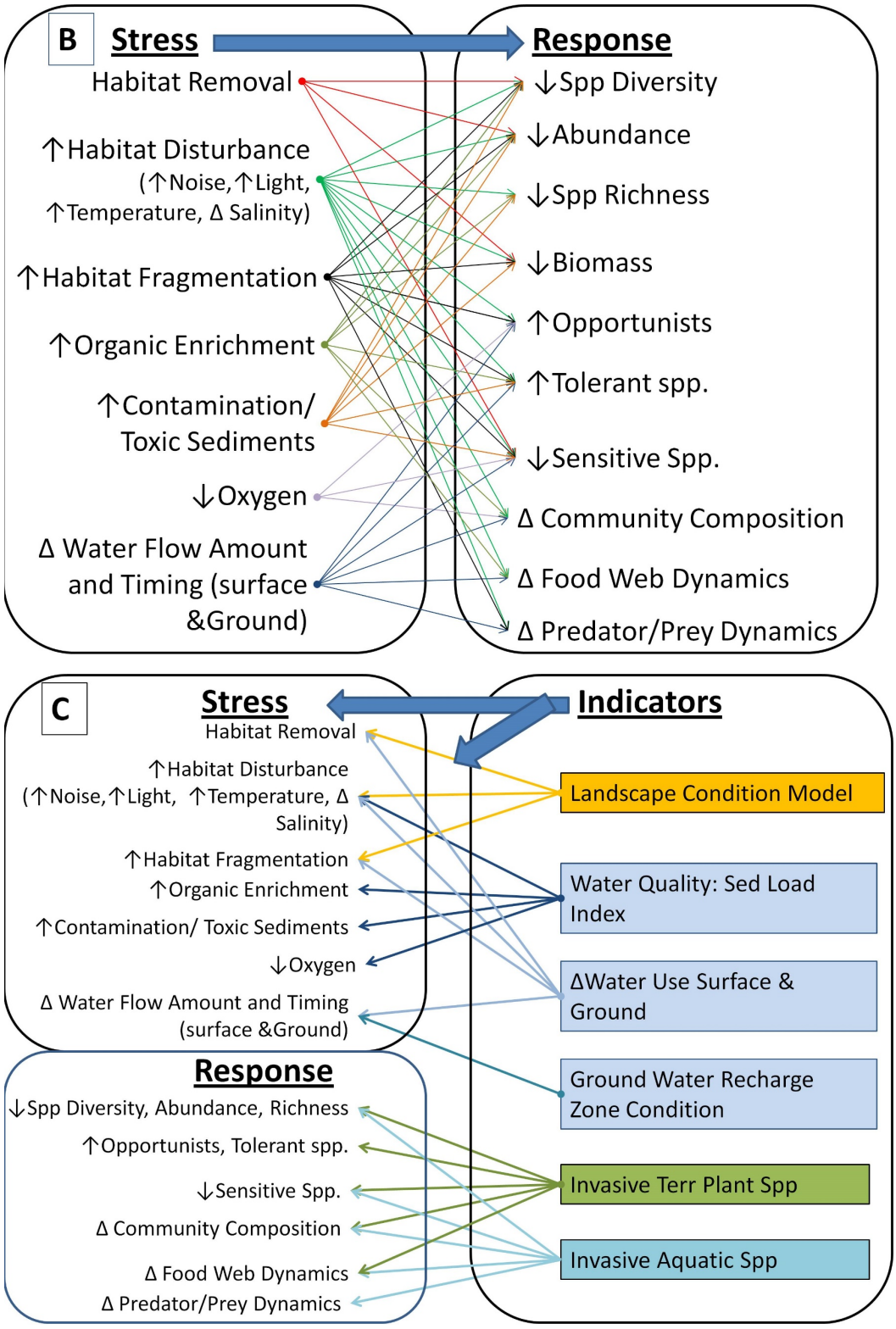

Figure B-10 (B and C). The conceptual model for Great Basin Springs and Seeps illustrates the effect of each Change Agent on the resource's ecological integrity. B. Different types of stressors invoke different responses. C. Indicators are metrics by which we can directly measure the amount of stress or response within each type of resource.

Ecological Integrity Criteria and Indicators

The conceptual model diagrams presented above in the discussion of Change Agent Effects indicate the stresses and responses expected. These stresses and responses were identified based on an assessment of the key ecological attributes for this resource type, based on the information presented in the Focal Resource Characterization section. Panel C of these diagrams, and Table B-10 below, identify a suite of indicators for assessing levels of stress and response. The indicators are organized by key ecological attributes (KEAs), which are pivotal ecological characteristics and primary ecological drivers. KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For coarse-filter conservation elements the reporting unit for the present assessment is at the 5th Level Watershed (10-digit hydrologic catalog units, or HUC10). The assessment indicators with justifications and definitions are presented in Table B-10, organized by Key Ecological Attributes.

Each indicator is normalized so that its values range between 0 and 1, with 1 being highest ecological status and 0 being lowest. The mean index scores of these indicators may then be averaged by each Key Ecological Attribute. Displaying the indicators with individual scores allows user to interpret which particular ecological attributes in a reporting area is driving the ecological status of the resource.

Table B-10. Indicators used for ecological status assessment of Great Basin Springs and Seeps

Key Ecological Attribute	Indicator	Definition	Justification
Surrounding Landscape Condition	Landscape Condition Index	This indicator is measured by intersecting the mapped area or habitat distribution map of the resource with the LCM layer and reporting the average LCM index value for the resource or habitat within each 5th level watershed, or 4x4 km square units for species. Landscape Condition Index is a 90x90m square unit resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. The results are a score for landscape condition from 0 to 1 with 1 being very high landscape condition and values close to 0 likely having very poor condition.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance.
Native Species Assemblag	Invasive Aquatic Index	The number of invasive taxa known to be present in HUC.	Impacts from invasive species are considered to be of equal importance with habitat loss and global climate change as the primary causal factors responsible for the world's rapidly decreasing biodiversity and altered ecosystem functioning.
	Presence of Invasive Plant Species	Number of known locations of non-native introduced tamarisk, Russian olive, and annual grasses in HUC..	Increased non-native plant species reduces habitat quality for numerous wildlife species, decreases forage for livestock, reduces ecosystem native species richness, increases soil erosion potential and decreases ecosystem resiliency and resistance to damage from impacts, including climate change.
Hydrologic Regime	Condition of Groundwater Recharge Zone	Measures the landscape condition of the likely groundwater recharge zone (areas above 2000 m within each 10 digit HUC) by percent area in hard-surface development as determined in Landscape Condition Index results.	Hard surface development within a groundwater recharge zone can divert and reduce the amount water entering the groundwater.
	Ground Water Use	Ratio of ground water use per HUC as defined by USGS Southwest Principal Aquifer study (Anning 2009; McKinney and Anning 2009) to total surface water discharge per the HUC (calculated from NHD).	Data show the degree to which surface water is being consumed for human use relative to availability within each watershed. The greater the use, the less water is available to support aquatic species, specifically higher ground water use is likely to draw down water tables and therefore springs.

Table B-10. Indicators used for ecological status assessment of Great Basin Springs and Seeps

Key Ecological Attribute	Indicator	Definition	Justification
Hydrologic Regime (continued)	Surface Water Use	Ratio of surface water use per HUC as defined by USGS Southwest Principal Aquifer study (Anning 2009; McKinney and Anning 2009) to total surface water per the HUC (calculated from NHD).	Data show the degree to which surface water is being consumed for human use relative to availability within each ten digit HUC. The greater the use, the less water is available to support aquatic species.
Water Quality	Sediment Loading Index	Index values of total Suspended Sediment (developed by NSPECT) which are based on percent of land uses (NLCD) that contribute excess sedimentation and suspended solids via surface water runoff and overland flow into a wetland, as measured within the 200 m buffer area.	Different surrounding land uses contributes to the sediment loading in adjacent waters. Increased sediment clogs fish gills, reduce successful spawning, decrease visibility and increase pollutant loadings, especially heavy metals.

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Inter-Mountain Basins Greasewood Flat

Model Group: Basin Wet System > Playa, Greasewood Flats, Washes

Focal Resource Characterization

Summary

This ecological system occurs throughout much of the western U.S. in intermountain basins and extends onto the western Great Plains and into central Montana. It typically occurs near drainages on stream terraces and flats or may form rings around more sparsely vegetated playas. Sites typically have saline soils, a shallow water table and flood intermittently, but remain dry for most growing seasons. The water table remains high enough to maintain vegetation, despite salt accumulations. This system usually occurs as a mosaic of multiple communities, with open to moderately dense shrublands dominated or codominated by *Sarcobatus vermiculatus*. Other shrubs that may be present to codominant in some occurrences include *Atriplex canescens, Atriplex confertifolia, Atriplex gardneri, Artemisia tridentata ssp. wyomingensis, Artemisia tridentata ssp. tridentata, Artemisia cana ssp. cana*, or *Krascheninnikovia lanata*. Occurrences are often surrounded by mixed salt desert scrub or big sagebrush shrublands. The herbaceous layer, if present, is usually dominated by graminoids. There may be inclusions of *Sporobolus airoides, Pascopyrum smithii, Distichlis spicata* (where water remains ponded the longest), *Calamovilfa longifolia, Poa pratensis, Puccinellia nuttalliana*, or *Eleocharis palustris* herbaceous types.

Greasewood flats are tolerant of a wide range of climatic conditions but most commonly grow in areas with hot, dry summers. *Sarcobatus vermiculatus* commonly occurs in areas with a seasonally high water table and is often the only green shrub in pluvial desert sites with available groundwater. Average annual precipitation ranges from 12.7 to 25.4 cm. Elevation ranges from 1220 to 2165 m. Stands occur on dry, sunny, flat valley bottoms, on lowland floodplains, in ephemeral stream channels, and at playa margins. It is a common system found throughout much of the Great Basin and Mojave Desert. Greasewood flat communities generally occur below the moister sagebrush or shadscale zones. In high saline areas, greasewood often grows in nearly pure stands, although on less saline sites, it commonly grows with a number of other shrub species and typically has a grass understory. It typically occurs near drainages on stream terraces and flats or may form rings around

more sparsely vegetated playas. Sites typically have saline soils, a shallow water table and flood intermittently, but remain dry for most growing seasons. The water table remains high enough to maintain vegetation, despite salt accumulations. Soils are fine-textured saline or alkaline, occasionally on coarsely-textured non-saline soils (USU 2002).

This system usually occurs as a mosaic of multiple communities, with open to moderately dense shrublands dominated or codominated by *Sarcobatus vermiculatus*. Other shrubs that may be present to codominant in some occurrences include *Atriplex canescens, Atriplex confertifolia, Atriplex gardneri, Artemisia tridentata ssp. wyomingensis, Artemisia tridentata ssp. tridentata, Artemisia cana ssp. cana*, or *Krascheninnikovia lanata*. The herbaceous layer, if present, is usually dominated by graminoids. There may be inclusions of *Sporobolus airoides, Pascopyrum smithii, Distichlis spicata* (where water remains ponded the longest), *Calamovilfa longifolia, Poa pratensis, Puccinellia nuttalliana*, or *Eleocharis palustris* herbaceous types.

Aquatic Ecology/Habitat

Greasewood flats are typically subirrigated and only rarely have open water except when associated with playas. As the water evaporates, salinity increases, affecting the biota. Greasewood flats only rarely have seasonally ponded water, and are completely dry on the surface for many years. Generally there is no open water component to this system.

Species of Conservation or Management Concern Assessed via Coarse-Filter

The Central Basin and Range Rapid Ecoregional Assessment (Comer et al. 2013) developed and applied criteria to identify species to be targeted for focused assessment. These species are of conservation or management concern due primarily to their relative vulnerability to extinction. These vulnerabilities stem from their sensitivity to past or current land/water uses, natural rarity, or forecasted vulnerabilities to climate change effects.

Listed below are species of conservation or management concern that are very strongly associated with this ecosystem type across the entire ecoregion. This close connection facilitates analysis in that the ecosystem type provides a practical "coarse filter" for analysis (Noss 1987), and documentation of ecological status for locations of this ecosystem type should provide a reliable indication of the ecological status for each of these species. Therefore, these species of conservation or management concern were not assessed and reported on individually.

Reptiles: Zebra-tailed Lizard (*Callisaurus draconoides*)

Flowering Plants: Bonneville Saltbush (*Atriplex bonnevillensis*), Winged Milkvetch (*Astragalus pterocarpus*)

Natural Dynamics

Sarcobatus vermiculatus sprouts vigorously following fire and may increase stem density, growing up to 0.76 m in height within three years, with 90% of the plants surviving one year after burning (Anderson 2004). It is also known to sprout after application of herbicides and other types of disturbance (USU 2002).

A state-and-transition model was developed for this system type using the Vegetation Dynamics Development Tool (VDDT) and simulations were run in the Path Landscape Model (ESSA Technologies). Models were developed by the Nevada chapter of The Nature Conservancy. VDDT is a state-and-transition modeling platform that simulates vegetation dynamics based on user-defined states and transitions. States (boxes) represent a vegetation community defined by a cover type and structural stage (Figure B-11). Transitions link states through processes such as succession, disturbance, and management, and can be either deterministic or probabilistic. Deterministic transitions usually simulate successional changes by defining the number of years until a transition occurs from one successional stage to the next, in the absence of disturbance. Probabilistic transitions specify an annual transition probability of moving from one state to another. Probabilistic transitions represent disturbances (e.g. fire and drought), ecological processes (e.g. tree encroachment and natural recovery), and land management activities (e.g. seeding and prescribed fire).

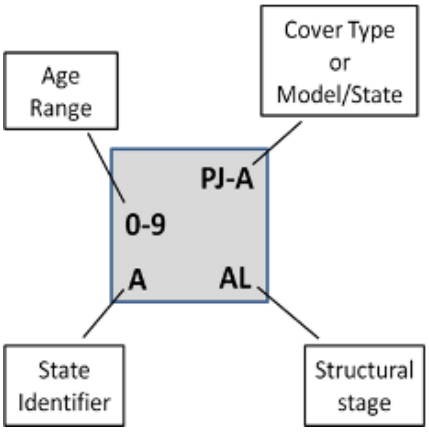

Figure B-11. State classes in VDDT describe a plant community type by defining the cover type, age range, structural stage and identifier of each of its vegetative state classes.

For each simulation, the landscape is partitioned into a number of cells or simulation units and allocated among state classes in the model. At each time step, deterministic transitions occur based on the age of the cell and probabilistic transitions may occur based on the specified transition probability. VDDT is a nonspatial model, and all cells are simulated independently of other cells. The Path model uses VDDT as a simulation engine but allows users to organize model runs, run many models simultaneously, and view output across all model runs simultaneously. Each coarse-filter resource was described using two VDDT models – one describing the natural range of variation (NRV) under historic conditions, and one describing contemporary dynamics and including uncharacteristic states such as annual grass or depleted shrub. The contemporary model includes all states and transitions from the NRV model in addition to a set of uncharacteristic states and transitions.

The historic (NRV) model contains state classes that characterize natural vegetation conditions and transitions that describe vegetation dynamics (Figure B-12).

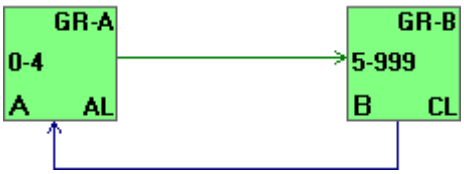

Figure B-12. VDDT model for historic (NRV) conditions of Inter-Mountain Basins Greasewood Flat. Green arrows show deterministic succession and other arrows represent all other probabilistic transitions.

The historic (NRV) VDDT model for Inter-Mountain Basins Greasewood Flat contains the following state classes:

- *Class A (Early):* 0-20% herbaceous (inland saltgrass, bottlebrush squirreltail, and alkali sacaton) cover; <5% cover rabbitbrush and resprouting greasewood. Age range is 0-5 years.
- *Class B (Late-Closed):* 15-25% greasewood cover; <10% cover other shrubs (rabbitbrush, saltbushes, and budsage); <10% cover of grass (inland saltgrass, bottlebrush squirreltail, and alkali sacaton). Age range is 5-999 years.

Change Agent (CA) Characterization

Greasewood flats are resilient and tough. A lowering of the groundwater table is the most devastating stressor.

The VDDT model for current conditions contains all states and transitions in the historic (NRV) model (Figure B-12; Table B-11) and contains additional uncharacteristic states and transitions that represent contemporary vegetation dynamics. The VDDT model for current conditions is presented in Figure B-13 and Table B-12.

Table B-11. Transition probabilities and return intervals for the Inter-Mountain Basins Greasewood Flat ecological system under NRV. These probabilities are used in the VDDT model to estimate the relative abundance of each class over time.

From Class	To Class	Transition Type	Probability	Return Interval (years)
B	A	Replacement Fire	0.00010	10,000
B	A	Very Wet Year	0.00700	143

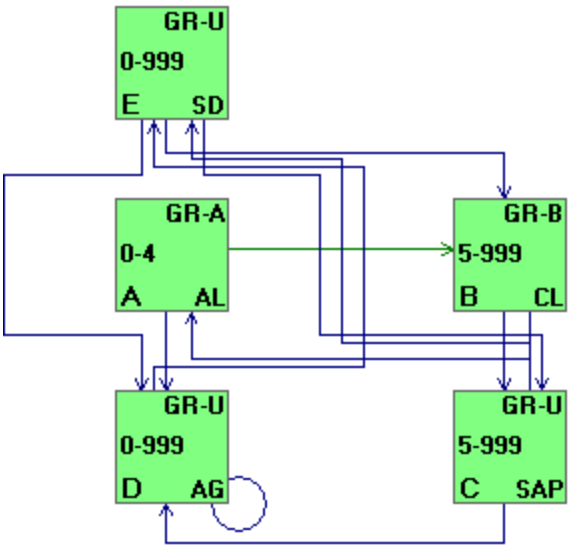

Figure B-13. VDDT model for current conditions of Inter-Mountain Basins Greasewood Flat. Uncharacteristic state classes are denoted with a U in the top-right corner of the box. Green arrows show deterministic succession and other arrows represent all other probabilistic transitions.

Table B-12. Transition probabilities and return intervals for the Inter-Mountain Basins Greasewood Flat ecological system under current conditions. These transition probabilities were used in the VDDT model illustrated in Figure 3 to calculate departure estimates.

From Class	To Class	Transition Type	Probability	Return Interval (years)
A	D	Annual Grass Invasion	0.00500	200
B	C	Annual Grass Invasion	0.00500	200
E	C	Annual Grass Invasion	0.00500	200
E	D	Annual Grass Invasion	0.00500	200
E	B	Natural Recovery	0.00100	1,000
B	A	Replacement Fire	0.00010	10,000
C	D	Replacement Fire	0.02500	40
D	D	Replacement Fire	0.10000	10
B	A	Very Wet Year	0.00700	143

The current conditions VDDT model for Inter-Mountain Basins Greasewood Flat contains all of the states found in the historic model (Figure B-12) in addition to the following uncharacteristic state classes:

- *Class C (Shrub-Annual Grass/Perennial Grass):* 5-25% cover of greasewood; 5-20% non-native grass cover. Age range is 5-999 years.
- *Class D (Annual Grass):* 5-30% non-native annual grass cover; <10% shrub cover. Age range is 0-999 years.
- *Class E (Seeded):* 5-20% seeded native or introduced species cover . Age range is 0-999 years.

Conceptual Diagram

Some Change Agents, such as new rural or urban development including mines and landfills, directly remove a resource. Other Change Agents such as roads and transportation corridors (railroads, power lines, solar arrays, oil pumping platforms and the like) fragment resource distribution and connectivity (Debinski and Holt 2001). Irrigated agriculture can remove entire aquatic resource occurrences and can cause increased pollution through runoff of fertilizers or metal-laden sediment (Boody and DeVore 2006, Chipps et al. 2006, Pimentel et al. 2004). Water development projects have a double effect on aquatic resources, as they both change the amount and timing of flow, and also fragment the network of flow (Poff et al. 2010). Aquatic invasive species can have profound effect on the amount of oxygen available, can directly compete with native species, and have been shown to completely alter the native ecosystem habitat (e.g. tamarisk) (Brussard et al. 2000; USGS 2011). These stressors result in different levels of response depending on the degree of impact and how many stressors are acting on the same resource simultaneously. Responses include a reduction in species diversity and species genetic diversity with the fragmentation and loss of habitat (Vryanckx et al. 2011). Species can become less abundant as their habitats become fragmented or continually disturbed such that reproduction is less successful (Brussard et al. 2000). As native species become stressed, other more tolerant and opportunistic species may increase in abundance, further altering the food web. Shifts in species abundance and presence can result in changes in species composition in the vegetative community of stream banks or in the aquatic community. The indicators shown in the causal diagrams below measure the amount of stress or the type and magnitude of response to stress within each resource. See the Ecological Status Scorecard section for full explanation of each indicator (Figure B-14).

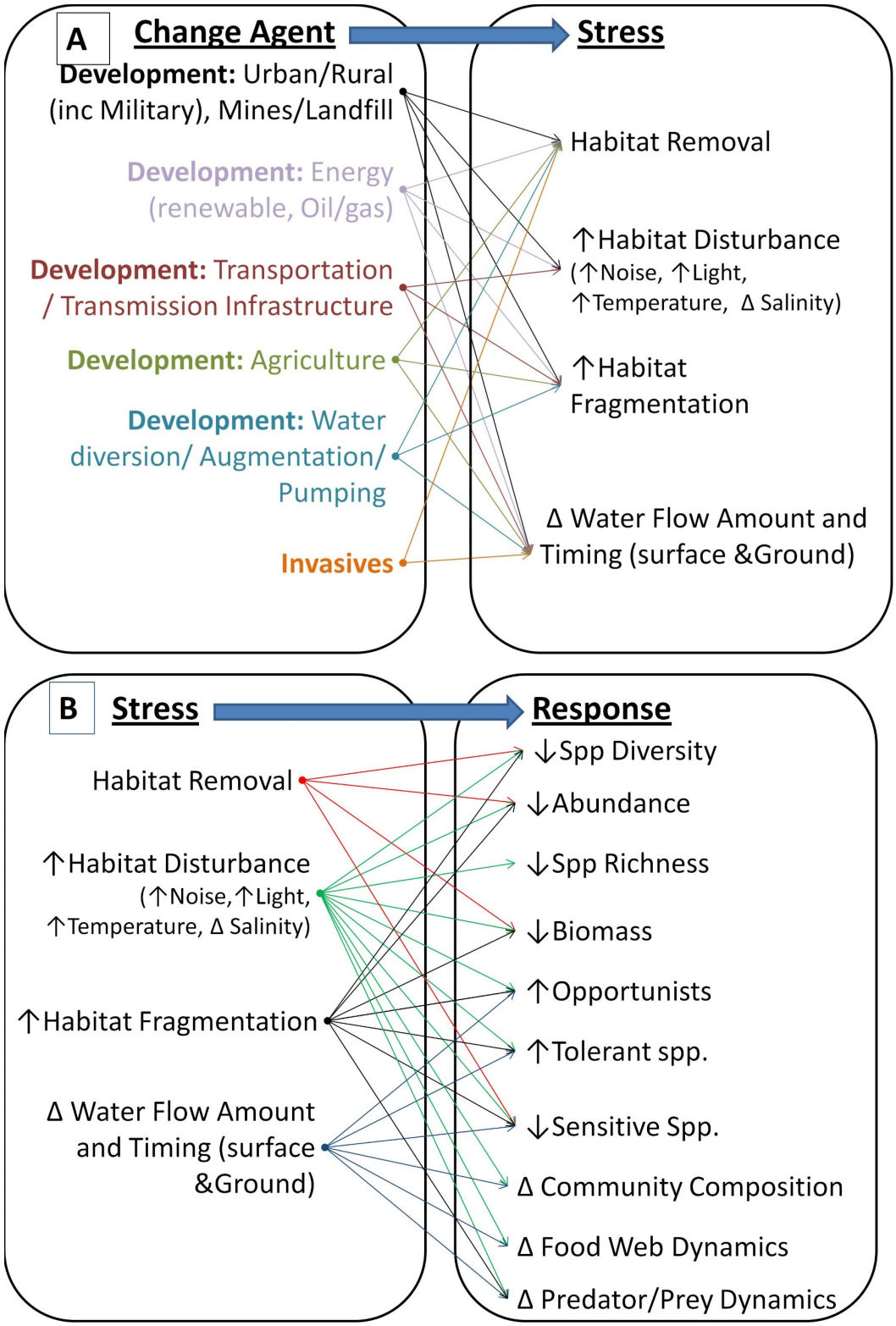

Figure B-14 (A and B). The conceptual model for Inter-Mountain Basins Greasewood Flat illustrates the effect of each Change Agent on the resource's ecological integrity. A. Change Agents are a source of different types of stressors. B. Different types of stressors invoke different responses.

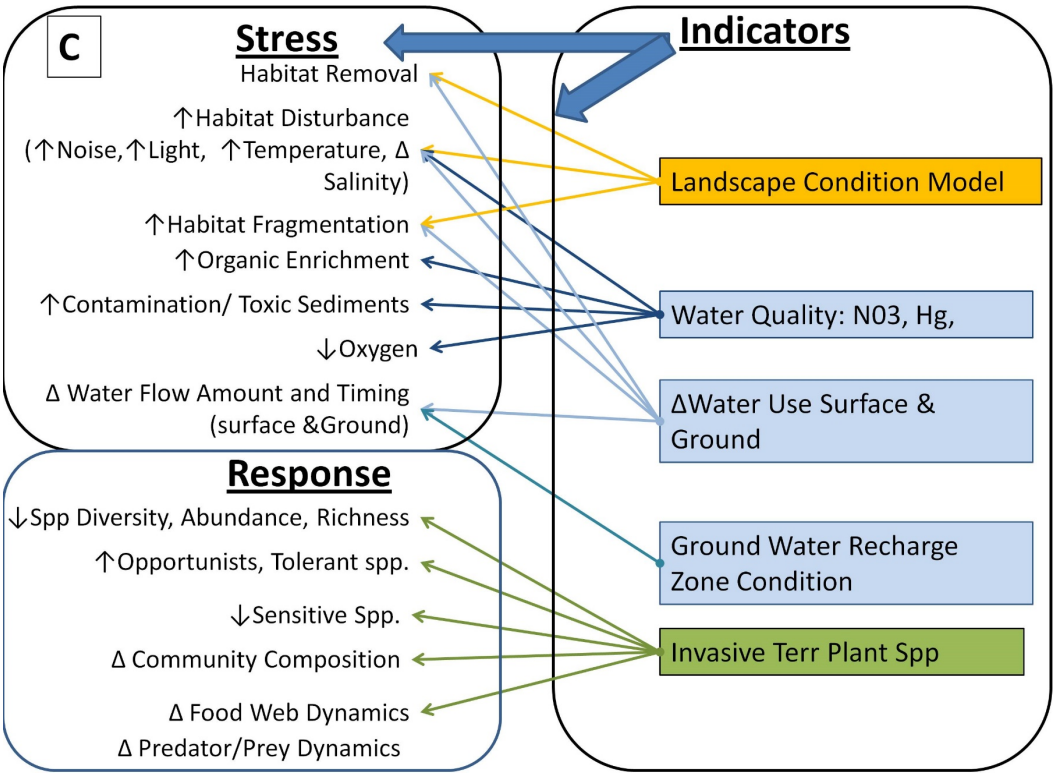

Figure B-14 (C). The conceptual model for Inter-Mountain Basins Greasewood Flat illustrates the effect of each Change Agent on the resource's ecological integrity. A. Change Agents are a source of different types of stressors. B. Different types of stressors invoke different responses. C. Indicators are metrics by which we can directly measure the amount of stress or response within each type of resource.

Ecological Integrity Criteria and Indicators

The conceptual model diagrams presented above in the discussion of Change Agent Effects indicate the stresses and responses expected. These stresses and responses were identified based on an assessment of the key ecological attributes for this resource type, based on the information presented in the Focal Resource Characterization section. Panel C of these diagrams, and Table B-13 below, identify a suite of indicators for assessing levels of stress and response. The indicators are organized by key ecological attributes (KEAs), which are pivotal ecological characteristics and primary ecological drivers. KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For coarse-filter conservation elements the reporting unit for the present assessment is at the 5th Level Watershed (10-digit hydrologic catalog units, or HUC10). The assessment indicators with justifications and definitions are presented in Table B-13, organized by Key Ecological Attributes.

Each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest. The mean index scores of these indicators may then be averaged by each Key Ecological Attribute. Displaying the indicators with individual scores allows user to interpret which particular ecological attributes in a reporting area is driving the ecological status of the resource.

Table B-13. Indicators used for ecological status assessment of Inter-Mountain Basins Greasewood Flat Conservation Element.

Key Ecological Attribute	Indicator	Definition	Justification
Surrounding Landscape Condition	Landscape Condition Index	This indicator is measured by intersecting the mapped area or habitat distribution map of the resource with the LCM layer and reporting the average LCM index value for the resource or habitat within each 5th level watershed, or 4x4 km square units for species. Landscape Condition Index is a 90x90m square unit resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. The results are a score for landscape condition from 0 to 1 with 1 being very high landscape condition and values close to 0 likely having very poor condition.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance.
	Invasive Annual Cover Index	This indicator is measured using the mapped area or habitat distribution of the resource with an abundance map of introduced invasive annual plant species. The output is predicted percent cover of invasive annual species within each 5th level HUC. The Invasive Annual Cover Index is calculated by multiplying the invasive annual cover percent by 4 then subtracting the product from 1 to produce a normalized scale from 0 to 1 with 0 being 25% or greater cover of invasive annuals and 1 being invasive annuals absent.	Invasive annual plant species displace natural composition and provide fine fuels that significantly increase spread of catastrophic fire.
Native Species Assemblage	Presence of Invasive Plant Species	Number of known locations of non-native introduced tamarisk, Russian olive, and annual grasses per HUC.	Increased non-native plant species reduces habitat quality for numerous wildlife species, decreases forage for livestock, reduces ecosystem native species richness, increases soil erosion potential and decreases ecosystem resiliency and resistance to damage from impacts, including climate change.

Table B-13 (continued). Indicators used for ecological status assessment of Inter-Mountain Basins Greasewood Flat Conservation Element.

Key Ecological Attribute	Indicator	Definition	Justification
Fire Regime	Fire Regime Departure Index	This indicator is assessed by calculating and summarizing the updated LandFire Succession classes (SClass) layer which characterizes current vegetation succession classes for the distribution of each resource within each 5th-level HUC. The resulting proportional calculation for current conditions is compared to the expected proportions, as derived from the VDDT or Path-Tools model characterizing the expected natural range of variation (NRV). This comparison defines the degree of departure (%). The SClass Departure Index is calculated by subtracting the Departure percent from 1 to produce a normalized scale from 0 to 1 with 1 being no departure from NRV in distribution of succession classes and 0 being complete departure from NRV.	A mix of successional classes among patches of a given vegetation type results from fire and other natural disturbances. Through field observation and modeling, one can establish a working hypothesis for the expected proportional mix of successional classes where human alterations are limited. Departure from the mixture predicted under NRV indicates uncharacteristic disturbance regime and declining integrity.
Hydrologic Regime	Condition of Groundwater Recharge Zone	Measures the landscape condition of the likely groundwater recharge zone (areas above 2000 m within each 10 digit HUC) by percent area in hard-surface development as determined in LCI.	Hard surface development within a groundwater recharge zone can divert and reduce the amount water entering the groundwater.
	Ground Water Use	Ratio of ground water use per HUC as defined by USGS Southwest Principal Aquifer study (Anning 2009; McKinney and Anning 2009) to total surface water discharge per the HUC (calculated from NHD).	Data show the degree to which ground water is being consumed for human use relative to availability within each watershed. The greater the use, the less water is available to support phreatophytes.
	Perennial Flow Modification by Diversion Structures	Number of aquaducts intersecting or branching from NHD perennial streams. Total per HUC.	Indication of the amount of flow modification and change in hydrologic regime.
	Surface Water Use	Ratio of surface water use per HUC as defined by USGS Southwest Principal Aquifer study (Anning 2009; McKinney and Anning 2009) to total surface water discharge per the HUC (calculated from NHD).	Data show the degree to which surface water is being consumed for human use relative to availability within each watershed. The greater the use, the less water is available to support phreatophytes through runoff and recharge.
Water Quality	Atmospheric Deposition-Nitrate Loading (NO3)	Rate of total (dry + wet) deposition of Nitrate (NO3) as N per unit area within HUC.	Used a representative indicator of nutrient loading pollutant. Increased nitrogen in aquatic systems can increase algal growth and decrease oxygen content.
	Atmospheric Deposition-Toxic Mercury Loading (Hg)	Rate of wet deposition of Mercury (Hg) per unit area within HUC.	Used as a representative of the amount of toxic pollutants. Toxic pollutants affect reproduction, growth and neurologic functioning of aquatic animals. Mercury in particular accumulates up the food chain and can affect human health as well.

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Inter-Mountain Basins Playa

Model Group: Basin Wet System > Playa, Greasewood Flats, Washes

Focal Resource Characterization

Summary

This ecological system is composed of barren and sparsely vegetated playas (generally < 10% plant cover) found in the intermountain western U.S. Salt crusts are common throughout, with small saltgrass beds in depressions and sparse shrubs around the margins. These systems are intermittently flooded. The water is prevented from percolating through the soil by an impermeable soil subhorizon and is left to evaporate. Soil salinity varies greatly with soil moisture and greatly affects species composition. Characteristic species may include *Allenrolfea occidentalis, Sarcobatus vermiculatus, Grayia spinosa, Puccinellia lemmonii, Leymus cinereus, Distichlis spicata*, and/or *Atriplex* spp.

The following physical description is from Desert Processes Working Group (DPWG no date): "Playas are enclosed shallow depressions in basins which contain deposits and evaporites from the impoundment of episodic streamflow or near-surface groundwater. Playas can be entirely dry or seasonally filled with water. The sediment load carried into a playa from streams or blown in by wind characteristically includes clay, silt, and fine-grained sand. The evaporites, which come from runoff as well as from groundwater, commonly contain chlorides, sulfates, nitrates, carbonates, borates, or other salts, including toxic ones such as cyanates or arsenates. Evaporation of water from playas leaves exposed surfaces of the resident material, which can be any mix of clay, silt, fine sand, and salt. Playa surfaces change seasonally with addition or loss of water, and with wind activity. They can be smooth to rough, wet to dry, and hard to soft, puffy, flaky, cracked, ridged, and friable, and they can have hummocky relief of 1 to 2 m. Although dust generation by wind erosion of fine particles is common, not all playas are equally susceptible to wind erosion. Hard, smooth, and dry

playas with a high clay/low salt content seem to be more frequent along ephemeral, intermittent, and dry desert water courses. Soft, rough, wet playas with high salt/low clay content tend to occur in depressions whose floors intersect the water table."

From DPWG (no date):"Playas are enclosed shallow depressions in basins, tectonic lows, interdune flats which contain deposits and evaporites from the impoundment of episodic streamflow or near-surface groundwater. Playas can be entirely dry or seasonally filled with water. The sediment load carried into a playa from streams or blown in by wind characteristically includes clay, silt, and fine-grained sand. The evaporites, which come from runoff as well as from groundwater, commonly contain chlorides, sulfates, nitrates, carbonates, borates, or other salts, including toxic ones such as cyanates or arsenates. Evaporation of water from playas leaves exposed surfaces of the resident material, which can be any mix of clay, silt, fine sand, and salt. Playa surfaces change seasonally with addition or loss of water, and with wind activity. They can be smooth to rough, wet to dry, and hard to soft, puffy, flaky, cracked, ridged, and friable, and they can have hummocky relief of 1 to 2 m. Although dust generation by wind erosion of fine particles is common, not all playas are equally susceptible to wind erosion. Hard, smooth, and dry playas with a high clay/low salt content seem to be more frequent along ephemeral, intermittent, and dry desert water courses. Soft, rough, wet playas with high salt/low clay content tend to occur in depressions whose floors intersect the water table."

Playas are shallow, intermittent wetlands. Some playas will only flood during years with high precipitation, sometimes only once or twice in a decade. Others will have standing water every spring, except in the driest of years. As the water evaporates, salinity increases, affecting the biota.

Clarke (2010) describes the aquatic successional pattern for playas as follows: When standing water stays on the playa's surface for a few days, green algae such as *Dunaliella* and *Dangeardinella* emerge and multiply and begin to tint the water green if the salinity is mild, reddish as the water evaporates. After water has stood for about a day and a half, the eggs of fairy shrimp begin to hatch. Fairy shrimp are crustaceans in the order Anostraca, which includes dozens of species of fairy shrimp native to ephemeral lakes in the southwestern deserts. Most of them are filter feeders about a half-inch long, gathering up the halobacteria, algae, and organic detritus that may have been blown or washed onto the playa. Also present can be *Branchinecta gigas*, the giant fairy shrimp that preys on its smaller cousins. Other crustaceans that emerge from wet playa soil include tadpole shrimp and clam shrimp whose dormant larvae can withstand several years (7+) of drought before a wet year allows them to become adults and breed. About a week after a good rain, spadefoot toads will emerge from their burrows. If the playa is of the mudflat variety rather than salty, the spadefoots head for the ephemeral lake, where the males fill the air with their odd, sheep-like calls to attract potential mates. The females lay eggs in the water, which hatch in a day or so, and the resulting tadpoles race to eat as much as they can, including algae, smaller invertebrates, organic detritus, and occasional smaller tadpoles. The tadpoles grow and develop quickly. If the standing water persists for a week, young adult frogs emerge and head uphill to dig burrows in which they can wait out the next drought. If the lake dries up in three days rather than eight, a generation of toads will perish. Ephemeral lakes in the desert often play host to an astonishing range of birds.

Species of Conservation or Management Concern Assessed via Coarse-Filter

The Central Basin and Range Rapid Ecoregional Assessment (Comer et al. 2013) developed and applied criteria to identify species to be targeted for focused assessment. These species are of conservation or management concern due primarily to their relative vulnerability to extinction. These vulnerabilities stem from their sensitivity to past or current land/water uses, natural rarity, or forecasted vulnerabilities to climate change effects.

Listed below are species of conservation or management concern that are very strongly associated with this ecosystem type across the entire ecoregion. This close connection facilitates analysis in that the ecosystem type provides a practical "coarse filter" for analysis, and documentation of ecological status for locations of this ecosystem type should provide a reliable indication of the ecological status for each of these species. Therefore, these species of conservation or management concern were not assessed and reported on individually.

Birds: Western Snowy Plover (Charadrius alexandrinus nivosus)

Flowering Plants: Desert Allocarya (Plagiobothrys salsus), Owens Valley Checker-mallow (Sidalcea covillei)

Natural Dynamics

Playas are shallow, seasonal wetlands that lie in the lowest point of a closed watershed. Their basins are lined with clay soils, which collect and hold water from rainfall and runoff events. Water evaporates, leaving high salt concentrations in the soils. Some playas will only flood with water during years with high precipitation, sometimes only once or twice in a decade. Others will have standing water every spring, except in the driest of years. During flooded years, some salt-tolerant marsh plant species may grow, such as cattails (*Typha* spp.) or bulrushes (*Scirpus* spp.).

Change Agent (CA) Characterization

Off-road vehicles that disturb the surface may impact fairy shrimp eggs and other dormant biota.

Conceptual Diagram

Some Change Agents, such as new rural or urban development including mines and landfills, directly remove playas. Other Change Agents such as roads and transportation corridors (railroads, power lines, solar arrays, oil pumping platforms and the like) fragment playa distribution and connectivity (Debinski and Holt 2001). Irrigated agriculture can remove entire playa occurrences and can cause increased pollution through runoff of fertilizers or metal-laden sediment (Boody and DeVore 2006, Chipps et al. 2006, Pimentel et al. 2004). Water development projects have a double effect on playas, as they both change the amount and timing of surface inflow, and also fragment the network of washes providing that inflow. These stressors result in different levels of response depending on the degree of impact and how many stressors are acting on the same resource simultaneously. Responses may include a reduction in species diversity and species genetic diversity with the fragmentation and loss of habitat (Vryanckx et al. 2011). Species can become less abundant as their habitats become fragmented or continually disturbed such that reproduction is less successful (Brussard et al. 2000). As native species become stressed, other more tolerant and opportunistic species may increase in abundance, further altering the food web. The indicators shown in the causal diagrams below

measure the amount of stress or the type and magnitude of response to stress within each resource. See the Ecological Status Scorecard section for full explanation of each indicator (Figure B-15).

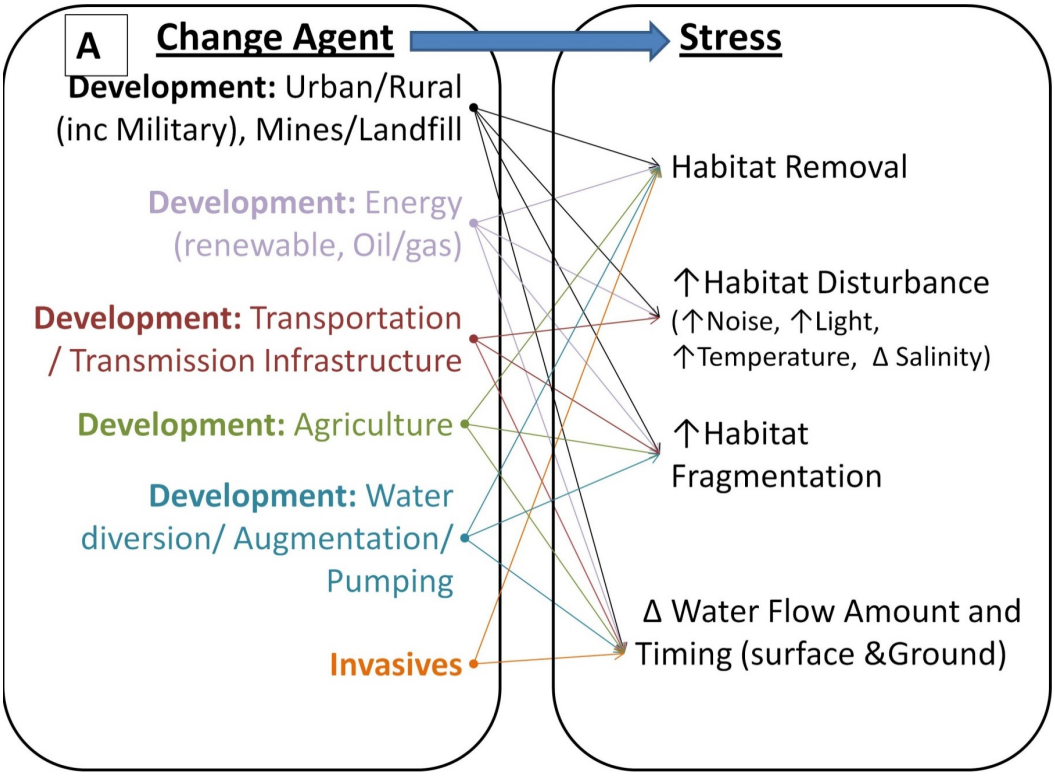

Figure B-15 (A). The conceptual model for Inter-Mountain Basins Playa illustrates the effect of each Change Agent on the resource's ecological integrity. A. Change Agents are a source of different types of stressors.

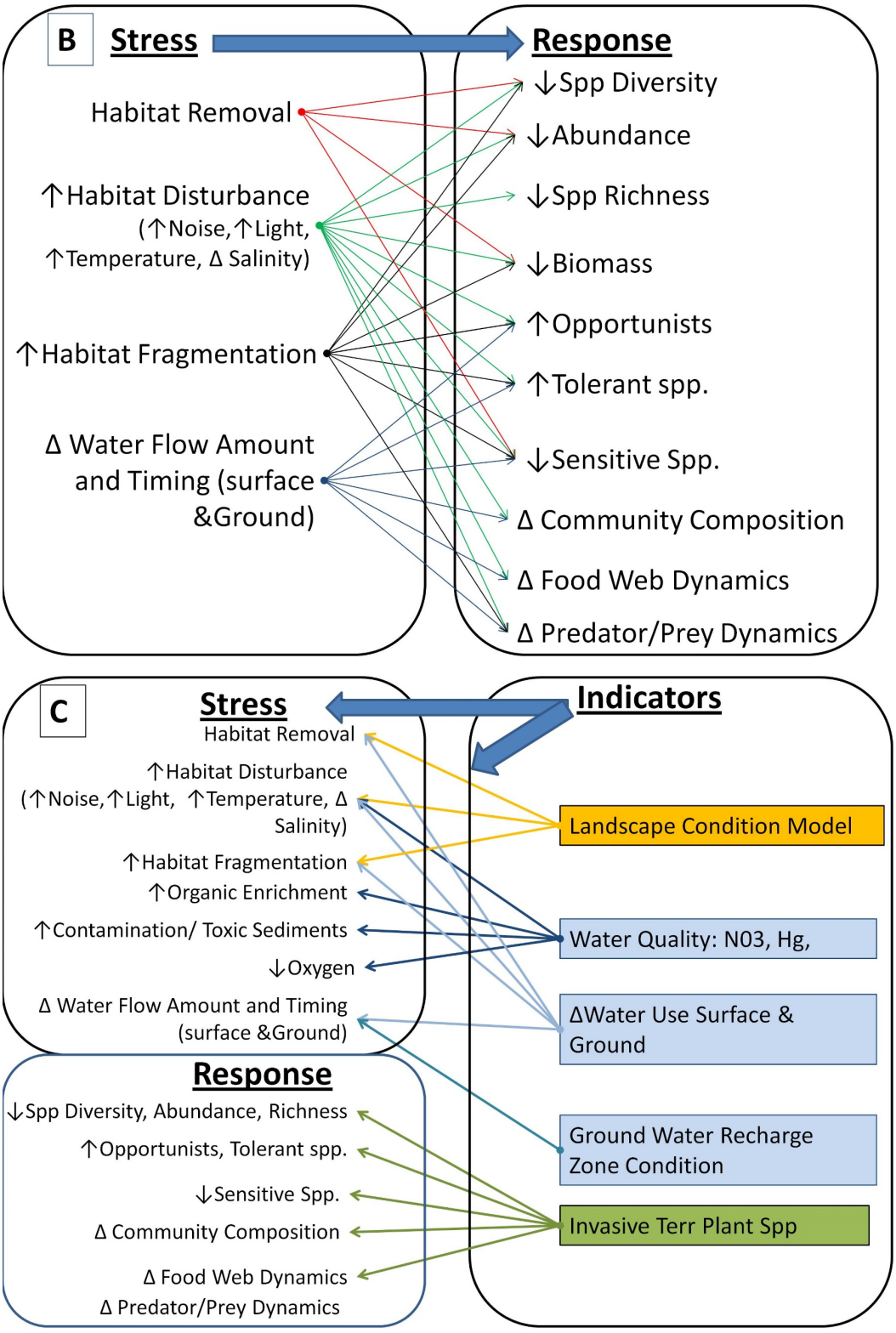

Figure B-15 (B and C). The conceptual model for Inter-Mountain Basins Playa illustrates the effect of each Change Agent on the resource's ecological integrity. B. Different types of stressors invoke different responses. C. Indicators are metrics by which we can directly measure the amount of stress or response within each type of resource.

Ecological Integrity Criteria and Indicators

The conceptual model diagrams presented above in the discussion of Change Agent Effects indicate the stresses and responses expected. These stresses and responses were identified based on an assessment of the key ecological attributes for this resource type, based on the information presented in the Focal Resource Characterization section. Panel C of these diagrams, and Table B-14 below, identify a suite of indicators for assessing levels of stress and response. The indicators are organized by key ecological attributes (KEAs), which are pivotal ecological characteristics and primary ecological drivers. KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For coarse-filter conservation elements the reporting unit for the present assessment is at the 5th Level Watershed (10-digit hydrologic catalog units, or HUC10). The assessment indicators with justifications and definitions are presented in Table B-14, organized by Key Ecological Attributes.

Each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest. The mean index scores of these indicators may then be averaged by each Key Ecological Attribute. Displaying the indicators with individual scores allows user to interpret which particular ecological attributes in a reporting area is driving the ecological status of the resource.

Table B-14. Indicators used for ecological status assessment of Inter-Mountain Basins Playa Conservation Element.

Key Ecological Attribute	Indicator	Definition	Justification
Surrounding Landscape Condition	Landscape Condition Index	This indicator is measured by intersecting the mapped area or habitat distribution map of the resource with the LCM layer and reporting the average LCM index value for the resource or habitat within each 5th level watershed, or 4x4 km square units for species. Landscape Condition Index is a 90x90m square unit resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. The results are a score for landscape condition from 0 to 1 with 1 being very high landscape condition and values close to 0 likely having very poor condition.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance.
Native Species Assemblage	Presence of Invasive Plant Species	Number of known locations of non-native introduced tamarisk, Russian olive, and annual grasses per HUC.	Increased non-native plant species reduces habitat quality for numerous wildlife species, decreases forage for livestock, reduces ecosystem native species richness, increases soil erosion potential and decreases ecosystem resiliency and resistance to damage from impacts, including climate change.
Hydrologic Regime	Condition of Groundwater Recharge Zone	Measures the landscape condition of the likely groundwater recharge zone (areas above 2000 m within each 10 digit HUC) by percent area in hard-surface development as determined in LCI.	Hard surface development within a groundwater recharge zone can divert and reduce the amount water entering the groundwater.
	Ground Water Use	Ratio of ground water use per HUC as defined by USGS Southwest Principal Aquifer study (Anning 2009; McKinney and Anning 2009) to total surface water discharge per the HUC (calculated from NHD).	Data show the degree to which ground water is being consumed for human use relative to availability within each watershed. The greater the use, the less water is available to support phreatophytes.
	Surface Water Use	Ratio of surface water use per HUC as defined by USGS Southwest Principal Aquifer study (Anning 2009; McKinney and Anning 2009) to total surface water discharge per the HUC (calculated from NHD).	Data show the degree to which surface water is being consumed for human use relative to availability within each watershed. The greater the use, the less water is available to support phreatophytes through runoff and recharge.
Water Quality	Atmospheric Deposition-Nitrate Loading (NO3)	Rate of total (dry + wet) deposition of Nitrate (NO3) as N per unit area within HUC.	Used a representative indicator of nutrient loading pollutant. Increased nitrogen in aquatic systems can increase algal growth and decrease oxygen content.

Table B-14. Indicators used for ecological status assessment of Inter-Mountain Basins Playa Conservation Element.

Key Ecological Attribute	Indicator	Definition	Justification
Water Quality (continued)	Atmospheric Deposition-Toxic Mercury Loading (Hg)	Rate of wet deposition of Mercury (Hg) per unit area within HUC.	Used as a representative of the amount of toxic pollutants. Toxic pollutants affect reproduction, growth and neurologic functioning of aquatic animals. Mercury in particular accumulates up the food chain and can affect human health as well.

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Inter-Mountain Basins Wash

Model Group: Basin Wet System > Playa, Greasewood Flats, Washes

Focal Resource Characterization

Summary

This barren and sparsely vegetated (generally < 10% plant cover) ecological system is restricted to intermittently flooded streambeds and banks that are often lined with shrubs such as *Sarcobatus vermiculatus, Ericameria nauseosa, Fallugia paradoxa, Artemisia tridentata ssp. tridentata*, and/or *Artemisia cana ssp. cana* (in more northern and mesic stands) that form relatively dense stringers in open dry uplands. *Grayia spinosa* may dominate in the Great Basin. Shrubs form a continuous or intermittent linear canopy in and along drainages but do not extend out into flats. Typicaly it includes patches of saltgrass meadow where water remains for the longest periods. In parts of Wyoming, stringers or patches of *Artemisia tridentata ssp. tridentata* are large and distinct enough from surrounding upland vegetation due to the influence of the wash that they can be classified separately. However, small intermittent washes may also be included with adjacent uplands if vegetation is not different enough floristically or structurally from uplands (e.g., just a little denser canopy). Soils are variable but are generally less alkaline than those found in the playa system. Desert scrub species (e.g., *Acacia greggii, Prosopis* spp.) that are common in the Mojave, Sonoran and Chihuahuan desert washes are not present. This type can occur in limited portions of the southwestern Great Plains. Where stringers or patches of *Artemisia tridentata ssp. tridentata* are large enough to be mapped separately from both the wash and from the adjacent upland, they are mapped as Inter-Mountain Basins Big Sagebrush Shrubland (resourceS304.777) or Inter-Mountain Basins Big Sagebrush Steppe (resourceS304.778). Invasive, exotic shrubs shrub as *Tamarix* spp. or *Chamaebatiaria millefolium* may be present to dominant in these washes where disturbed.

Aquatic Ecology/Habitat

Washes remain dry for much of the year and flow after seasonal rains that often fall much higher in the watershed. They have limited aquatic habitat, except in occasional pools that fill after wash flows.

Species of Conservation or Management Concern Assessed via Coarse-Filter

The Central Basin and Range Rapid Ecoregional Assessment (Comer et al. 2013) developed and applied criteria to identify species to be targeted for focused assessment. These species are of conservation or management concern due primarily to their relative vulnerability to extinction. These vulnerabilities stem from their sensitivity to past or current land/water uses, natural rarity, or forecasted vulnerabilities to climate change effects.

Listed below are species of conservation or management concern that are very strongly associated with this ecosystem type across the entire ecoregion. This close connection facilitates analysis in that the ecosystem type provides a practical "coarse filter" for analysis, and documentation of ecological status for locations of this ecosystem type should provide a reliable indication of the ecological status for each of these species. Therefore, these species of conservation or management concern were not assessed and reported on individually.

Flowering Plants: Lahontan Beardtongue (*Penstemon palmeri var. macranthus*)

Natural Dynamics

Washes are streambeds of intermittent and ephemeral streams that remain dry for much of the year, and flow after seasonal rains that often fall much higher in the watershed. Pulses of flow distribute sediments and nutrients into playas and other downstream systems.

Change Agent (CA) Characterization

Road crossings (fords and bridges) may alter flow direction during high runoff years. Off-road vehicle use can cause accelerated erosion when streams flow and damage bank configuration.

Conceptual Diagram

Some Change Agents, such as new rural or urban development including mines and landfills, directly remove washes. Other Change Agents such as roads and transportation corridors (railroads, power lines, solar arrays, oil pumping platforms and the like) fragment wash network connectivity (Debinski and Holt 2001). Irrigated agriculture can remove entire wash occurrences and can cause increased pollution through runoff of fertilizers or metal-laden sediment (Boody and DeVore 2006, Chipps et al. 2006, Pimentel et al. 2004). Water development projects have a double effect on washes, as they both change the frequency, amount, and timing of surface inflow, and also fragment drainage network connectivity. These stressors result in different levels of response depending on the degree of impact and how many stressors are acting on the same resource simultaneously. Responses may include a reduction in species diversity and species genetic diversity with the fragmentation and loss of habitat (Vryanckx et al. 2011). Species can become less abundant as their habitats become fragmented or continually disturbed such that reproduction is less successful (Brussard et al. 2000). As native species become stressed, other more tolerant and opportunistic species may increase in abundance, further altering the food web. The indicators shown in the causal diagrams below

measure the amount of stress or the type and magnitude of response to stress within each resource. See the Ecological Status Scorecard section for full explanation of each indicator (Figure B-16).

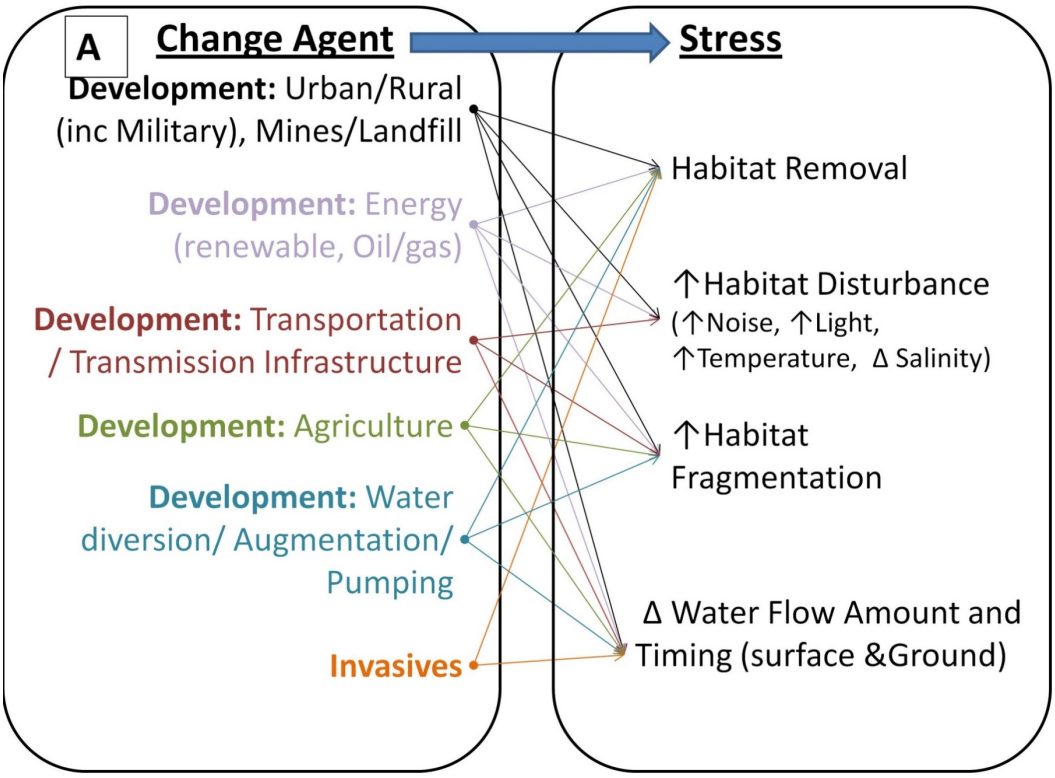

Figure B-16 (A). The conceptual model for Inter-Mountain Basins Wash illustrates the effect of each Change Agent on the resource's ecological integrity. A. Change Agents are a source of different types of stressors.

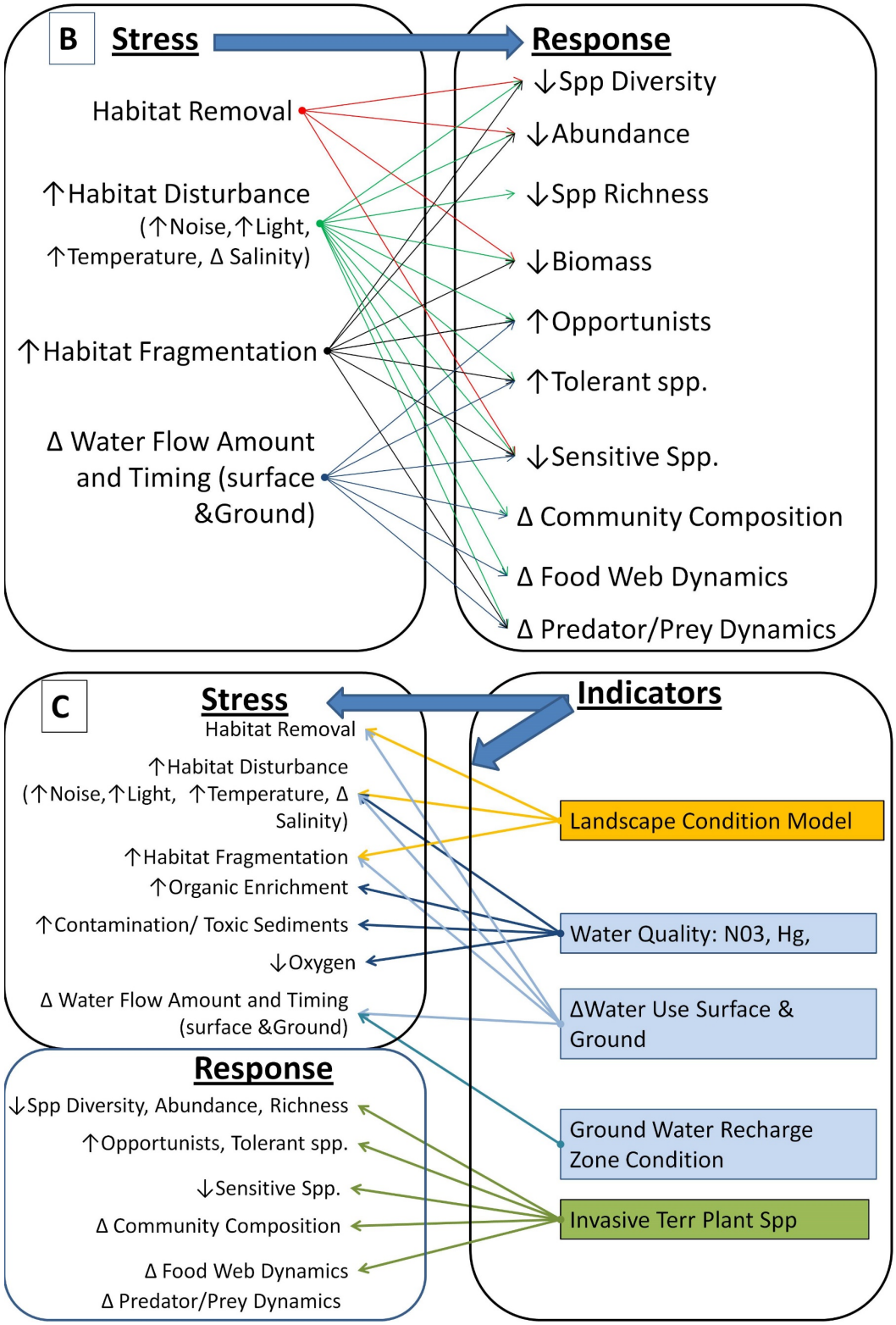

Figure B-16 (B and C). The conceptual model for Inter-Mountain Basins Wash illustrates the effect of each Change Agent on the resource's ecological integrity. B. Different types of stressors invoke different responses. C. Indicators are metrics by which we can directly measure the amount of stress or response within each type of resource.

Ecological Integrity Criteria and Indicators

The conceptual model diagrams presented above in the discussion of Change Agent Effects indicate the stresses and responses expected. These stresses and responses were identified based on an assessment of the key ecological attributes for this resource type, based on the information presented in the Focal Resource Characterization section. Panel C of these diagrams, and Table B-15 below, identify a suite of indicators for assessing levels of stress and response. The indicators are organized by key ecological attributes (KEAs), which are pivotal ecological characteristics and primary ecological drivers. KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For coarse-filter conservation elements the reporting unit for the present assessment is at the 5th Level Watershed (10-digit hydrologic catalog units, or HUC10). The assessment indicators with justifications and definitions are presented in Table B-15, organized by Key Ecological Attributes.

Each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest. The mean index scores of these indicators may then be averaged by each Key Ecological Attribute. Displaying the indicators with individual scores allows user to interpret which particular ecological attributes in a reporting area is driving the ecological status of the resource.

Table B-15. Indicators used for ecological status assessment of Inter-Mountain Basins Wash.

Key Ecological Attribute	Indicator	Definition	Justification
Surrounding Landscape Condition	Landscape Condition Index	This indicator is measured by intersecting the mapped area or habitat distribution map of the resource with the LCM layer and reporting the average LCM index value for the resource or habitat within each 5th level watershed, or 4x4 km square units for species. Landscape Condition Index is a 90x90m square unit resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. The results are a score for landscape condition from 0 to 1 with 1 being very high landscape condition and values close to 0 likely having very poor condition.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance.
Native Species Assemblage	Presence of Invasive Plant Species	Number of known locations of non-native introduced tamarisk, Russian olive, and annual grasses per HUC.	Increased non-native plant species reduces habitat quality for numerous wildlife species, decreases forage for livestock, reduces ecosystem native species richness, increases soil erosion potential and decreases ecosystem resiliency and resistance to damage from impacts, including climate change.
Hydrologic Regime	Condition of Groundwater Recharge Zone	Measures the landscape condition of the likely groundwater recharge zone (areas above 2000 m within each 10 digit HUC) by percent area in hard-surface development as determined in LCI.	Hard surface development within a groundwater recharge zone can divert and reduce the amount water entering the groundwater.
	Ground Water Use	Ratio of ground water use per HUC as defined by USGS Southwest Principal Aquifer study (Anning 2009; McKinney and Anning 2009) to total surface water discharge per the HUC (calculated from NHD).	Data show the degree to which ground water is being consumed for human use relative to availability within each watershed. The greater the use, the less water is available to support phreatophytes.
	Surface Water Use	Ratio of surface water use per HUC as defined by USGS Southwest Principal Aquifer study (Anning 2009; McKinney and Anning 2009) to total surface water discharge per the HUC (calculated from NHD).	Data show the degree to which surface water is being consumed for human use relative to availability within each watershed. The greater the use, the less water is available to support phreatophytes through runoff and recharge.
Water Quality	Atmospheric Deposition-Nitrate Loading (NO3)	Rate of total (dry + wet) deposition of Nitrate (NO3) as N per unit area within HUC.	Used a representative indicator of nutrient loading pollutant. Increased nitrogen in aquatic systems can increase algal growth and decrease oxygen content.

Table B-15 (continued). Indicators used for ecological status assessment of Inter-Mountain Basins Wash.

Key Ecological Attribute	Indicator	Definition	Justification
Water Quaity (continued)	Atmospheric Deposition-Toxic Mercury Loading (Hg)	Rate of wet deposition of Mercury (Hg) per unit area within HUC.	Used as a representative of the amount of toxic pollutants. Toxic pollutants affect reproduction, growth and neurologic functioning of aquatic animals. Mercury in particular accumulates up the food chain and can affect human health as well.

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Vulnerable Species Assemblage Conservation Element Characterization and Conceptual Models

The vulnerable species assemblage Conservation Elements were identified by botany and zoology staff of the Nevada Natural Heritage Program, based on a list of species identified by NatureServe that met one or more of the following criteria:

- Taxa listed under Federal or State protective legislation (including species, subspecies, or designated subpopulations)
- Full species with NatureServe Global Conservation Status rank of G1-G3[3]
- Full species or subspecies listed as BLM Special Status and those listed by applicable State Wildlife Action Plans with habitat included within the ecoregion
- Full species and subspecies scored as *Vulnerable* within the ecoregion according to the NatureServe Climate Change Vulnerability Index (CCVI).

A number of possible assemblages were identified. The ones included in this Appendix are those for which it was possible to develop a spatial model of habitat distribution for the assemblage; several others were dropped due to a lack of data from which to build a model, or because the model itself yielded a poor result. The assemblages range from having only two species (one assemblage), to being composed of a couple of dozen species; some are entirely flowering plants, others a mix of plants and animals including birds, mammals, invertebrates, and reptiles.

The conceptual model for each resource type begins by characterizing the resource and its place within a broader conceptual model and classification of ecological system types for the ecoregion. Table B-16 presents this broader ecoregional model. Each resource is placed within one of the "Level 1" components of the ecoregional model, and within one of the "Level 2" categories that further characterize each Level-1 component.

Each conceptual model presentation includes sections on "Conservation Element Characterization," "Change Agent Effects," "Ecological Integrity Criteria and Indicators," and "References."

[3] See http://www.natureserve.org/explorer/ranking.htm for NatureServe Conservation Status Rank definitions

Table B-16. Ecoregional Conceptual Model, Vulnerable Species Assemblage Conservation Elements, Central Basin and Range Ecoregion.

Level 1	Level 2	Coarse-filter Element Name
Basin Wet System	Basin River & Riparian	Migratory waterfowl & shorebirds
Montane Dry Land System	Alpine Uplands	Carbonate (Limestone/Dolomite) alpine
	Alpine Uplands	Non-carbonate alpine
	Subalpine/Montane Forests & Woodlands	Montane conifer
Basin Dry Land System	Cliff & Outcrop	Azonal carbonate rock crevices
	Cliff & Outcrop	Azonal non-carbonate rock crevices
	Desert Scrub	Gypsum soils
	Semi-desert Shrub & Steppe	Clay soil patches
	Semi-desert Shrub & Steppe	Sand dunes/sandy soils (when deep and loose)

The concept of "vulnerable species assemblage" was developed specifically for the Central Basin and Range Rapid Ecoregional Assessment (Comer et al. 2013). REA assessment, Consequently, these Conservation Elements are not addressed by the types of documentation available for terrestrial and aquatic ecological systems. The descriptive information for these assemblages therefore is relatively simple, summarizing information available for the species within the assemblage and for the environmental setting in which the assemblage is found. Some of the assemblages were particularly difficult to describe (e.g., montane conifer) because the species in the assemblage are diverse in their habitat requirements, many of them are highly mobile, and the "montane conifer zone" itself is a complex mosaic of vegetation types.

The description for each vulnerable species assemblage resource includes a short summary of the concept of the assemblage; and a description of its general range within the ecoregion, its environmental setting, and its "habitat" or ecosystem setting. The descriptions use scientific names for the plants when they are mentioned in the text, although in places the common name for a genus might be used, such as "cottonwood", or "willow". The description provides a complete listing of the species in the assemblage organized by informal taxonomy and with both common and scientific names. All Tables and Figures are numbered within each resources conceptual model, not sequentially through the entire document.

Vascular plant species nomenclature follows the nationally standardized list of Kartesz (1999), with very few exceptions. Nomenclature for nonvascular plants follows Anderson (1990) and Anderson et al. (1990) for mosses, Egan (1987, 1989, 1990, 1991) and Esslinger and Egan (1995) for lichens, and Stotler and Crandall-Stotler (1977) for liverworts/hornworts. Within Reference Appendices not yet developed we will include a table with common names for each species.

The section on “Change Agent Effects” characterizes the primary change agents and current knowledge of their effects on each resource. In most cases, this information was derived by reviewing information for the species within the assemblage, but expert knowledge was included concerning some impacts on particular habitats (e.g. rock climbing is a probable change agent for assemblages found in rock crevices). Some CAs have specific effects on each resource such as the alteration of expected hydrologic regimes and the interacting effects of introduced weed infestations. This section provides a narrative on the effects of CAs on the individual resource, in an “altered dynamics” sub-section. Wildfire and invasive plant CAs are described and modeled within the context of their effects on coarse filter resources.

The section on “Ecological Integrity Criteria and Indicators” describes the methods and data used to assess ecological status, following NatureServe’s ecological integrity framework (Faber-Langendoen et al. 2006, Unnasch et al. 2018). Implementation of this framework results in a scorecard for reporting on the ecological status of a given resource within a given location, and facilitates the aggregation and synthesis of the component results for broader measures of ecological integrity at landscape and ecoregional scales. Using this framework, indicators are chosen to provide a measurement for a limited set of key ecological attributes, or ecological drivers for each resource. Key ecological attributes may include natural characteristics, such as native species composition, or stressors such as effects of relevant change agents, that are well known to affect the natural function and integrity of the resource.

Conceptual or “causal” diagrams are a crucial component of the presentation of the conceptual model of Change Agent effects and the ecological status criteria and indicators. Each diagram consists of three sub-figures, conceptualizing the relationships between Change Agents, the stresses they induce in the resource, the response of the resource to those stressors, and indicators with which to measure either the stress or the resource response with indicators. The diagrams do not show all possible Change Agents, stresses, responses, or indicators – only those relevant to the present assessment.

In part because of project constraints, indicators identified for this assessment emphasize ecosystem stressors that can be more readily measured using available remotely sensed data. Spatial models that reflect these indicators serve as the link between the conceptual models and the spatial representation of ecological status. For each resource, the text provides the definitions and justifications for each of the indicators for that resource, organized in an Ecological Status Scorecard table. Each indicator is scored according to criteria described in the table and is calculated between 0 and 1, with 1 indicating highest ecological status and 0 indicating lowest status (and presumably transitional to a wholly different ecological state).

The section on “References” for each resource lists literature pertaining to the classification, distribution, floristic composition, ecological processes, threats, stressors, or management of individual species included in the resource. However, these are not exhaustive bibliographies, but rather selected lists of key references. Some documents may be listed that are not cited in the narrative text.

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Migratory Waterfowl & Shorebirds

Model Group: Basin Wet System > Basin River & Riparian

Focal Resource Characterization

Summary

This is an assemblage of bird species such as ducks, geese, mergansers, stilts, and avocets, associated with wetlands and waterbodies, or shorelines along rivers and streams. All of the species have wide-ranging migratory routes which include much of both North and South America. The assemblage in the Great Basin is associated with wet meadows, mudflats, flooded fields, shores of intermittent pools and lakes, narrow channels, edges of salt marshes, river sandbars, and sandy beaches. In some areas the birds are utilizing these habitats for nesting and brood-rearing, while other species are foraging or resting during migrations.

All species within this assemblage have wide-ranging migratory routes that include most Canadian provinces, American states and parts of Central and South America. Within the Great Basin, as an assemblage, they are concentrated mostly in western Utah and western Nevada with scattered locations throughout the rest of the ecoregion.

Wet meadows, mudflats, flooded fields, shores of pools and lakes, narrow channels, edges of salt marshes, river sandbars, and sandy beaches. Typicaly where the assemblage occurs is wetlands found at lower elevations, and in basins, rather than higher elevation riparian zones in the montane or subalpine.

Habitat (vegetation) composition is variable with elevation and hydrologic regime. Drier, intermittently flooded areas such as small streams and spring-influenced areas may be shrub-dominated by *Artemisia* spp., *Sarcobatus*, and *Chrysothamnus*, whereas more inundated areas are typically dominated by hydrophytic sedges, grasses and emergent forbs.

Species of Conservation or Management Concern

The Central Basin and Range Rapid Ecoregional Assessment (Comer et al. 2013) developed and applied criteria to identify species to be targeted for focused assessment. These species are of conservation or management concern due primarily to their relative vulnerability to local extirpation. These vulnerabilities stem from their sensitivity to past or current land/water uses or forecasted vulnerabilities to climate change effects.

Listed below are species of conservation or management concern that are very strongly associated with this assemblage. This close connection facilitates our analysis as it provides a practical "coarse filter" for analysis, and documentation of ecological status for locations of the habitat for this assemblage should provide a reliable indication of the ecological status for each of these species. Therefore, these species of conservation or management concern were not assessed and reported on individually.

Birds: American Avocet (*Recurvirostra americana*), American Wigeon (*Anas americana*), Barrow's Goldeneye (*Bucephala islandica*), Black-necked Stilt (*Himantopus mexicanus*), Blue-winged Teal (*Anas discors*), Canada Goose (*Branta canadensis*), Canvasback (*Aythya*

valisineria), Cinnamon Teal (*Anas cyanoptera*), Common Loon (*Gavia immer*), Common Merganser (*Mergus merganser*), Hooded Merganser (*Lophodytes cucullatus*), Least Sandpiper (*Calidris minutilla*), Lesser Scaup (*Aythya affinis*), Long-billed Dowitcher (*Limnodromus scolopaceus*), Northern Pintail (*Anas acuta*), Northern Shoveler (*Anas clypeata*), Redhead (*Aythya americana*), red-necked phalarope (*Phalaropus lobatus*), White-faced Ibis (*Plegadis chihi*), Willet (*Tringa semipalmata*)

Change Agent (CA) Characterization

Threats and stressors include hydrologic alterations (dredging, ditching, drawdowns), wetland degradation, development, pollution, pesticides, and recreational activity.

Conceptual Diagram

Species and assemblages of species experience stress when faced with Change Agents. Some change agents directly remove the element, such as new rural or urban development including mines and landfills. Other change agents such as roads and transportation corridors (railroads, power lines, solar arrays, oil pumping platforms and the like) fragment its distribution (Debinski and Holt 2001). For waterfowl and other species dependent upon water bodies or marshy habitat, irrigated agriculture, in addition to complete replacement of wetland vegetation, can have an effect of increased pollution through fertilizers or heavy metal-laden sedimentation runoff (Boody and DeVore 2006). More dispersed human activities, such as recreation, hunting, logging, or ORV activities result in increases in road densities or disturbance via disrupted breeding, nesting, foraging of animals, soil surface disturbance which affects biological soil crusts (Rosentreter and Eldridge 2002), or uprooting or damage to plants; but these dispersed activities are difficult to measure other than via mapping of roads.

Invasive plant species can have profound effects on ecosystems, and hence upon the species or assemblages occurring in those habitats. Invasive plant species directly compete with native species, and have been shown to completely remove the native ecosystem habitat (e.g., tamarisk) (Brussard et al. 2000). Fragmentation of shrub-steppe and grasslands by agriculture increases cover of annual grasses, total annual/biennial forbs, and bare ground, and decreases cover of perennial forbs and biological soil crusts, and reduces obligate insects (Quinn 2004) and obligate birds and small mammals (Vander Haegen et al. 2001). Fine fuels accumulating from alien annual grasses, such as *Bromus tectorum* are an important fuelbed component in many western ecosytems and can substantially increase the fire frequency (Chambers et al. 2007, Condon et al. 2011, Keeler-Wolf 2007), altering vegetation structure and composition, which in turn leads to alteration of faunal composition, species habitat, direct loss of habitat, and other impacts.

These stressors result in different levels of response depending on the degree of impact and how many stressors are acting on the same resource simultaneously. Responses include a reduction in species diversity and species genetic diversity with the fragmentation and loss of habitat (Vryanckx et al. 2011). Species can become less abundant as their habitats become fragmented or continually disturbed such that reproduction is less successful (Brussard et al. 2000). As native species become stressed, other more tolerant and opportunistic species may increase in abundance, further tipping the balance of food webs in both terrestrial and aquatic systems, and predator/prey dynamics. Shifts in

species or population abundance and presence cause changes in species composition. The indicators shown in the causal diagrams below measure the amount of stress or the type and magnitude of response to stress within each resource. See the Ecological Status Scorecard section for full explanation of each indicator (Figure B-17).

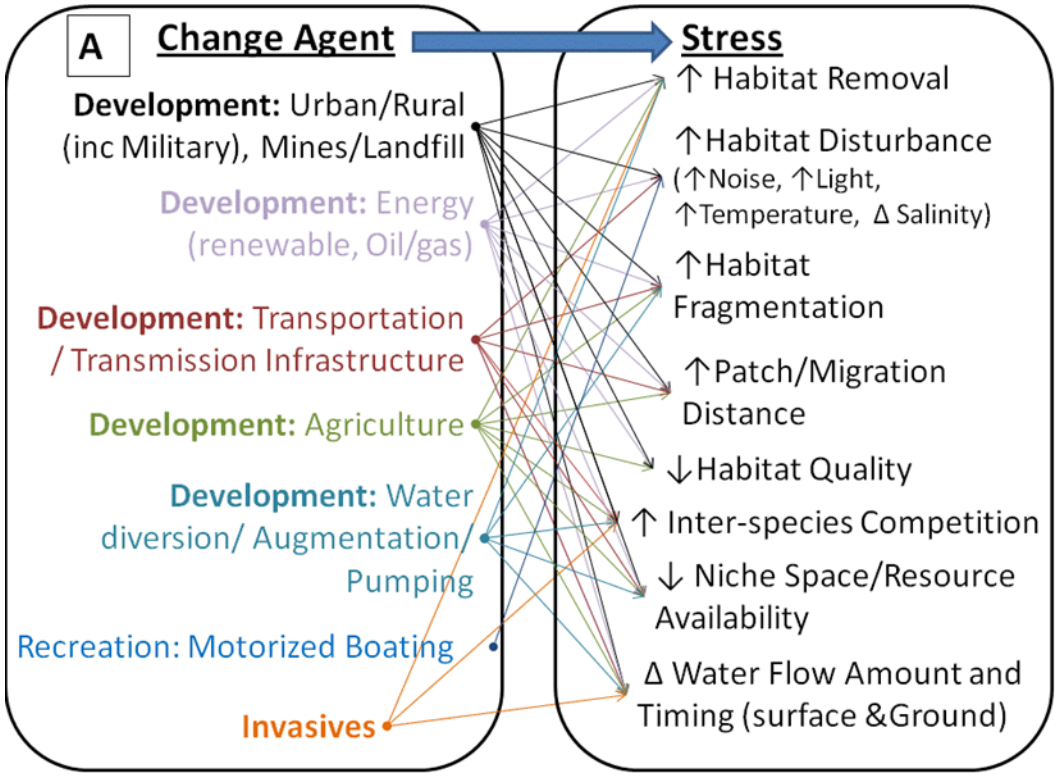

Figure B-17 (A). The conceptual model for Migratory Waterfowl & Shorebirds illustrates the effect of each Change Agent on the resource's ecological integrity. A. Change Agents are a source of different types of stressors.

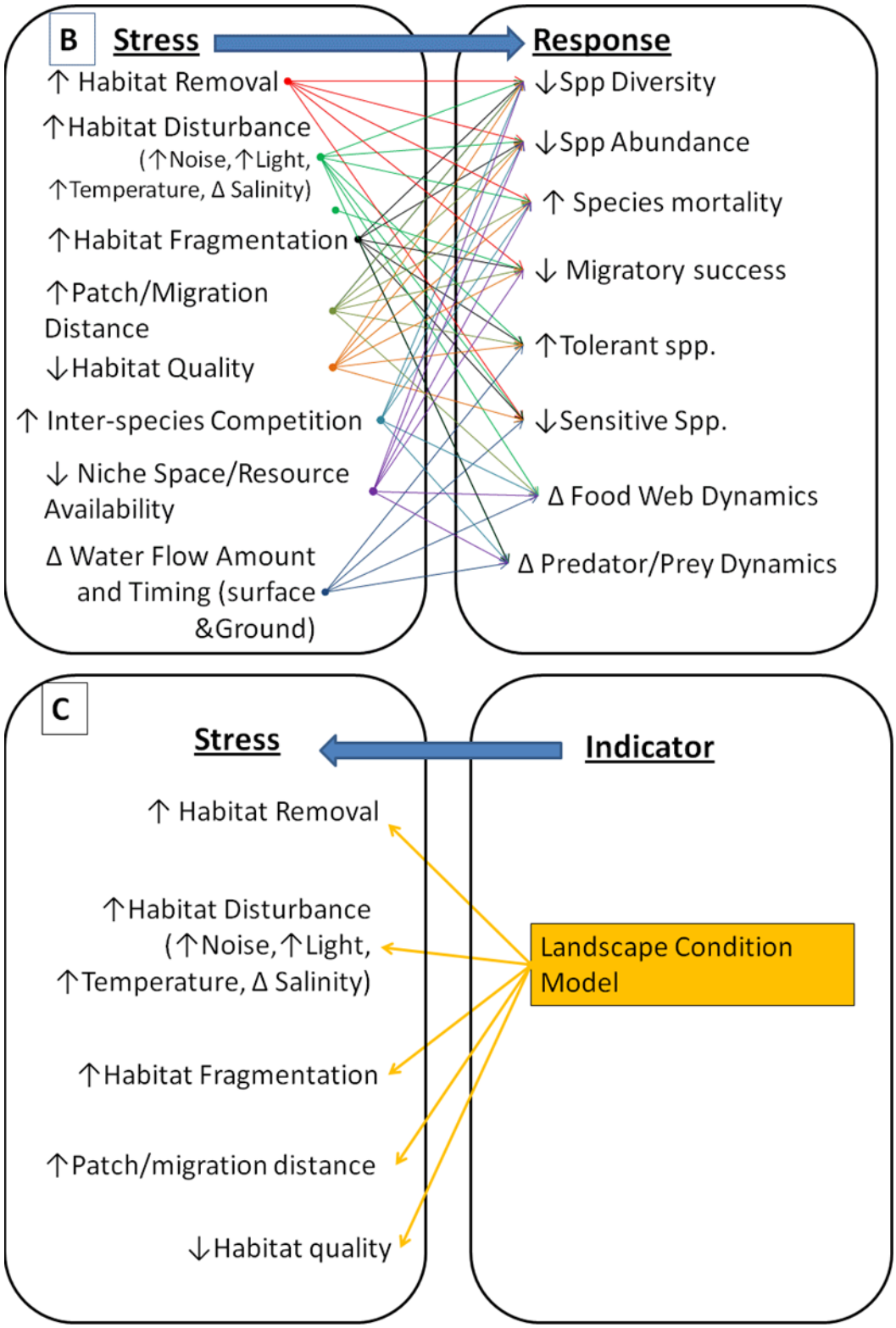

Figure B-17 (B and C). The conceptual model for Migratory Waterfowl & Shorebirds illustrates the effect of each Change Agent on the resource's ecological integrity. B. Different types of stressors invoke different responses. C. Indicators are metrics by which we can directly measure the amount of stress or response within each type of resource.

Ecological Integrity Criteria and Indicators

The Habitat Status Scorecard links conceptual models that describe the relationships between change agents and the habitat requirements of each resource to spatial models that provide practical indicators of habitat status.

The conceptual model diagrams presented above in the discussion of Change Agent Effects indicate the stresses and responses expected at the scale of the habitat for the resource of concern. These stresses and responses were identified based on an assessment of the key habitat attributes for this resource type, based on the information presented in the Focal Resource Characterization section. Panel C of these diagrams, and Table B-17 below, identify a suite of indicators for assessing levels of stress and response. The indicators are organized by key ecological attributes (KEAs), which for vulnerable species assemblages consist of pivotal habitat characteristics and primary ecological drivers. KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. The Habitat Status Scorecard (Table B-17) is designed to report on habitat status indicators by 4x4 km square units for landscape species and species assemblage conservation elements. The assessment indicators with justifications and definitions are presented in Table B-17, organized by Key Ecological Attributes.

Table B-17. Indicators used for habitat status assessment of Migratory Waterfowl & Shorebirds.

Key Ecological Attribute	Indicator	Definition	Justification
Landscape Condition	Landscape Condition Index	This indicator is measured by intersecting the mapped area or habitat distribution map of the resource with the LCM layer and reporting the average LCM index value for the resource or habitat within each 5th level watershed, or 4x4 km square units for species. Landscape Condition Index is a 90x90m square unit resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. The results are a score for landscape condition from 0 to 1 with 1 being very high landscape condition and values close to 0 likely having very poor condition.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance.

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Vander Haegen, W. M, S. M. McCorquodale, C. R. Pearson, G. A. Green, and E. Yensen. 2001. Wildlife of eastside shrubland and grassland habitats. Chapter 11, pages 317-341 in: D. H. Johnson and T. A. O'Neil. Wildlife-habitat relationships in Oregon and Washington. Oregon State University Press, Corvallis, OR.

Vander Haegen, W. M., F. C. Dobler, and D. J. Pierce. 2000. Shrub-steppe bird response to habitat and landscape variables in eastern Washington, USA. Conservation Biology 14:1145-1160.

Vranckx, G., H. Jacquemyn, B. Muys, and O. Honnay. 2011. Meta-analysis of susceptibility of woody plants to loss of genetic diversity through habitat fragmentation. Conservation Biology, November 2011. Early on-line publication. [10.1111/j.1523-1739.2011.01778.x]

Species Conservation Element Characterization and Conceptual Models

The conceptual models for Species Conservation Elements combine text, causal diagrams, and tabular summaries in order to clearly state key assumptions about these resources and their interactions with major Change Agents (CAs) within the ecoregion. These conceptual models are the basis for spatial models developed to gauge the relative ecological status for the habitat of each resource within 4x4 km spatial units. Below we describe what content we include for each resource. Some text is repeated for each resource, such as the indicator justification information, to allow the reader to view or print the entire material for an individual resource.

The conceptual models developed for the species resources are intended to represent each taxon across the entire range of its distribution (i.e., global-level data). Species resource data were extracted from a biodiversity database developed centrally at NatureServe over the past thirty-five years. This database is dynamic, maintained and refined through updates made to reflect current changes to taxonomy; and through the periodic import of new records developed according to a standard methodology by natural heritage member program scientists and other collaborators, including government agencies, universities, natural history museums and botanical gardens, and additional conservation organizations.

NatureServe's species database contains an array of information about elements of biodiversity, with particular emphasis on those that are more threatened across their range. Tracked data includes taxonomy, conservation status, ecological and life history, habitat requirements, and distribution, with primary sources of this information consisting of scientific literature, museum specimen records, reliably documented observation records, species lists, range maps, external databases, and experts, including scientists from natural heritage member programs. The NatureServe maintains range maps and/or data representing all native species vertebrates and vascular plants. At the level of the heritage programs that support the central database, resources generally limit the tracking of specific locations where elements occur within their jurisdictions to those having the highest conservation concern.

Species Taxonomy References

NatureServe scientists use a set of references generally accepted by researchers working on a given taxonomic group, supplemented by recent scientific literature and expert opinion, to establish a standard "global" scientific name and taxon circumscription for every element of biodiversity contained in the central database. Arranged by taxonomic level and species type, the major references NatureServe used (December 2011) for the species resource names and taxonomy follows:

<u>Phyla and Subphyla</u>

Integrated Taxonomic Information System. Integrated Taxonomic Information System: Biological Names. Available online at: http://www.itis.gov/.

Margulis, L., and K. V. Schwartz. 1998. Five kingdoms: An Illustrated Guide to the Phyla of Life on Earth. Third edition. W. H. Freeman and Company, New York. 520 pp.

Phylum Craniata (Vertebrates)

Class Mammalia (Mammals)

American Society of Mammalogists. Mammalian species. Cumulative index available online: http://www.science.smith.edu/departments/Biology/VHAYSSEN/msi/default.html

[ASM publishes 20-30 species accounts each year; each summarizes the current understanding of a species' biology.]

Baker, R. J., L. C. Bradley, R. D. Bradley, J. W. Dragoo, M. D. Engstrom, R. S. Hoffman, C. A. Jones, F. Reid, D. W. Rice, and C. Jones. 2003. Revised checklist of North American mammals north of Mexico, 2003. Museum of Texas Tech University Occasional Papers 229:1-23.

Da Fonseca, G., G. Herrmann, Y. Leite, R. Mittermeier, A. Rylands, and J. L. Patton. 1996. Lista anotada dos mamíferos do Brasil. Conservation International, Washington, D.C.

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Wilson, D. E., and F. R. Cole. 2000. Common names of mammals of the world. Smithsonian Institution Press, Washington, D.C.

Wilson, D. E., and D. M. Reeder (editors). 2005. Mammal species of the world: a taxonomic and geographic reference. Third edition. The Johns Hopkins University Press, Baltimore. Two volumes. 2,142 pp. Available online at: http://www.bucknell.edu/msw3/.

Class Aves (Birds)

American Ornithologists' Union. 1957. Checklist of North American birds. Fifth edition. Port City Press, Inc., Baltimore, Maryland. [Used for North American bird subspecies names, within the framework of the species classification in AOU checklist.]

American Ornithologists' Union (AOU). 1998. Check-list of North American birds. Seventh edition. American Ornithologists' Union, Washington, D.C. [as modified by subsequent supplements and corrections published in *The Auk*]. Also available online: http://www.aou.org/.

The Birds of North American Online. Available at: http://bna.birds.cornell.edu/BNA/. [subscription required]

Howard, R. and A. Moore. 2003. A complete checklist of the birds of the world. Third edition. Princeton University Press, Princeton, New Jersey. 1039 pp.

Remsen, J. V., Jr., A. Jaramillo, M. Nores, M. B. Robbins, T. S. Schulenberg, F. G. Stiles, J. M. C. da Silva, D. F. Stotz, and K. J. Zimmer. Version [11 November 2011]. A classification of the bird

species of South America. American Ornithologists' Union. http://www.museum.lsu.edu/~Remsen/SACCBaseline.html.

Classes Chelonia, Crocodylia, and Reptilia (Turtles, Crocodilians, and Reptiles)

Collins, J. T., S. L. Collins, and T. W. Taggart. 2010. Amphibians, reptiles, and turtles in Kansas. Eagle Mountain Publishing, Eagle Mountain, Utah. xvi + 312 pp.

Crother, B. I. (editor). 2008. Scientific and standard English names of amphibians and reptiles of North America north of Mexico, with comments regarding confidence in our understanding. Sixth edition. Society for the Study of Amphibians and Reptiles Herpetological Circular 37:1-84.

Ernst, C. H., and R. W. Barbour. 1989. Turtles of the world. Smithsonian Institution Press, Washington, D.C.

Ernst, C. H., R. W. Barbour, and J. E. Lovich. 1994. Turtles of the United States and Canada. Smithsonian Institution Press, Washington, D.C.

Ernst, C. H., and E. M. Ernst. 2003. Snakes of the United States and Canada. Smithsonian Books, Washington, D.C.

Iverson, J. B. 1992. A revised checklist with distribution maps of the turtles of the world. Privately printed, Earlham, Indiana.

King, F. W., and R. L. Burke, editors. 1989. Crocodilian, tuatara, and turtle species of the world: a taxonomic and geographic reference. Association of Systematics Collections, Washington, D.C. 216 pp.

McDiarmid, R. W., J. A. Campbell, and T. A. Touré. 1999. Snake species of the world: a taxonomic and geographic reference. Volume 1. The Herpetologists' League, Washington, D.C.

Schwartz, A., and R.W. Henderson. 1988. West Indian amphibians and reptiles: a check-list. Milwaukee Public Museum, Contributions in Biology and Geology. No. 74:1-264. [Major source for West Indian reptiles]

Society for the Study of Amphibians and Reptiles. 1971 et seq. Catalogue of American Amphibians and Reptiles. (Published by the American Society of Ichthyologists and Herpetologists, 1963-1970.)

Stebbins, R. C. 2003. A field guide to western reptiles and amphibians. Third edition. Houghton Mifflin Company, Boston.

Overview of Species Conservation Element Conceptual Models

The primary purpose of the species resource conceptual models is to provide information on the classification, range, ecology and life history, and habitat requirements of each resource. This information serves as the basis for models of the effects to each resource that would likely result from change agents such as development, invasive plant species or changes in fire that may threaten its survival.

The conceptual model for each resource type begins by characterizing the resource and its place within a broader conceptual model and classification of ecological system types for the ecoregion. Table B-18 presents this broader ecoregional model. Each resource is placed within one of the "Level 1" components of the ecoregional model, and within one of the "Level 2" categories that further characterize each Level-1 component.

Table B-18. Ecoregional conceptual model, species conservation elements, Central Basin and Range Ecoregion.

Level 1	Level 2	Coarse-filter Element Name
Montane Dry Land System	Montane Canyons	Desert Bighorn Sheep *Ovis canadensis nelsoni*
	Montane Canyons	Golden Eagle *Aquila chrysaetos*
	Montane Shrublands	Loggerhead Shrike *Lanius ludovicianus*
	Montane Shrublands	Mule Deer *Odocoileus hemionus*
	Montane Shrublands	White-tailed Jackrabbit *Lepus townsendii*
	Subalpine/Montane Forests & Woodlands	Big Brown Bat *Eptesicus fuscus*
	Subalpine/Montane Forests & Woodlands	Clark's Nutcracker *Nucifraga columbiana*
	Subalpine/Montane Forests & Woodlands	Cooper's Hawk *Accipiter cooperii*
	Subalpine/Montane Forests & Woodlands	Northern Rubber Boa *Charina bottae*
	Subalpine/Montane Forests & Woodlands	Swainson's Hawk *Buteo swainsoni*
Basin Dry Land System	Cliff & Outcrop	Brazilian Free-tailed Bat *Tadarida brasiliensis*
	Cliff & Outcrop	Great Basin Collared Lizard *Crotaphytus bicinctores*
	Desert Scrub	Coachwhip *Masticophis flagellum*
	Desert Scrub	Western Patch-nosed Snake *Salvadora hexalepis*
	Semi-desert Shrub & Steppe	Brewer's Sparrow *Spizella breweri*

Table B-18 (continued). Ecoregional conceptual model, species conservation elements, Central Basin and Range Ecoregion.

Level 1	Level 2	Coarse-filter Element Name
Basin Dry Land System (continued)	Semi-desert Shrub & Steppe	Columbian Sharp-tailed Grouse *Tympanuchus phasianellus columbianus*
	Semi-desert Shrub & Steppe	Ferruginous Hawk *Buteo regalis*
	Semi-desert Shrub & Steppe	Greater Sage Grouse *Centrocercus urophasianus*
	Semi-desert Shrub & Steppe	Kit Fox *Vulpes macrotis*
	Semi-desert Shrub & Steppe	Northern Sagebrush Lizard *Sceloporus graciosus graciosus*
	Semi-desert Shrub & Steppe	Prairie Falcon *Falco mexicanus*
	Semi-desert Shrub & Steppe	Pygmy Rabbit *Brachylagus idahoensis*
	Semi-desert Shrub & Steppe	Sage Sparrow *Amphispiza belli*
	Semi-desert Shrub & Steppe	Sage Thrasher *Oreoscoptes montanus*
	Semi-desert Shrub & Steppe	Savannah Sparrow *Passerculus sandwichensis*
Montane Wet System	Montane Lakes & Wetlands	Northern Harrier *Circus cyaneus*
Basin Wet System	Basin River & Riparian	Bald Eagle *Haliaeetus leucocephalus*
	Basin River & Riparian	Common Kingsnake *Lampropeltis getula*

The conceptual model for each species resource has several individual components, described below. The information developed for each species resources is intended to represent the taxon across the entire range of its distribution (i.e., global-level data); therefore, the information may be more relevant to subpopulations or specific areas within that range, which might extend beyond the ecoregion. Note that for some species, particular components of information may be lacking.

The narrative provided includes information on classification, range, ecology and life history, and habitat requirements, as well as major threats. Each field of information is described below with a brief description of the field's contents.

Classification Comments
Brief clarification of any anomalies or changes in the element taxonomy concerning the validity or taxonomic distinctness of the species.

Range
Current total geographic range-wide extent of the species, with breeding/nonbreeding or seasonal ranges specified, if different.

Occurrences
Estimate of total number of precise locations where the species is known to occur across its range, including information on how the estimate was derived. Occurrence data is developed and maintained by natural heritage member programs, which document and delimit the presence and extent of individual species on the landscape. Species occurrences commonly reflect populations or subpopulations.

Population
Estimate of total population size for the species across its range, including information on how the estimate was derived, variations, and data for specific portions of the range.

Habitat
Summary of the habitats and microhabitats commonly used by the species throughout its range, including any daily, seasonal, and geographic variation in habitat use.

Phenology
Summary of the seasonal variations of the species across its range, including differences in seasons of activity and periods of daily activity.

Ecology
Summary of the ecology of the species across its range, including any additional information resulting from studies that have been conducted, and citations where appropriate. Information on population density, dispersal distances, home range size, annual and seasonal fluctuations in population size, nonbreeding coloniality/sociality, major predators, competitors, parasites, age-specific survival rates, and other significant ecological factors could be included.

Mobility
Discussion of the seasonality, direction, distances, major routes, sociality/dispersion, daily timing, and variability (e.g., between populations) in movement/migration patterns of the species across its range.

Food
Information on food types, food location (e.g., microhabitat), foraging methods/strategy, seasonal and geographic variation in diet, and major differences in diet among age classes (e.g., young vs. adults) for the species across its range. Additional information resulting from studies that have been conducted should be included, along with citations where appropriate. If the species is classically considered to be an omnivore, this fact should be included, along with appropriate references.

Reproduction

Description of the reproduction of the species across its range, including information on clutch/litter size and frequency, gestation/incubation period, seasonal timing of reproductive activities, nature and period of any parental care, age of sexual maturity, and size and general nature of breeding aggregations. Additional information resulting from studies that have been conducted is included, along with citations where appropriate.

Change Agent (CA) Characterization

Description of the primary change agents, including information on the scope, severity, and immediacy (timing) of threats, and current knowledge of their effects on the species across its range. Comments should include whether the scope and severity of the threats to species are observed, inferred, or suspected, or result from qualitative observation of its impact on the resource. The extent, including geographic variation, and effects of current or projected extrinsic influences on the species should be described, along with any additional threats or interactions among different threats, including high-magnitude threats considered insignificant in immediacy.

Conceptual Model Diagram

Each conceptual model includes a diagram (composed of three sub-figures) conceptualizing the relationships between Change Agents, the stresses they induce in the resource, the response of the resource to those stressors, and the indicators selected to measure either the stress or the resource response. The diagram does not attempt to list all change agents, stresses, or responses; and the indicators are those used in the assessment, rather than a complete suite of possible indicators.

Ecological [Habitat] Status Criteria and Indicators

NatureServe's ecological integrity framework sets up practical criteria and indicators for assessing ecological status for each resource within the ecoregion (Faber-Langendoen et al. 2006, Unnasch et al. 2018). This framework includes development of a scorecard for reporting on the ecological status of a given resource within a given location, and facilitates the aggregation and synthesis of the component results for broader measures of ecological integrity at landscape and ecoregional scales. Using this framework, indicators are chosen to provide a measurement for a limited set of key ecological attributes, or ecological drivers for each resource. Ecological attributes may include natural characteristics, such as native species composition, or stressors such as effects of relevant change agents, that are well known to affect the natural function and integrity of the resource.

In part because of project constraints, indicators identified in the species resource conceptual models emphasize ecosystem stressors that can be more readily measured using available remotely sensed data. Spatial models that reflect these indicators serve as the link between the conceptual models and the spatial representation of ecological status. For each resource, a table provides the definitions and justifications for each of the indicators assessed for that resource. Each indicator is scored according to criteria described in the table and its values normalized to range between 0 and 1, with 1 indicating highest ecological status and 0 indicating lowest status (and presumably transitional to a wholly different ecological state).

For most of the species conservation elements, spatial models are developed to predict the distribution of habitat for each species; only a few species have current occupied habitat mapped. Hence for the ecological status assessment, the unit of assessment for most species is its predicted habitat, rather than currently occupied habitat. Only greater sage-grouse, mule deer and desert bighorn sheep have occupied habitat models; habitat for bald and golden eagles is represented by point localities for actual occurrences and these serve as the assessment units. For all other species predicted habitat is the habitat unit of assessment.

References for the resource

Each species resource conceptual model includes a list of literature relevant to the classification, distribution, ecology and life history, threats, and habitat requirements of the individual resource, in some cases from portions of its range outside of the ecoregion. These are not exhaustive literature surveys, but rather an accumulation of known references. Some documents may be listed that are not cited in the narrative text.

Bighorn Sheep (Ovis canadensis)

Model Group: Montane Dry Land System > Montane Canyons

Focal Resource Characterization

Taxonomic Comments

Individuals found within Great Basin National Park are thought to be Rocky Mountain bighorn sheep (*Ovis canadensis canadensis* – Shaw 1804). However, due to environmental characteristics and proximity, and the fact that other bighorn sheep populations occur to the southwest within the study area, for this treatment characterics of the desert bighorn (*Ovis canadensis nelsoni*) have been used. Wehausen and Ramey (2000) examined variation in skull and horn characters in populations from the Great Basin north to British Columbia and Alberta and concluded that: (1) *O. c. auduboni* does not warrant recognition separate from *O. c. canadensis*; (2) populations of *O. c. "californiana"* in British Columbia and Washington are best treated as *O. c. canadensis*; (3) extirpated native populations of *O. c. "californiana"* in northeastern California, Oregon, northern Nevada, and southwestern Idaho should be included in *O. c. nelsoni* (recognizing that some transition to *O. c. canadensis* probably occurred along that northern boundary); and (4) *O. c. californiana* is restricted to the central and southern Sierra Nevada in California. Wehausen et al. (2005) and USFWS (2008) reviewed available taxonomic information and concluded that the Sierra Nevada population should be recognized as a distinct subspecies (*Ovis canadensis sierrae*). Ramey (1995) examined mtDNA variation in *O. canadensis* populations in the southwestern United States and adjacent northern Baja California and found a lack of concordance between mtDNA haplotype distributions and current subspecies designations. Additionally, Ramey (1995) and Wehausen and Ramey (1993) found no morphological support for the separation of desert sheep into four subspecies. Ramey (1995) suggested that populations formerly considered to be *O. c. nelsoni*, *O. c. mexicana*, *O. c. cremnobates*, and *O. c. weemsi* probably should be recognized as a single polytypic subspecies on the basis of morphological and mtDNA data. As such, individuals from any of these subspecies would be *O. c. nelsoni* Merriam, 1897, and it includes bighorn sheep populations in the Peninsular Ranges of southern California and Baja Califdornia. A study of nuclear DNA markers is needed to test this

taxonomic arrangement (Ramey 1995). As of 2011, Integrated Taxonomic Information System (www.itis.gov; accessed 23 August 2011) did not recognize any subspecies of *Ovis canadensis*.

Range

Bighorn sheep remain widespread in western North America from Canada to Mexico, although populations are much smaller than in the past. In some areas they are threatened by habitat changes resulting from fire suppression, interactions with feral and domestic livestock, and human encroachment; protected in some areas through adequate management. Under the taxonomic concept of Wehausen and Ramey (2000), the historical range of *O.c. canadnesis* extended from western North Dakota, west to Washington, and south throughout northern NV and UT. *O c. nelsoni* extended south to Baja California and east to western Texas.

Habitat

Bighorn sheep occur in mesic to xeric, alpine to desert grasslands or shrub-steppe in mountains, foothills, or river canyons (Shackleton et al. 1999, Krausman et al. 1999). Many of these grasslands are fire-maintained (Geist 1971, Erickson 1972). Suitable escape terrain (cliffs, talus slopes, etc.) is an important feature of the habitat. In winter, Rocky Mountain Bighorns spend as much as 86% of their time within 100 meters of escape terrain (Oldemayer et al. 1971, Erickson 1972), and usually stay within 800 meters of escape terrain throughout the year (Pallister 1974). Mineral licks are more important in the range of Rocky Mountain Bighorn than in the range of "California" Bighorn, presumably because the soils in the range of the former are generally lower in mineral content (Van Dyke 1978). Distribution is correlated with low precipitation levels, especially in winter and spring. Elevation varies considerably, both geographically and seasonally, from as low as 450 meters to over 3,300 meters (Shackleton et al. 1999). Winter ranges of northern populations are relatively snow-free because of light snow, steep south aspect, and/or high winds; bighorns generally avoid snow deeper than 30 centimeters (Stelfox 1975). The solar heat on south aspects also reduces cold stress on sheep (Shackleton et al. 1999).

In the north, bighorn sheep usually are not dependent on free-standing water, getting water instead from succulent vegetation in the summer and snow or ice in the winter (Van Dyke 1978). However, in some southwestern deserts they may be dependent on access to free water during summer (Turner 1979, Turner and Weaver 1980, Seegmiller and Ohmart 1981).

Phenology

During the day, feeding alternates with rest-rumination periods. Daily activity may vary seasonally; often feeding peaks in early morning and at dusk. In winter, feeding periods are longer.

Ecology

While gregarious, for most of the year adult males live apart from females/young (Shackleton et al. 1999, Krausman et al. 1999). Among mature males, older males (up to an age of not more than 10 years) generally dominate younger males during the breeding season; males older than 10 years decline rapidly in condition. In western Arizona, January-June home range of adult females was 19-27 km^2 (Seegmiller and Ohmart 1981). Male annual home range up to 37 km^2 in Nevada (Leslie and Douglas 1979).

Carrying capacity for bighorn can be reduced through grazing by other ungulates (cattle, burros, etc.). Contact with a stray domestic sheep is believed to have resulted in the death (through bacterial pneumonia) of entire reintroduced herd of 65 in Warner Mountains, California (California Department of Fish and Game 1990). In some areas, lungworm infections may predispose bighorn to respiratory infection by opportunistic bacteria; lungworm life cycle involves gastropod intermediate host.

In deserts, bighorns can survive 10 or more days in summer without drinking; may meet water needs in part by eating barrel cacti (Warrick and Krausman 1989). Bighorns probably live in groups primarily to reduce predation (Shackleton et al. 1999). Coyotes may be a significant predator on young in some areas, killing up to 80% of the year's lambs (Hebert and Harrison 1988, Harper 1984, Hass 1989). Cougars can be important predators as well (Harrison and Hebert 1988, Krausman et al. 1999), and can have significant impacts on remnant or transplant herds (Krausman et al. 1999). Direct losses to predation are not generally as important as the fact that predation has forced females and young to use less productive habitats in and near escape terrain (Festa-Bianchet 1988, Demarchi et al. 1999a).

Mobility

Populations other than those in low deserts typically migrate between an alpine or montane summer range and a lower elevation winter range (Shackleton et al. 1999). Some may occupy as many as five separate ranges during a year (Geist 1971). This vertical migration is probably a response to the increasing abundance of nutritious, new vegetative growth at higher elevations as spring and summer progress (Shackleton et al. 1999). The downward migration is motivated by snow accumulation in the high elevation summer ranges (Shackleton et al. 1999).

Food

Diet is diverse and variable. Bighorn sheep are primarily grazers of grass and forbs, but the diet can also include significant amounts of shrubs (Miller and Gaud 1989, Krausman et al. 1999, Shackleton et al. 1999). Diet changes seasonally. Access to mineral lick may be important for Rocky Mountain and desert bighorns, especially in spring (Shackleton et al. 1999, Krausman et al. 1999).

Reproduction

In the mating season, mature males battle over access to females through vigorous head butting contests, but during most of the rest of the year they live amiably in small bands apart from the females. The timing of the mating season varies throughout the range. Bighorns in southwestern deserts have an extended season encompassing several months (Krausman et al. 1999), but the season is relatively later and shorter elsewhere, generally November in the northern part of the range (Shackleton et al. 1999), November-December in some southern California mountains (DeForge 1980). Gestation lasts about 175 days (Geist 1971, Shackleton et al. 1999). Lambing generally peaks in March in desert populations (Rubin et al. 2000), May (occasionally April or June) in the remainder of range (Krausman et al. 1999, Shackleton et al. 1999). Litter size is 1, rarely 2 (Geist 1971, Turner and Hansen 1980).Young are weaned in 4-6 months. Females first breed usually in second year in south, third year in north; occasionally in first year in some areas (Krausman et al. 1999, Shackleton et al. 1999); fecundity generally declines only slightly after eight years of age (Caughley 1977).

Change Agent Effects

Initial large historic declines were primarily the result of competition with domestic stock (e.g., cattle, domestic sheep, burros), diseases and parasites introduced by domestic sheep, overhunting, and habitat loss (Cowan 1940, Buechner 1960, Sugden 1961, Stelfox 1971, Goodson 1982, Boyce et al. 1990, Valdez and Krausman 1999).

Domestic Stock: In Idaho, introduced bighorns avoided cattle and were more sensitive to cattle presence than were established populations, based on previous studies (Bissonette and Steinkamp 1996). Decline of desert populations has been attributed to destruction of habitat and competition with domestic livestock and other native and domestic species (e.g., may be limited through resource competition with burros) (Seegmiller and Ohmart 1981).

Parasites and Disease: Psoroptic scabies from domestic sheep devastated bighorn populations in the first half of the twentieth century (Boyce et al. 1990). The Peninsula Ranges population (California and Baja California) has declined due to disease-caused low survival rate of juveniles (California Department of Fish and Game 1990). Many dieoffs (greater than 50% mortality over a few months) of herds have been reported over the last century; these are poorly understood, but seem to result from stress, which interacts with endemic lungworm infestations and lowers the animals' resistance to organisms such as *Pasteurella* bacteria. The animals subsequently die from acute bronchopneumonia (Ryder et al. 1992, Dunbar 1992, Schwantje 1988). See Bunch et al. (1999) for a general account of diseases and parasites affecting Bighorn Sheep.

Habitat Loss and Degradation: Loss and degradation of habitat, especially key winter forage sites, is a key threat (Valdez and Krausman 1999, Shackleton et al. 1999, Krausman et al. 1999). Habitat degradation can occur through overgrazing by domestic stock, competition with exotic ungulates (e.g., Aoudad or Barbary, *Ammotragus lervia*), excessive off-road vehicle use, spread of rangeland weeds, and the usurpation of water sources (Simpson 1980, Valdez and Krausman 1999, Krausman et al. 1999). Fire suppression and resulting vegetation succession (encroachment of tall dense shrubland and forest) have been a major cause of habitat loss in Colorado and British Columbia (Davidson 1991, Cannings et al. 1999, Wakelyn 1987); see also Etchberger et al. (1989) for similar conclusion on the importance of fire in Santa Catalina Mountains, Arizona. Fragmentation of habitat reduces or eliminates genetic interchange among populations (Ramey 2000) and reduces the probability of recolonization following local extirpation; both these effects are especially of concern in small populations (fewer than 100 individuals), which are especially vulnerable to extirpation (Berger 1990).

Other: The social behavior and predator evasion strategy may have contributed to their decline (Miller and Gaud 1989). Feral honey bees may interfere with sheep attempting to drink at artificial water sources (guzzlers) in desert environments (Boyce et al. 2003).

Conceptual Diagram

Given their life history characteristics, the key ecological attribute driving the integrity of bighorn sheep populations is the maintenance of interacting healthy individuals. Bighorn sheep experience stress when faced with change agents, such as industrial development, including mines or landfills,

directly remove habitat. Other change agents such as roads and transportation corridors (railroads, power lines, solar arrays, oil pumping platforms), fragment habitat distribution (Debinski and Holt 2001). More dispersed human activities, such as recreation, hunting, logging, or ORV activities result in increases in road densities or disturbance via disrupted breeding, foraging, soil surface disturbance that affects biological soil crusts or uprooting or damage to plants (Figure B-18).

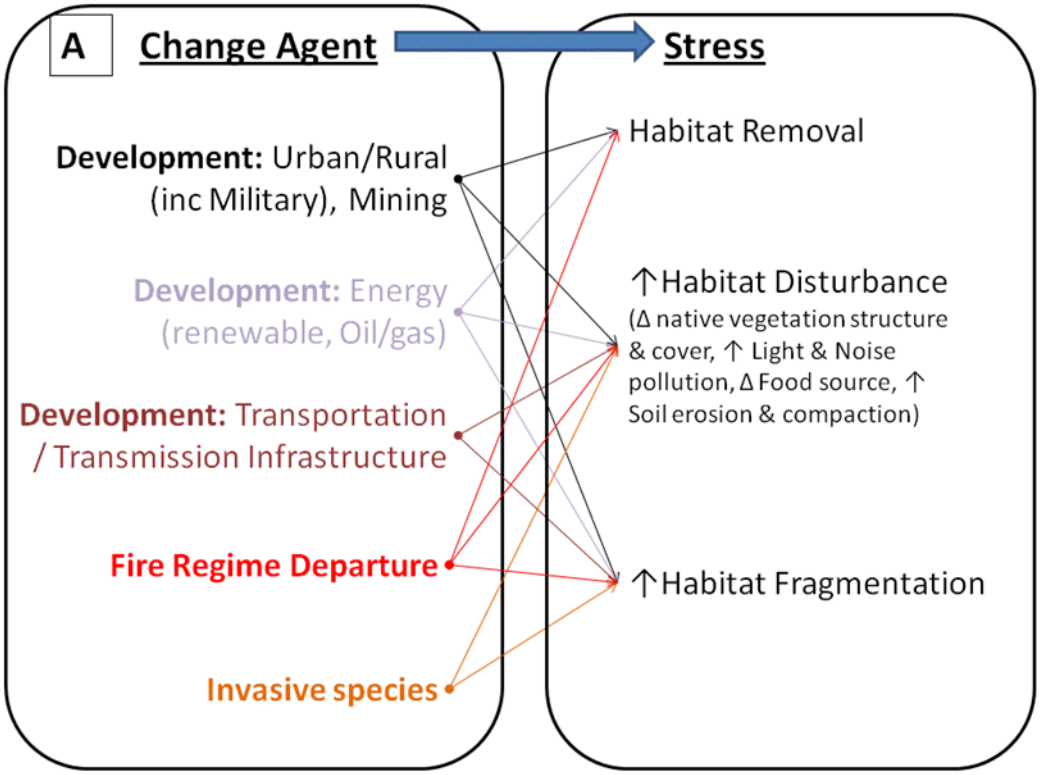

Figure B-18 (A). The conceptual model for Bighorn Sheep (*Ovis canadensis*) illustrates the effect of each Change Agent on the resource's ecological integrity. A. Change Agents are a source of different types of stressors.

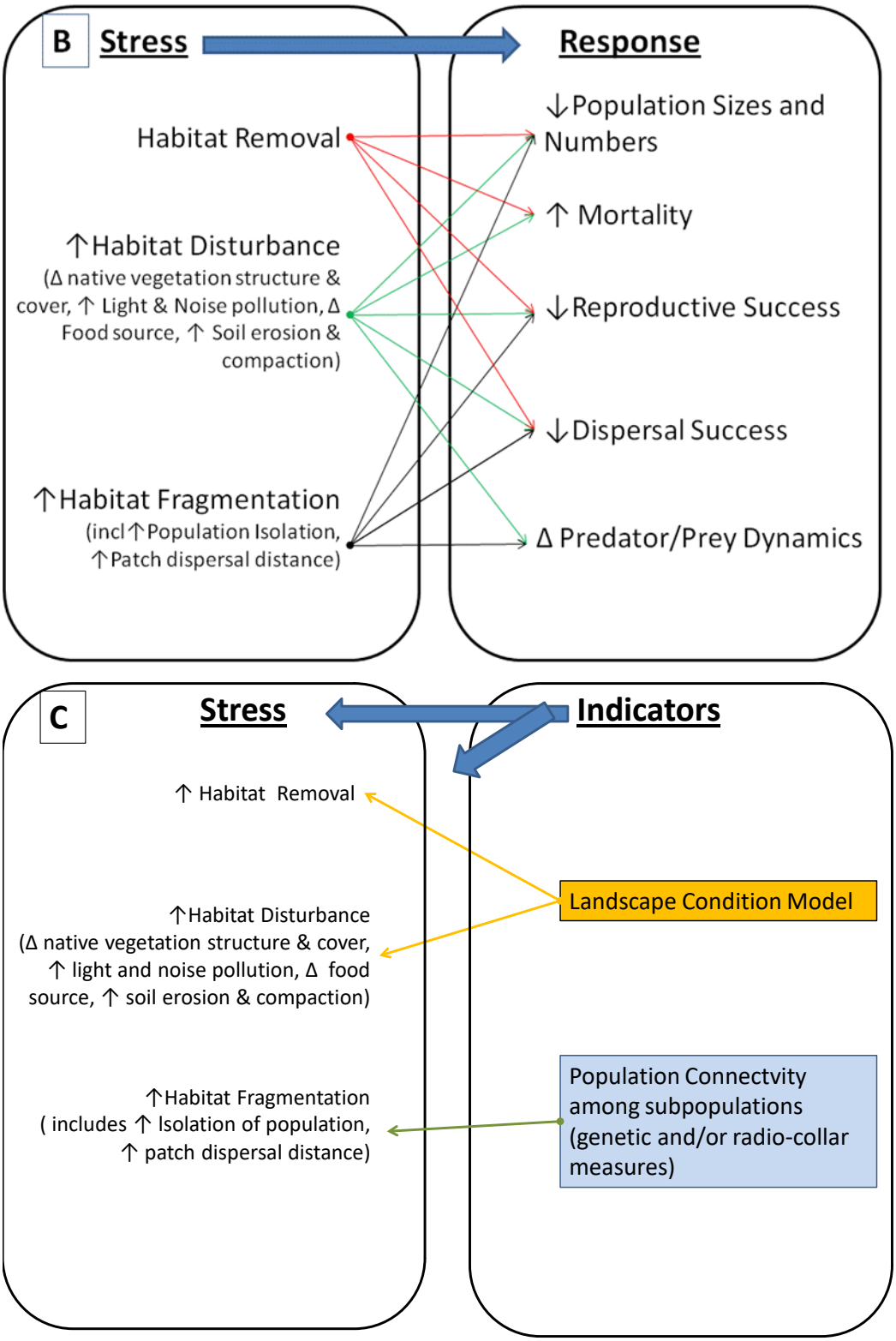

Figure B-18 (B and C). The conceptual model for Bighorn Sheep (*Ovis canadensis*) illustrates the effect of each Change Agent on the resource's ecological integrity. A. Change Agents are a source of different types of stressors. B. Different types of stressors invoke different responses. C. Indicators are metrics by which we can directly measure the amount of stress.

Any of these stressors can result in responses, such as decreased dispersal success, reproductuive success, and increases in direct mortality. One practical level 1 indicator of integrity for bighorn sheep populations is the landscape condition model (LCM), which reflects surface disturbance and distance effects of those disturbances. This addresses the stressors of habitat removal and habitat disturbance. Ideally, fragmentation among sheep populations would be addressed through direct measurement of interchange among sheep individuals across multiple subpopulations. This could be addressed though direct field measurements of movement (e.g., radio-collar tracking) and/or through analysis of genetic material among individuals from distinct subpopulations.

Where feasible, a characterization of the expected range of variation for values from each of these indicators would be desirable. Landscape condition is a stressor-based measure, and so comparison of current scores (i.e., 0.0-1.0 for a given area) are in fact compared against a score of 1.0 (i.e. the lack of surface disturbance). However, for the indicator of population connectivity, one could characterize an expected range of variation suitable for the assessment area. For example, one might expect a healthy set of subpopulations to each consist of some range in the number of individuals, with a expected range in the number of individuals that move between subpopulations (or disperse to establish new populations) for a given time period (e.g., every 10 years). This task was beyond the scope of this effort, but could be prioritized for future research.

Ecological Integrity Criteria and Indicators

The Ecological Integrity Scorecard links conceptual diagrams that describe the relationships between change agents, stress, response, and indicators, to spatial models that provide practical measures across the landscape. The primary indicator of integrity for bighorn sheep is scored as described in Table B-19. The landscape condition model is used here as a level 1 indicator for the key attribute of population health and interchange. The score using the landscape condition model (LCM) is normalized between 0 and 1 with 1 being most intact habitat status and 0 being least.

Table B-19. Indicators used for habitat status assessment of Bighorn Sheep (*Ovis canadensis*).

Key Ecological Attribute	Indicator	Definition	Justification
Population health and interchange	Landscape Condition Index	This indicator is measured by intersecting the mapped area or habitat distribution map of the the focal resource with the LCM layer and reporting the average LCM index value for the occupied habitat within each 4x4 km square units for species. Landscape Condition Index is a 90x90m square unit resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. The results are a score for landscape condition from 0 to 1 with 1 being very high landscape condition and values close to 0 likely having very poor condition.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance.

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Golden Eagle (Aquila chrysaetos)

Model Group: Montane Dry Land System > Montane Canyons

Focal Resource Characterization

Range

In North America, breeding occurs from western and northern Alaska eastward through Northwest Territories to Labrador, and south to northern Mexico, Texas, western Oklahoma, and western Kansas, and in eastern North America southward to New York and northern New England (rare). See Lee and Spofford (1990) for a review of nesting records from the central and southern Appalachians (most nesting records south of the Adirondacks are doubtful). Golden eagles breed also in the Palearctic. The winter range in North America extends from south-central Alaska and southern Canada southward through the breeding range, and casually farther southward. In the United States, the species is most numerous in winter in the Rocky Mountain states, Great Basin, and western edge of the Great Plains (Root 1988). See Milsap and Vana (1984) for information on winter range in the eastern United States. Northernmost populations in Eurasia winter south to northern Africa (Sibley and Monroe 1990).

Occurrences

The global number of occurrences has not been precisely determined using standardized criteria, but this species clearly is represented by a large number of occurrences (subpopulations).

Population

North American population in the mid-1980s was estimated at about 70,000; perhaps about 20,000 breeding pairs occur in the western United States. De Smet (1987 COSEWIC report) gave an estimate of 50,000-100,000 for North America. Kirk et al. (1995) reported that the estimated number of breeding pairs in Canada was 1,000-5,000. Rich et al. (2004) estimated global population size at 170,000, with approximately half of the total in the United States and Canada.

Habitat

Golden eagles generally inhabit open and semi-open country such as prairies, sagebrush, arctic and alpine tundra, savannah or sparse woodland, and barren areas, especially in hilly or mountainous regions, in areas with sufficient mammalian prey base and near suitable nesting sites. In Nevada, the only habitats routinely avoided by golden eagles are forests, large agricultural areas, and urban areas (GBBO 2010).

Nests are most often on rock ledges of cliffs but sometimes in large trees (e.g., oak or eucalytus in California, white pine in eastern North America), on steep hillsides, or on the ground. Nesting cliffs may face any direction and may be close to or distant from water. In Elko County, Nevada, 93 percent of nests were on cliffs, 71 percent were at elevations between 1,524 and 1,981m, and 43

percent faced east; 84 percent of nests were within three kilometers of water with desert riparian habitat (Page and Seibert 1973).

A pair may have multiple alternate nests; the pair may use the same or alternate nests in consecutive years.

Phenology

Foraging commonly occurs in early morning and early evening.

Mobility

Migratory populations may exist in areas where the species is present throughout the year, so specific migration patterns may be obscure. Northernmost populations withdraw southward for winter (some individuals may remain in north); these migrants may migrate farther south than do birds from breeding populations to the south; migrants return to northern breeding areas mainly in March-April. Most vacate hot deserts during summer.

In predatory bird surveys over 12 months in the eastern Mohave Desert, San Bernardino County, California, Knight et al. (1999) observed golden eagles only during November and December, despite the species being a regular nesting bird in the Mohave Desert. The low number of observations may have reflected a naturally low density of eagles, lack of overlap of survey routes with eagle territories, or seasonal migrations of eagles between summer nesting areas in desert mountains and wintering areas in desert basins (Knight et al. 1999). See Palmer (1988) for discussion of seasonal movements.

A juvenile from Denali National Park, Alaska, migrated through Yukon Territory and interior British Columbia to a wintering site in east-central Idaho; another juvenile migrated through the Yukon, Alberta, and Saskatchewan to northeastern Montana (Britten et al. 1995).

Territory size in several areas of the western United States averaged 57-142 sq km (Palmer 1988). In desert regions, territories may be much larger (e.g., 258-310 sq km; see Wildlife Research Institute 2010).

Food

The diet consists promarily of small mammals (e.g., rabbits, marmots, ground squirrels) but sometimes also includes large insects, snakes, birds, juvenile ungulates, and carrion. In the western Great Basin, the four most frequent prey species were black-tailed jackrabbit, mountain cottontail, yellow-bellied marmot, and chukar; Lagomorpha accounted for 91 percent of the prey biomass (Bloom and Hawks 1982). Golden eagles rarely attack large, healthy mammals (e.g., pigs, sheep, deer) (Terres 1980). Individual can fast for days between feedings. They hunt while soaring or from a perch (the latter especially used by young), and individuals may hunt cooperatively. See Palmer (1988) for further details.

Reproduction

Egg dates: by late April in northern Alaska (later if snow persists); peak in late February-March in the region from California to Texas (but earlier nesting may yield young ready to fly as early as

March 1 in Texas); late February-early March in Utah; March-April in northeastern United States. Clutch size is 1-3, rarely 4 (usually 2). Incubation, mostly by the female, lasts about 43-45 days. Young can fly at 60-77 days (fledging takes longer in the far north than in the southern part of the range). Young are cared for by parents for 30+ additional days; family unit sometimes may remain together several months. Typically first breeds in 4th or 5th year. Lifelong monogamy may be the rule, though some apparent exceptions have been recorded. A positive correlation between breeding success and jackrabbit number was reported in Idaho, Colorado, and Utah. Distance between active nests almost never is less than 0.8 km. See Palmer (1988) for further details on reproduction.

Change Agent (CA) Effects

Decline in the early 1900s was due to eradication campaigns, frequently encouraged by the use of bounties (eagle was believed to be a major predator on livestock).

Golden eagles are extremely susceptible to powerline electrocution because the wings can span phase-to-phase or phase-to-ground wires (Biosystems Analysis 1989); modifications have been made in problem areas.

Other threats include ingestion of poison intended for coyotes; ingestion of toxic water from mining activities; occasional shootings; habitat loss to agriculture, suburban land uses, and energy development; loss of potential food resources as a result of habitat degradation or rodent/rabbit control; mortality in inappropriately designed stock tanks, and collisions with structures and with vehicles on roadways. Human disturbance or activity may cause nest abandonment, render a nest site less productive, or prevent a suitable nest site from being utilized, but direct disturbance of nests appears to be infrequent (see GBBO 2010).

Mortality resulting from inappropriate wind turbine design and placement looms as an increasing threat. Many eagle deaths have been recorded at the Altamont Pass Wind Resource Area in northern California and at the Pine Tree wind turbine facility in Tehachapi in southern California. Several dozen wind energy developments have been proposed for desert areas in southern California, where there are many occupied golden eagle territories (LaPré 2011). Proposed solar energy developments in the Mohave Desert overlap with golden eagle territories (Wildlife Research Institute 2010). Large-scale wind/solar energy development could reduce prey populations and reduce eagle hunting opportunities (GBBO 2010).

The small population in eastern North America may be negatively affected by poor survival to breeding age (Palmer 1988).

See De Smet (1987 COSEWIC report) for further discussion of threats.

Conceptual Diagram

Species experience stress when faced with Change Agents. Some change agents, such as new rural or urban development including mines and landfills, directly remove the element. Other change agents such as roads and transportation corridors (railroads, power lines, solar arrays, oil pumping platforms and the like) fragment habitat distribution (Debinski and Holt 2001). More dispersed human activities, such as recreation, hunting, logging, or ORV activities result in increases in road densities

or disturbance via disrupted breeding, nesting, foraging, soil surface disturbance which affects biological soil crusts (Rosentreter and Eldridge 2002), or uprooting or damage to plants; but these dispersed activities are difficult to measure other than via mapping of roads.

Invasive plant species can have profound effects on ecosystems, and hence upon the species or assemblages occurring in those habitats. Invasive plant species directly compete with native species, and have been shown to completely remove the native ecosystem habitat (e.g. tamarisk) (Brussard et al. 2000). Fragmentation of shrub-steppe and grasslands by agriculture increases cover of annual grasses, total annual/biennial forbs, and bare ground, and decreases cover of perennial forbs and biological soil crusts, and reduces obligate insects (Quinn 2004) and obligate birds and small mammals (Vander Haegen et al. 2001). Fine fuels accumulating from alien annual grasses, such as *Bromus madritensis, Bromus tectorum*, and *Schismus* spp., are an important fuelbed component in many western ecosytems and can substantially increase the fire frequency (Chambers et al. 2007, Condon et al. 2011, Keeler-Wolf 2007), altering vegetation structure and composition, which in turn leads to alteration of faunal composition, species habitat, direct loss of habitat, and other impacts.

These stressors result in different levels of response depending on the degree of impact and how many stressors are acting on the same resource simultaneously. Responses include a reduction in species diversity and species genetic diversity with the fragmentation and loss of habitat (Vryanckx et al. 2011). Species can become less abundant as their habitats become fragmented or continually disturbed such that reproduction is less successful (Brussard et al. 2000). As native species become stressed, other more tolerant and opportunistic species may increase in abundance, further tipping the balance of food webs in both terrestrial and aquatic systems, and predator/prey dynamics. The indicators shown in the causal diagrams below measure the amount of stress or the type and magnitude of response to stress within each resource. See the Ecological Status Scorecard section for full explanation of each indicator (Figure B-19).

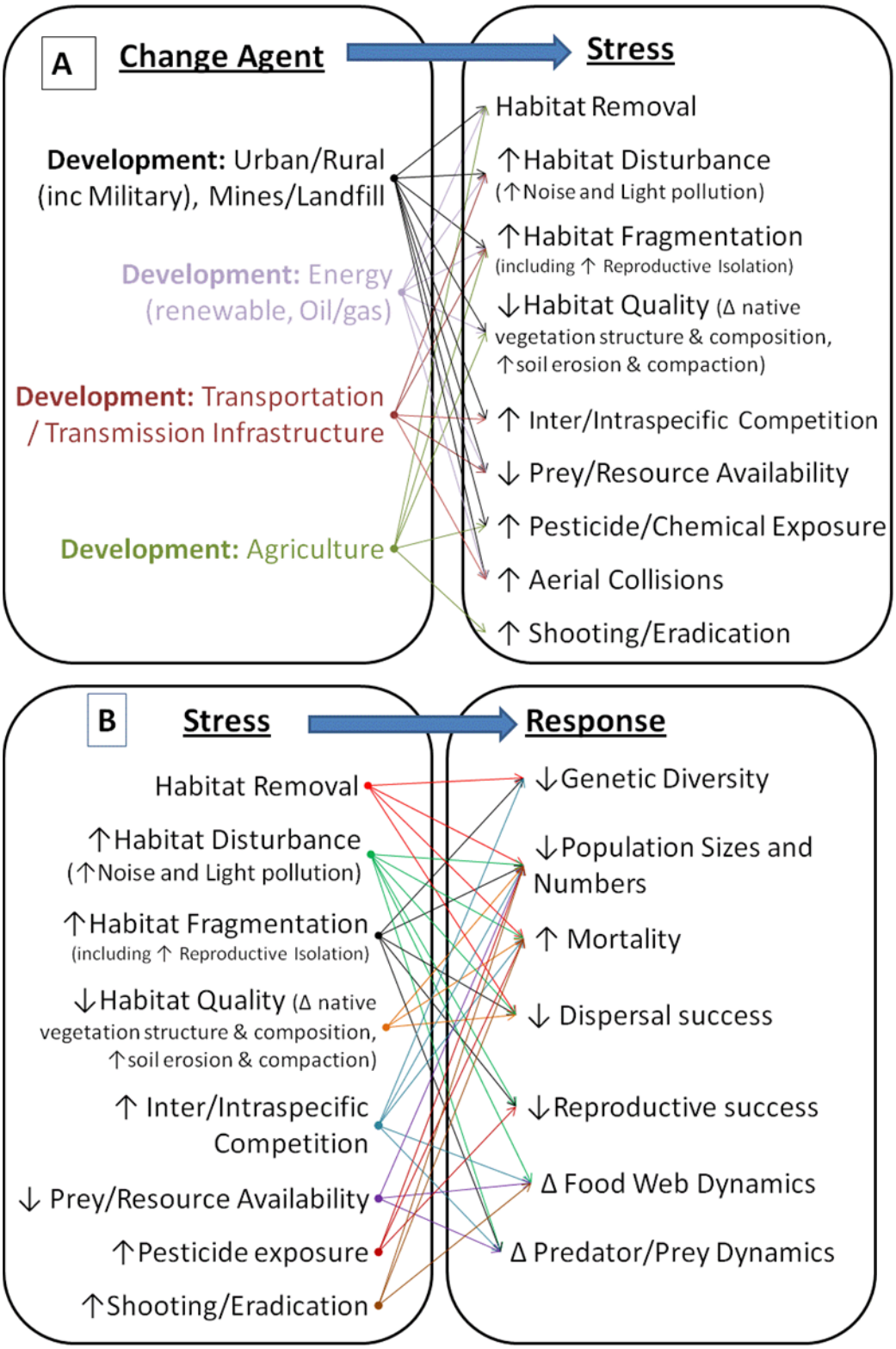

Figure B-19 (A and B). The conceptual model for Golden Eagle (*Aquila chrysaetos*) illustrates the effect of each Change Agent on the resource's ecological integrity. A. Change Agents are a source of different types of stressors. B. Different types of stressors invoke different responses.

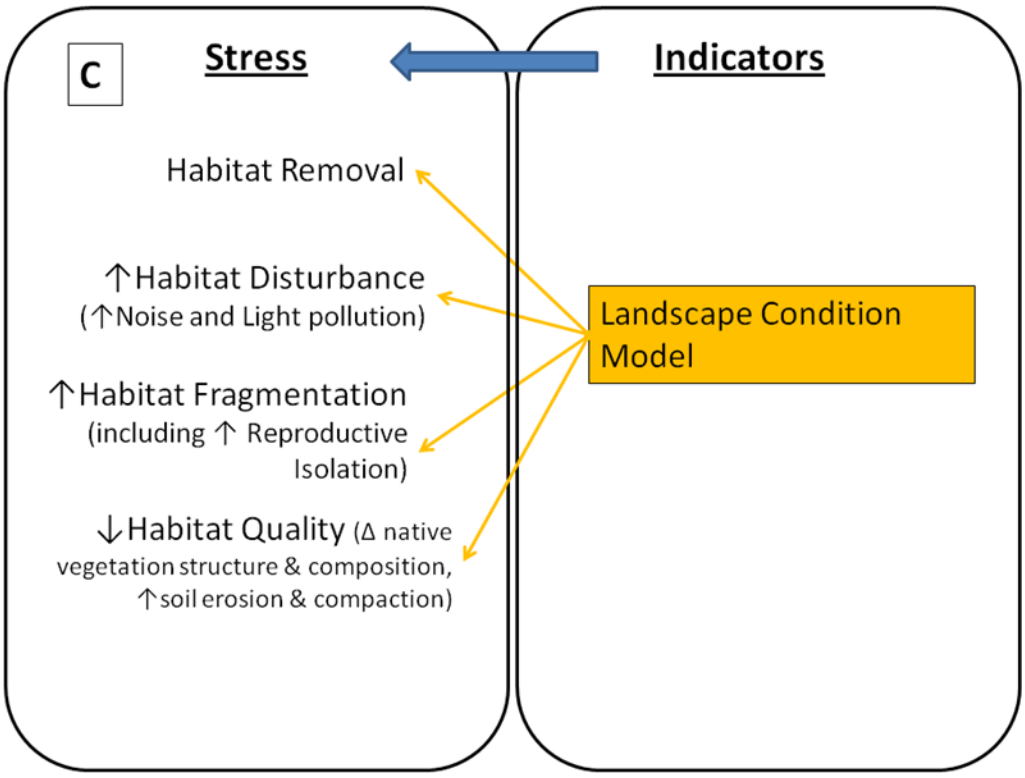

Figure B-19 (C). The conceptual model for Golden Eagle (*Aquila chrysaetos*) illustrates the effect of each Change Agent on the resource's ecological integrity. C. Indicators are metrics by which we can directly measure the amount of stress or response within each type of resource.

Ecological Integrity Criteria and Indicators

The Habitat Status Scorecard links conceptual models that describe the relationships between change agents and the habitat requirements of each species resource to spatial models that provide practical indicators of habitat status.

The conceptual model diagrams presented above in the discussion of Change Agent Effects indicate the stresses and responses expected at the scale of the habitat for the resource of concern. These stresses and responses were identified based on an assessment of the key habitat attributes for this resource type, based on the information presented in the Focal Resource Characterization section. Panel C of these diagrams, and Table B-20 below, identify a suite of indicators for assessing levels of stress and response. The indicators are organized by key ecological attributes (KEAs), which for species resources consist of pivotal habitat characteristics and primary ecological drivers. KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. The Habitat Status Scorecard (Table B-20) is designed to report on habitat status indicators by 4x4 km square units. The assessment indicators with justifications and definitions are presented in Table B-20, organized by Key Ecological Attributes.

Table B-20. Indicators used for habitat status assessment of Golden Eagle (*Aquila chrysaetos*).

Key Ecological Attribute	Indicator	Definition	Justification
Landscape Condition	Landscape Condition Index	This indicator is measured by intersecting the mapped area or habitat distribution map of the resource with the LCM layer and reporting the average LCM index value for the resource or habitat within each 5th level watershed, or 4x4 km square units for species. Landscape Condition Index is a 90x90m square unit resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. The results are a score for landscape condition from 0 to 1 with 1 being very high landscape condition and values close to 0 likely having very poor condition.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance.

Each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest. The mean index scores of these indicators may then be averaged by each Key Ecological Attribute. Displaying the indicators with individual scores allows user to interpret which particular ecological attributes in a reporting area is driving the ecological status of the resource.

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Big Brown Bat (Eptesicus fuscus)

Model Group: Montane Dry Land System > Subalpine/Montane Forests & Woodlands

Focal Resource Characterization

Classification Comments

Koopman (1989) included both *E. fuscus* and *E. lynni* in *E. serotinus*. Jones et al. (1992) used the name *E. fuscus* for this species. Koopman (in Wilson and Reeder 1993) and Simmons (in Wilson and Reeder 2005) listed *E. fuscus* and *E. serotinus* as separate species but noted that the two may be conspecific; Koopman and Simmons both included *E. lynni* in *E. fuscus*.

Eptesicus fuscus exhibits significant morphological variation across its range and is represented by 11 subspecies (Agosta 2002). Subspecies fuscus and pallidus apparently intergrade in northwestern Texas (Jones and Manning 1990).

The relationships of the genera Eptesicus and Pipistrellus are unclear; for several Old World species there is some uncertainty as to which is the appropriate genus; the species of Eptesicus that are chromosomally characterized by 2n=50 and FN=48 form a genetically homogeneous group, despite the included taxa coming from different continents (Hill and Harrison 1987, Morales et al. 1991).

Range

Southern Canada (including all provinces bordering the U.S.) south to northern Colombia, northwestern Venezuela, and northern Brazil; all Mexican states except those of Yucatan Peninsula (in northern Mexico most prevalent in eastern and western Sierra Madre bordering arid midlands of Mexican Plateau); in and along central mountain chain in Central America; Greater Antilles; Bahamas; Dominica and Barbados in Lesser Antilles; perhaps Alaska (Honacki et al. 1982; Kurta and Baker 1990; Jones 1989; Koopman, in Wilson and Reeder 1993).

Occurrences

This species is represented by a very large number of occurrences (subpopulations).

Population

Total adult population size is unknown but presumably exceeds 100,000. See Arita (1993) for information on population size in Mexico.

Habitat

Various wooded and semi-open habitats, including cities. Much more abundant in regions dominated by deciduous forest than in coniferous forest areas. Summer roosts generally are in buildings and also hollow trees, rock crevices, tunnels, and cliff swallow nests; prefers sites that do not get hot.

Typically roosts in twilight part of cave. Maternity colonies form in attics, barns and occasionally tree cavities; often in rock crevices or dead ponderosa pines in western Canada; in deep crevices and holes in limestone caves in Puerto Rico (Anthony 1925). Most adult females return to same maternity roost site in successive years. About 10-30% of volant immature females return to natal site (Kurta and Baker 1990). Caves, mines, and especially buildings and manmade structures are used for hibernation (e.g., see Whitaker and Gummer, 1992).

Vonhof and Barclay (1996) provide information on characterisitcs of roost trees in British Columbia. In Alberta, reproductive females selected warmer diurnal roost sites than did males and nonreproductive females (Hamilton and Barclay 1994).

Phenology

Initial foraging period occurs within 5 hours after sunset; most activity within second hour after sunset; subsequently may retire to night roost. Flies less than 2 hours each night. In Alberta, both sexes exhibited daily torpor during the gestation, lactation, and postlactation periods; males were torpid more frequently and used deeper torpor than did reproductive females (Hamilton and Barclay 1994).

In temperate areas many do not appear at hibernacula until November (Barbour and Davis 1969). Apparently does not hibernate in Cuba; may become torpid on cool winter nights (Kurta and Baker 1990).

Ecology

Males most often solitary in summer, or may roost with females or in all-male colonies. Winter colonies rarely number more than a few hundred. Less gregarious in winter; usually solitary in crevice, sometimes in small groups. When young flying, males may join nursery groups to form large late-summer colonies (Barbour and Davis 1969). Capable of living at least 20 years, though few actually attain old age.

Mobility

Fairly sedentary. Probably remains within 50 km (32 mi) of birthplace (Barbour and Davis 1969). Rarely moves more than 80 km between summer and winter roosts, though there is evidence that some individuals in the Midwest migrate south for winter.

Food

Dependent upon flying insects; small beetles are the most common prey in many areas. Large size, powerful jaw muscles, and robust teeth allow predation on larger insects with tough exoskeletons (e.g., beetles). Basically a generalist in foraging habitat; forages over land or water, clearings and lake edges; may forage around lights in rural areas. According to Schmidly 1991, seems to prefer foraging among tree foliage rather than above or below the forest canopy. Distance from day roost to foraging area averages about 1-2 km (Brigham 1991).

Reproduction

Copulate in fall and intermittently throughout winter. In temperate regions, ovulation and fertilization delayed until after hibernation. Gestation lasts 2 months. Young are born May-July, with slight trend

toward earlier parturition in lower latitudes (Barbour and Davis 1969); mostly late May to June in Texas (Schmidly 1991). Litter size usually is 1 in western North America, 2 in eastern North America and Cuba. Lactation lasts 32-40 days; young fly at 4-5 weeks. Males usually are sexually mature in first fall; not all females reproduce at end of first year. Nursery colony rarely numbers more than a few hundred (mostly 25-75 adults in the eastern U.S.).

Change Agent (CA) Effects

On a range-wide scale, no major threats have been identified. Locally, the following factors may be significant.

Because *E. fuscus* appears to be a habitat generalist, readily uses human-made structures as roosts, and takes advantage of insect concentrations near lights, habitat is probably a less important conservation component than it is for other bats. However, current forestry practices may have a negative impact on tree-roosting bat species, and foraging activity has been shown to decrease with increasing urbanization, possibly because of lower insect abundance (Agosta 2002).

Big brown bats and other species that roost in buildings are often perceived as a nuisance and are vulnerable to exclusion and eradication attempts (Pierson 1998, Agosta 2002).

Big brown bats are vulnerable to the bodily accumulation of toxins (e.g., pesticides) because of their high trophic rank and longevity. Adverse effects of organochlorine pesticides (e.g., DDTs) on bats are well documented; pesticides can cause mortality, altered behavior, and can be transferred to nursing young. Although banned in the U.S., residues still persist in soils and accumulate in some bat populations. Pesticide exposure is likely an important cause of decline for some insectivorous bat populations (Agosta 2002).

A new threat, "white-nose syndrome" is devastating hibernating bat populations in parts of eastern North America (Cryan 2009). Species affected include little brown bats (*Myotis lucifugus*), northern long-eared bats (*M. septentrionalis*), federally listed (endangered) Indiana bats (*M. sodalis*) and several other species (Cryan 2009). Big brown bats (*Eptesicus fuscus)* frequently hibernate in caves, mines or buildings, usually alone or in small groups. In New Hampshire, the bats in buildings may be protected from white-nose syndrome, but those in caves and mines do get the disease (NHFG 2012). Although not reported from the western U.S., white-nose syndrome is now confirmed in Oklahoma and there is concern it may spread to bats in the western U.S. (BCI 2010).

Conceptual Diagram

Species and assemblages of species experience stress when faced with Change Agents. Some change agents, such as new rural or urban development including mines and landfills, directly remove the element. Other change agents such as roads and transportation corridors (railroads, power lines, solar arrays, oil pumping platforms and the like) fragment habitat distribution (Debinski and Holt 2001). More dispersed human activities, such as recreation, hunting, logging, or ORV activities result in increases in road densities or disturbance via disrupted breeding, nesting, foraging, soil surface disturbance which affects biological soil crusts (Rosentreter and Eldridge 2002), or uprooting or

damage to plants; but these dispersed activities are difficult to measure other than via mapping of roads.

Invasive plant species can have profound effects on ecosystems, and hence upon the species or assemblages occurring in those habitats. Invasive plant species directly compete with native species, and have been shown to completely remove the native ecosystem habitat (e.g. tamarisk) (Brussard et al. 2000). Fragmentation of shrub-steppe and grasslands by agriculture increases cover of annual grasses, total annual/biennial forbs, and bare ground, and decreases cover of perennial forbs and biological soil crusts, and reduces obligate insects (Quinn 2004) and obligate birds and small mammals (Vander Haegen et al. 2001). Fine fuels accumulating from alien annual grasses, such as *Bromus madritensis, Bromus tectorum*, and *Schismus* spp., are an important fuelbed component in many western ecosytems and can substantially increase the fire frequency (Chambers et al. 2007, Condon et al. 2011, Keeler-Wolf 2007), altering vegetation structure and composition, which in turn leads to alteration of faunal composition, species habitat, direct loss of habitat, and other impacts.

These stressors result in different levels of response depending on the degree of impact and how many stressors are acting on the same resource simultaneously. Responses include a reduction in species diversity and species genetic diversity with the fragmentation and loss of habitat (Vryanckx et al. 2011). Species can become less abundant as their habitats become fragmented or continually disturbed such that reproduction is less successful (Brussard et al. 2000). As native species become stressed, other more tolerant and opportunistic species may increase in abundance, further tipping the balance of food webs in both terrestrial and aquatic systems, and predator/prey dynamics. The indicators shown in the causal diagrams below measure the amount of stress or the type and magnitude of response to stress within each resource. See the Ecological Status Scorecard section for full explanation of each indicator (Figure B-20).

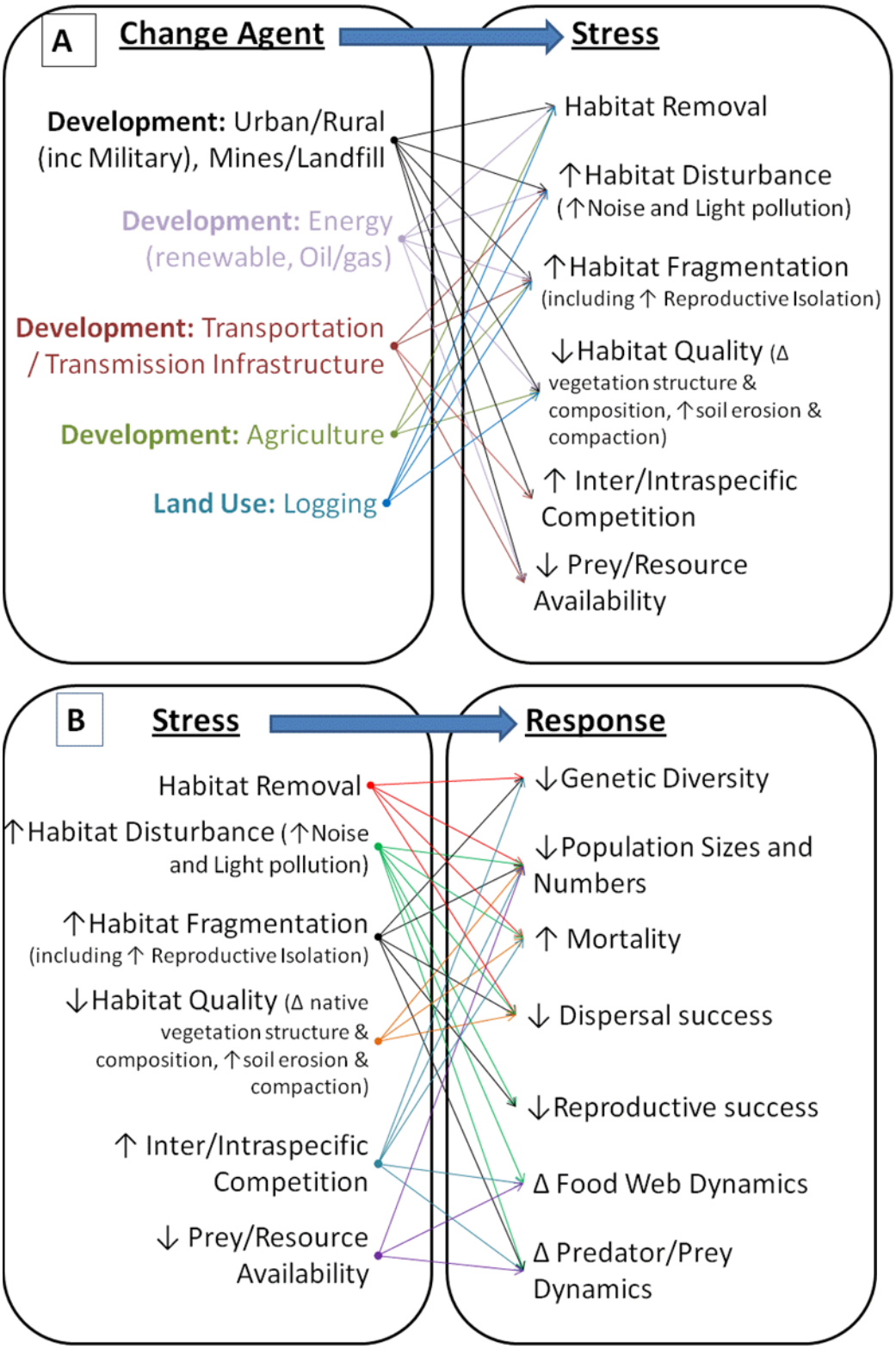

Figure B-20 (A and B). The conceptual model for Big Brown Bat (*Eptesicus fuscus*) illustrates the effect of each Change Agent on the resource's ecological integrity. A. Change Agents are a source of different types of stressors. B. Different types of stressors invoke different responses.

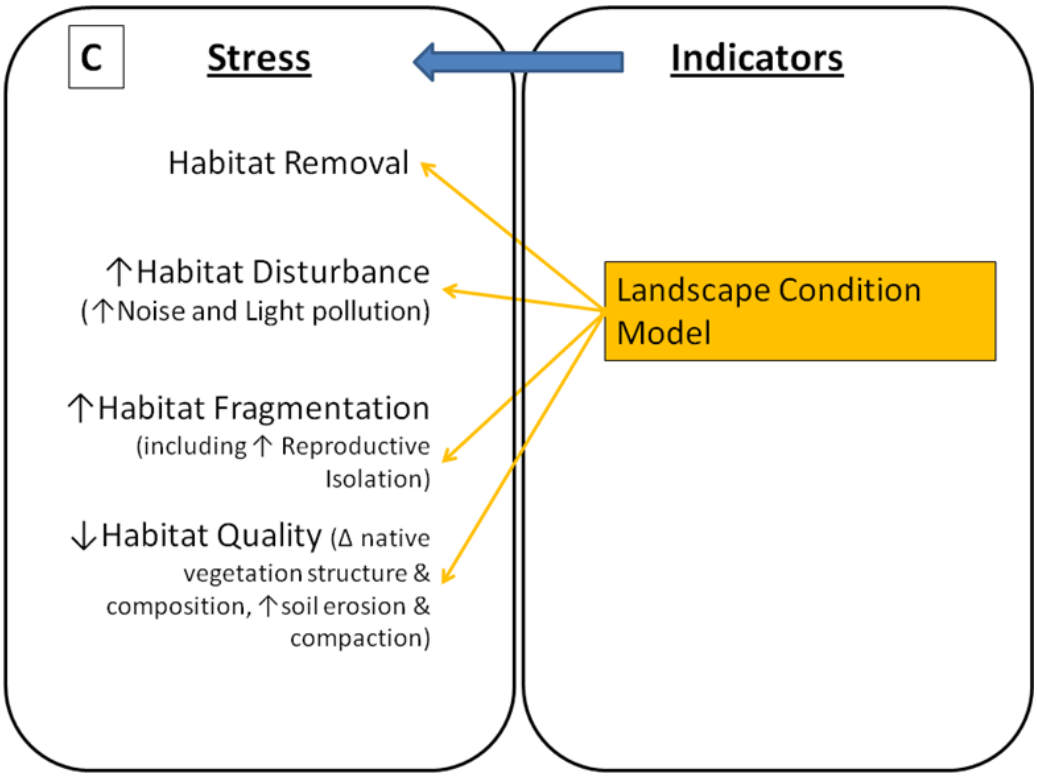

Figure B-20 (C). The conceptual model for Big Brown Bat (*Eptesicus fuscus*) illustrates the effect of each Change Agent on the resource's ecological integrity. C. Indicators are metrics by which we can directly measure the amount of stress or response within each type of resource.

Ecological Integrity Criteria and Indicators

The Habitat Status Scorecard links conceptual models that describe the relationships between change agents and the habitat requirements of each species resource to spatial models that provide practical indicators of habitat status.

The conceptual model diagrams presented above in the discussion of Change Agent Effects indicate the stresses and responses expected at the scale of the habitat for the resource of concern. These stresses and responses were identified based on an assessment of the key habitat attributes for this resource type, based on the information presented in the Focal Resource Characterization section. Panel C of these diagrams, and Table B-21 below, identify a suite of indicators for assessing levels of stress and response. The indicators are organized by key ecological attributes (KEAs), which for species resources consist of pivotal habitat characteristics and primary ecological drivers. KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. The Habitat Status Scorecard (Table B-21) is designed to report on habitat status indicators by 4x4 km square units. The assessment indicators with justifications and definitions are presented in Table B-21, organized by Key Ecological Attributes.

Table B-21. Indicators used for habitat status assessment of Big Brown Bat (*Eptesicus fuscus*).

Key Ecological Attribute	Indicator	Definition	Justification
Landscape Condition	Landscape Condition Index	This indicator is measured by intersecting the mapped area or habitat distribution map of the resource with the LCM layer and reporting the average LCM index value for the resource or habitat within each 5th level watershed, or 4x4 km square units for species. Landscape Condition Index is a 90x90m square unit resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. The results are a score for landscape condition from 0 to 1 with 1 being very high landscape condition and values close to 0 likely having very poor condition.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance.

Each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest. The mean index scores of these indicators may then be averaged by each Key Ecological Attribute. Displaying the indicators with individual scores allows user to interpret which particular ecological attributes in a reporting area is driving the ecological status of the resource.

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Brazilian Free-tailed Bat (Tadarida brasiliensis)
Model Group: Basin Dry Land System > Cliff & Outcrop

Focal Resource Characterization

Classification Comments

The specific relationships of Antillean populations of *Tadarida* remain obscure; it has been suggested that Caribbean populations represent a distinct species or that they are related to *T. b. cynocephala* (of the southeastern U.S.) but not to other populations of the *brasiliensis* complex (Jones 1989). Two of the nine subspecies (*T. b. mexicana* and *T. b. cynocephala*) occur in the U.S. Though morphological data suggest intergradation (Schmidly 1977), these two subspecies differ widely in behavior (migratory vs. nonmigratory) and roost preference, and gene flow between them has been reported to be minimal and unidirectional at most (Owen et al. 1990). However, McCracken and Gassel (1997) found high genetic similarity and evidence of gene flow between these nominal subspecies, such as typically seen between geographic populations of the same subspecies.

The generic name *Rhizomops* was proposed in 1984 for *Tadarida brasiliensis* (and presumably all subspecies), but this was rejected by Owen et al. (1990) because the genus was based entirely on plesiomorphic characters.

McCracken et al. (1994) examined allozyme data from several maternity and winter colonies within the range of subspecies *mexicana* and determined that populations are not structured genetically into distinct geographic units.

Range

Southern Oregon, northern Nebraska, and southern North Carolina (some records farther north) southward through most of Central America and Antilles (south to St. Lucia in Lesser Antilles; Tobago record probably an accidental, Jones 1989) to central Argentina, southern Brazil, and central Chile, excluding Amazonia (Wilkins 1989, Honacki et al. 1982).

Occurrences

Bulk of total abundance is confined to about 20 caves in the southwestern U.S. Rest are small in size, though numerous. All large colonies are probably known.

Population

Estimated 120-150 million. See Arita (1993) for information on population size in Mexico.

Habitat

Roosts primarily in buildings (generally old ones) in southeastern U.S. (sometimes in hollow trees), U.S. West Coast, and Jamaica; in caves in southwestern U.S.; in both buildings and caves in Puerto Rico. May use rock crevice, bridge, sign, or cliff swallow nest as roost during migration. Generaly roosts high (at least 3 m) above ground to allow free fall required to attain flight. Large maternity colonies inhabit buildings and caves (rarely used in Florida); also uses culverts and bridges. Tends to return to natal cave to breed (Caire et al. 1989).

Phenology

On overcast days, often found feeding in early evening. In predominantly male colony in Colorado: began to leave mine shaft at about 2300 h; a few began returning by 2300, continuing until 0430; none returned after 0515 (Freeman and Wunder 1988); in some areas some groups do not return to cave until after daylight (Caire et al. 1989); in other areas may forage for a few hours, return to cave roost for a few hours, then go out on another foraging trip, returning after dawn. Typically hibernates in the eastern U.S. and on U.S. West Coast.

Ecology

Roosts in tightly packed groups. Winter congregations typically much smaller than summer colonies. Sexes generally segregate during summer; males may form small (but sometimes up to 100,000) at higher elevations, whereas females usually form nursery colonies in warmer areas of the species' northern range (Freeman and Wunder 1988). Typically feeds within 80.5 km radius of day roost, but up to 241km away (Whitaker 1980).

Mobility

In the eastern U.S. (to eastern Texas) and U.S. West Coast: hibernates but does not migrate. Antillean subspecies ANTILLARUM does not migrate (Jones 1989). Texas and Great Plains through southwestern U.S.: most migrate to Mexico or to southwestern U.S., usually toward end of October, return in March. (See Wilkins 1989 for more detail.) Individuals from southern Great Plains migrate, beginning in late August, to winter range from southern edge of Edwards Plateau in Texas south nearly to latitude of Mexico City (Caire et al. 1989).

Foraging habitat is very broad. May range as far as 80 km from cave to feed (Caire et al. 1989). Bats that roost in Carlsbad Cavern, New Mexico, forage up to at least 56 km (35 mi) from the cavern (Best and Geluso 2003).

Food

Opportunistic; diet includes moths, flying ants, beetles, bugs, and other insects; often preys on densely swarming insects. May fly considerable distances to favorite feeding areas.

Reproduction

Breeds late February-March or early April in North America. None of 8 females collected in late December in Jamaica was pregnant (Goodwin 1970). Gestation lasts 2.5-3.5 months. Births mainly June-July in North America (early to mid-June in Texas). Litter size: 1 (females occasionally carry 2 embryos). Despite the huge numbers of young that may be present in a colony, females recognize and nurse their own offspring. Young nurse for about 45 days, first fly at 6-7 weeks. Females may become pregnant as yearlings; males become sexually mature at 18-22 months. Maternity colonies initially consist of almost only of pregnant females. Some colonies include more than 1 million individuals (20 million adult females give birth in Bracken Cave near San Antonio, Texas); 10,000s in eastern North America. If a nursery falls below about 20,000 females, usually it is abandoned (Caire et al. 1989).

Change Agent (CA) Effects

This species is threatened by disturbance, pesticides, and habitat destruction in tropics. A new threat, "white-nose syndrome" is devastating hibernating bat populations in parts of northeastern North America (Cryan 2009). Species affected include little brown bats (*Myotis lucifugus*), northern long-eared bats (*M. septentrionalis*), and federally listed (endangered) Indiana bats (*M. sodalis*) and several other species (Cryan 2009). This disease is now confirmed in Oklahoma, and there is concern it may spread to bats in the western U.S. (BCI 2010). Brazilian Free-tailed Bats do not hibernate, but migrate south during winter, so there is less concern about them being infected. However, there is concern that this species may spread the white-nose syndrome fungus to other hibernating bat species.

Conceptual Diagram

Species and assemblages of species experience stress when faced with Change Agents. Some change agents, such as new rural or urban development including mines and landfills, directly remove the element. Other change agents such as roads and transportation corridors (railroads, power lines, solar arrays, oil pumping platforms and the like) fragment habitat distribution (Debinski and Holt 2001). More dispersed human activities, such as recreation, hunting, logging, or ORV activities result in increases in road densities or disturbance via disrupted breeding, nesting, foraging, soil surface disturbance which affects biological soil crusts (Rosentreter and Eldridge 2002), or uprooting or damage to plants; but these dispersed activities are difficult to measure other than via mapping of roads.

Invasive plant species can have profound effects on ecosystems, and hence upon the species or assemblages occurring in those habitats. Invasive plant species directly compete with native species, and have been shown to completely remove the native ecosystem habitat (e.g. tamarisk) (Brussard et al. 2000). Fragmentation of shrub-steppe and grasslands by agriculture increases cover of annual grasses, total annual/biennial forbs, and bare ground, and decreases cover of perennial forbs and biological soil crusts, and reduces obligate insects (Quinn 2004) and obligate birds and small mammals (Vander Haegen et al. 2001). Fine fuels accumulating from alien annual grasses, such as *Bromus madritensis, Bromus tectorum*, and *Schismus* spp., are an important fuelbed component in many western ecosytems and can substantially increase the fire frequency (Chambers et al. 2007, Condon et al. 2011, Keeler-Wolf 2007), altering vegetation structure and composition, which in turn leads to alteration of faunal composition, species habitat, direct loss of habitat, and other impacts.

These stressors result in different levels of response depending on the degree of impact and how many stressors are acting on the same resource simultaneously. Responses include a reduction in species diversity and species genetic diversity with the fragmentation and loss of habitat (Vryanckx et al. 2011). Species can become less abundant as their habitats become fragmented or continually disturbed such that reproduction is less successful (Brussard et al. 2000). As native species become stressed, other more tolerant and opportunistic species may increase in abundance, further tipping the balance of food webs in both terrestrial and aquatic systems, and predator/prey dynamics. The indicators shown in the causal diagrams below measure the amount of stress or the type and

magnitude of response to stress within each resource. See the Ecological Status Scorecard section for full explanation of each indicator (Figure B-21).

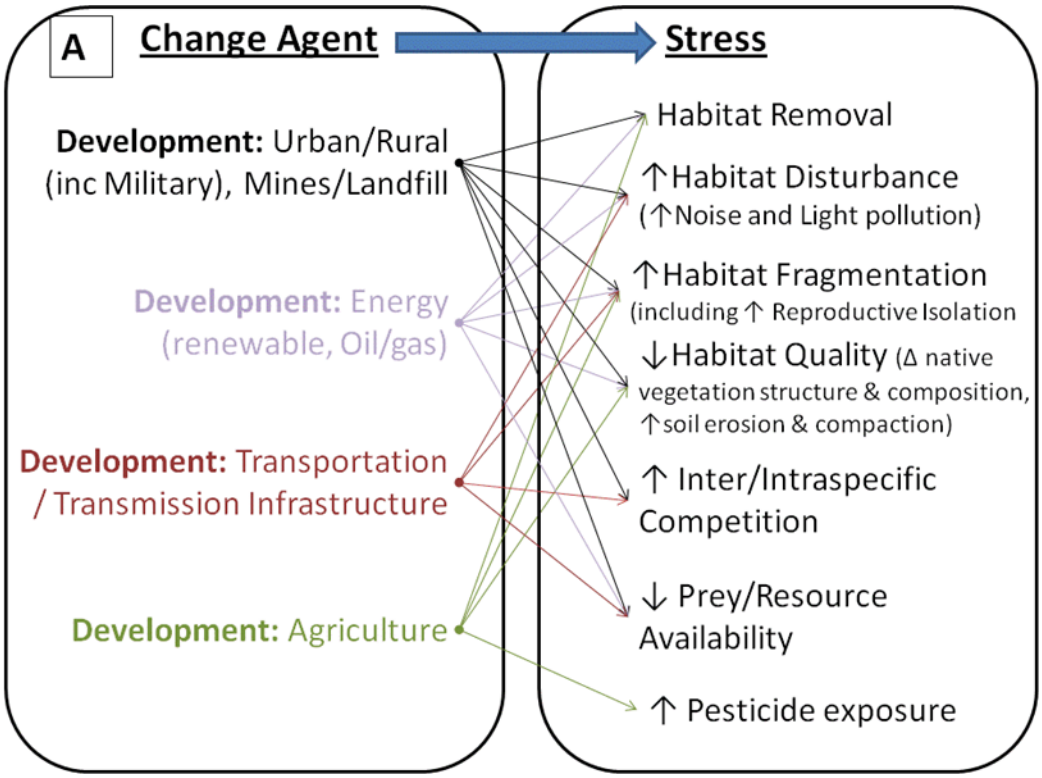

Figure B-21 (A). The conceptual model for Brazilian Free-tailed Bat (*Tadarida brasiliensis*) illustrates the effect of each Change Agent on the resource's ecological integrity. A. Change Agents are a source of different types of stressors.

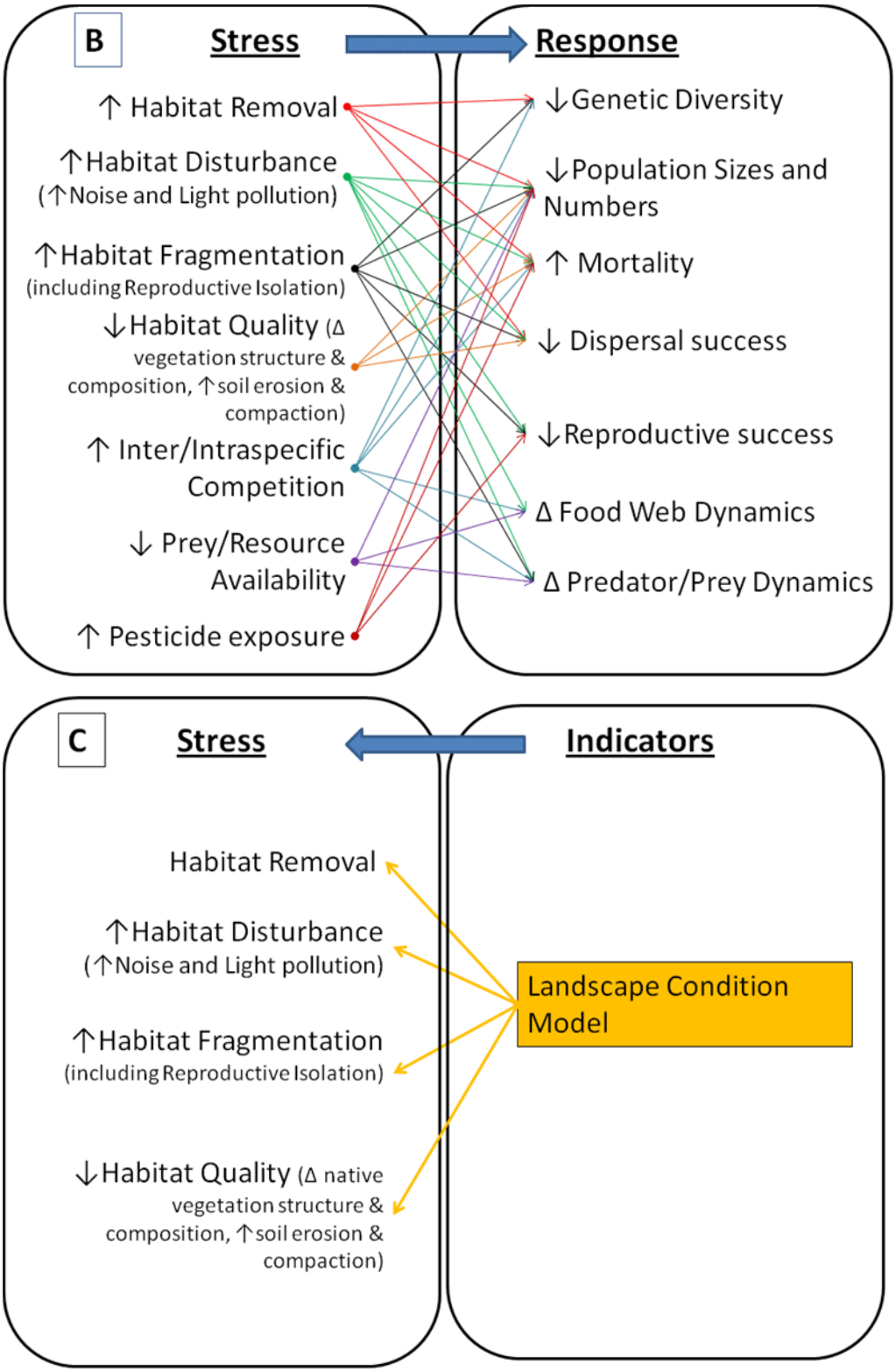

Figure B-21 (B and C). The conceptual model for Brazilian Free-tailed Bat (*Tadarida brasiliensis*) illustrates the effect of each Change Agent on the resource's ecological integrity. B. Different types of stressors invoke different responses. C. Indicators are metrics by which we can directly measure the amount of stress or response within each type of resource.

Ecological Integrity Criteria and Indicators

The Habitat Status Scorecard links conceptual models that describe the relationships between change agents and the habitat requirements of each species resource to spatial models that provide practical indicators of habitat status.

The conceptual model diagrams presented above in the discussion of Change Agent Effects indicate the stresses and responses expected at the scale of the habitat for the resource of concern. These stresses and responses were identified based on an assessment of the key habitat attributes for this resource type, based on the information presented in the Focal Resource Characterization section. Panel C of these diagrams, and Table B-22 below, identify a suite of indicators for assessing levels of stress and response. The indicators are organized by key ecological attributes (KEAs), which for species resources consist of pivotal habitat characteristics and primary ecological drivers. KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. The Habitat Status Scorecard (Table B-22) is designed to report on habitat status indicators by 4x4 km square units. The assessment indicators with justifications and definitions are presented in Table B-22, organized by Key Ecological Attributes.

Each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest. The mean index scores of these indicators may then be averaged by each Key Ecological Attribute. Displaying the indicators with individual scores allows user to interpret which particular ecological attributes in a reporting area is driving the ecological status of the resource.

Table B-22. Indicators used for habitat status assessment of Brazilian Free-tailed Bat (*Tadarida brasiliensis*).

Key Ecological Attribute	Indicator	Definition	Justification
Landscape Condition	Landscape Condition Index	This indicator is measured by intersecting the mapped area or habitat distribution map of the resource with the LCM layer and reporting the average LCM index value for the resource or habitat within each 5th level watershed, or 4x4 km square units for species. Landscape Condition Index is a 90x90m square unit resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. The results are a score for landscape condition from 0 to 1 with 1 being very high landscape condition and values close to 0 likely having very poor condition.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance.

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Greater Sage Grouse (Centrocercus urophasianus)
Model Group: Basin Dry Land System > Semi-desert Shrub & Steppe

Focal Resource Characterization

Classification Comments

This species formerly included *C. minimus*, which is now recognized as a distinct species, the Gunnison sage-grouse (AOU 1998). Subspecies *phaios* is of questionable taxonomic validity; validity may be impossible to determine because of introductions of nominate subspecies into range of *phaios* (Johnsgard 1983, Banks 1995). Accordingly, USFWS (2003, 2010) did not recognize any valid subspecies of *C. urophasianus*.

Columbia Basin Distinct Population Segment: USFWS (2003) found that the discrete population segment of greater sage-grouse that remains in Washington is significant to the remainder of the taxon and thus represents a distinct population segment. The significance of this population segment is primarily due to its persistence in the unique ecological setting of the Columbia Basin. In addition, the available genetic and morphological information on greater sage-grouse, while inconclusive, indicates that this population segment may be differentiating from the remainder of the taxon, and its extirpation could preclude further scientific inquiry into these characteristics. Finally, information concerning the historic and current distribution of greater sage-grouse indicates that the loss of the Columbia Basin population segment would represent a significant gap in the historical range of the taxon.

Range

This species is resident locally from central Washington, southern Idaho, Montana, southeastern Alberta, southwestern Saskatchewan, southwestern North Dakota, and western South Dakota south to east-central California, south-central Nevada, southern Utah, and northwestern Colorado; extirpated from historical range in southern British Columbia, western Nebraska, and possibly northern Arizona (USFWS 2010). Current distribution is estimated at 668,412 sq km or 56 percent of the potential pre-settlement distribution (see USFWS 2010).

Columbia Basin Distinct Population Segment: The historical distribution of greater sage grouse populations within the Columbia Basin (i.e., the northwestern portion of the species' range) extended from northern Oregon throughout eastern Washington and into extreme south-central British Columbia (USFWS 2003). Currently, all (or very nearly all) of the greater sage-grouse in Oregon occur outside of the Columbia Basin (WDFW 2000) and are not part of this DPS. Historically, greater sage-grouse in Washington ranged from Oroville in the north, west along the Cascade foothills, east to the Spokane River, and south to the Oregon border (Yocom 1956). Currently,

greater sage grouse occupy two relatively small areas within the Columbia Basin in central Washington (USFWS 2003).

Occurrences

The species as a whole is represented by many distinct occurrences (subpopulations).

Columbia Basin Distinct Population Segment: The two subpopulations of greater sage-grouse that remain in central Washington are separated by approximately 55 km. While this distance is well within the species' maximum estimated dispersal distance, a number of recent telemetry studies have never documented their intermixing (M. Schroeder, pers. comm., 1999; M. Pounds, YTC, pers. comm., 1999; cited by USFWS 2003). However, until recently, the two subpopulations were considered relatively continuous and may now represent isolated components of a single metapopulation (WDFW 1995, Schroeder et al. 2000). In addition, sporadic sightings outside current concentrations indicate there may be some minimal interaction and, possibly, genetic interchange between them (WDFW 1995). [from USFWS 2003]

Population

Based on data from 2002-2008, total range-wide population size was estimated at approximately 536,000 (USFWS 2010). This estimate, though not precise and based on certain assumptions that may be incorrect, likely is of the correct order of magnitude.

Habitat

Habitat includes foothills, plains, and mountain slopes where sagebrush is present (AOU 1983), often with a mixture of sagebrush, meadows, and aspen, in close proximity. This species uses a wide variety of sagebrush mosaic habitats, including (1) tall sagebrush types such as big sagebrush (*Artemisia tridentata*), three-tip sagebrush (*A. tripartita*), and silver sagebrush (*A. cana*); (2) low sagebrush types, such as low sagebrush (*A. arbuscula*) and black sagebrush (*A. nova*); (3) mixes of low and tall sagebrush with abundant forbs; (4) riparian and wet meadows; (5) steppe dominated by native forbs and bunchgrasses; (6) scrub-willow (*Salix* spp.); and (7) sagebrush/woodland mixes with juniper (*Juniperus* spp.), ponderosa pine (*Pinus ponderosa*), or quaking aspen (*Populus tremuloides*; Schroeder et al. 1999).

Lekking: The quality of adjacent nesting and brood-rearing habitat may be the most important factor in lek choice, and males apparently form leks opportunistically within potential nesting habitat where female traffic is high (Wakkinen et al. 1992, Connelly 1999b, Schroeder et al. 1999, Connelly et al. 2000). Leks are located on relatively open sites surrounded by sagebrush, or in areas where sagebrush density is low, such as exposed ridges, knolls or grassy swales (Schroeder et al. 1999). Lek sites themselves are highly variable and may include many types of clearings and disturbed sites, including landing strips, old lake beds, roads, gravel pits, cropland, and burned areas in addition to natural openings (Connelly et al. 1981, Gates 1985, Schroeder et al. 1999, Connelly et al. 2000).

Habitats used by pre-laying females are also important for subsequent reproductive success. At this time, hens require areas rich with forbs that are high in calcium, phosphorus, and protein (Barnett and Crawford 1994, Connelly et al. in prep.). In Oregon, important forbs included desert-parsley (*Lomatium* spp.), hawksbeard (*Crepis* spp.), long-leaf phlox (*Phlox longifolia* Nutt.), everlasting

(*Antennaria* spp.), clover (*Trifolium* spp.), mountain-dandelion (*Agoseris* spp.), Pursh's milk-vetch (*Astragalus purshii* Dougl.), obscure milk-vetch (*A. obscurus*), and buckwheat (*Eriogonum* spp.; Barnett and Crawford 1994).

Nesting: Hens typically nest in same specific area in successive years (Fisher et al. 1993). Nest in thick cover in sagebrush habitat, beneath a sagebrush or other shrub; nests are on the ground in a shallow depression. Usually choose areas dominated by sagebrush, in sites with taller sagebrush, greater shrub canopy cover, and more ground litter (Musil et al. 1994), and nest beneath one of tallest shrubs in stand with greater lateral cover (Roberson 1986, Wakkinen 1990). Occasionally use areas dominated by grasses or other shrubs (Schroeder et al. 1999). Proximity to water may be more important in some areas than in others (Schroder et al. 1999).

Both a dense sagebrush overstory and an herbaceous understory of grasses are important to provide shade and security, and both new herbaceous growth and residual cover are important in the understory (Connelly 1999b). Tall grass cover is critical for concealment and a warmer microclimate (Call and Maser 1985, Gregg et al. 1994). Most often nest beneath a sagebrush and approximately 20 percent of time may nest beneath other shrub species or grass, but nest success is higher beneath sagebrush than other shrubs (Connelly 1999b). In southeastern Idaho, nest success averaged 53 percent for females nesting under sagebrush, 22 percent for those using non-sagebrush cover (Connelly et al. 1991). Favor nesting in sagebrush 40 to 80 centimeters in height with 15 to 25 percent canopy cover (sometimes more than 30 percent), and grasses 15 to 30 centimeters high (usually more than 18 centimeters, measured in May) and 3 to 30 percent grass cover (15-25 percent best; Connelly 1999b).

In northern Washington, where native sagebrush habitats have been largely lost and greatly fragmented, females nest in older Conservation Reserve Program (CRP) lands that have been converted from wheat to a mix of crested wheatgrass, sagebrush, and native and non-native forbs. These areas typically have fragments of remnant sagebrush shrub-steppe in the surrounding landscape mosaic. Hens also nest in very small fragments of high-quality habitat within the fragmented landscape, and they move large distances from leks to nests and throughout the season (Braun and Schroeder 1999).

Early Brood-Rearing: Habitat for brood-rearing in early spring is critical to brood survival. Hens with broods tend to use sagebrush uplands adjacent to nest sites, but distance of movement varies (Connelly et al. 2000). Sagebrush overstory, herbaceous understory, and the presence of plentiful insects that provide a high-protein diet for broods (especially Hymenoptera and Coleoptera; species typical of sagebrush upland steppe) are the three important factors (Connelly 1999b). Stands may be relatively open (approximately 14 percent sagebrush canopy cover; Martin 1970, Wallestad 1971) with more than or equal to 5 percent grass and forb cover (Sveum et al. 1998).

Summer: As spring habitats dry, hens move their broods to wetter sites in June and July (Connelly et al. 2000). Habitats used are highly variable, but food-rich areas with succulent forbs and abundant insects are key. In this season, sage-grouse may roost in sagebrush and use seeps, wet meadows, riparian areas, alfalfa fields, potato fields, and other cultivated and irrigated areas. Males and

broodless females use a wide variety of habitats, and they may move to uplands and into mountains, using high mountain meadows and grasslands (Connelly 1999b).

In southeastern Oregon, broodless hens moved to meadows by early July whereas hens with broods remained in upland habitats (Gregg et al. 1993); hens with broods initially selected low sagebrush cover types during early brood-rearing, big sagebrush cover types later in brood-rearing, and ultimately concentrated habitat use in and near lakebeds and meadows (Drut et al. 1994a). In Wyoming, broods most often occupied sagebrush-grass and sagebrush-bitterbrush habitats, in sites containing *Stipa comata* and *Alyssum desertorum* (Klott and Lindzey 1990).

Winter: This species is well-adapted to winter extremes, but access to sagebrush for food and cover in all snow conditions is critical to survival. Individuals are known to move considerable distances to find good habitat, and winter ranges may exceed 140 km^2 (54 mi^2) (Robertson 1991). Thus, sage-grouse require a landscape mosaic with a diversity of sagebrush canopy cover and heights over 100s of square kilometers (Connelly 1999b). Winter sites may be selected on the basis of topography and availability of sagebrush above the snow. Sage-grouse tend to feed in low, open sagebrush flats, and once these are covered with snow will move into taller sagebrush (Connelly 1999b). Favored conditions include stands with highest available sagebrush canopy cover (10-25 percent and up to 40 percent) and sagebrush heights of 25-30 centimeters above the snow level (Braun et al. 1977, Call and Maser 1985, Connelly 1999b). Sagebrush subspecies and stands that contain the highest levels of protein may be selected (Remington and Braun 1985). Sage-grouse use snow burrows for thermal cover, tunneling into soft drifts on the lee side of shrubs, or burrowing into dry soft snow (when snow depths more than 25 centimeters) in open, level areas without visible shrub cover above the snow (Back et al. 1987).

Ecology

Males and females gather into separate flocks in winter, as do broodless hens in early summer.

Mobility

Populations can be defined by their migration habit. Populations are either nonmigratory, or undertake a 1-stage migration or two-stage migration. One-stage migrants move between distinct summer and winter ranges, often 15-48 kilometers apart. Two-stage migrants move between breeding habitat, summer range, and winter range, and their annual movements can exceed 80 to 100 kilometers (Connelly 1999b). Fall movements to winter range can span several months, from late August to December (Connelly et al. 1988). Males and females flock separately. In some areas, populations make local elevational migrations between summer and winter habitats. See Schroeder et al. (1999) for more detail on migration habits.

Median dispersal distance from natal area to breeding area was about 7-9 km in Colorado; probably over half of all yearling grouse attended natal-area lek (Dunn and Braun 1985). Sage-grouse moved average of 10-15 km, (up to 82 km/51 mi) between summer and winter ranges in Idaho. Over the year, individuals in migratory populations may cover home ranges that exceed 1,500 km^2; size of home ranges vary greatly with migratory habit and season (Connelly et al. 2000). Distances between nest sites and nearest leks average 1.1 to 6.2 km, but females may move more than 20 km from a lek

to nest (Connelly et al. 2000). In Colorado, sage-grouse generally stayed within 6 km of their lek (Schoenberg 1982).

Food

Sagebrush provides most of the winter diet. At other times of the year sage-grouse feed on sagebrush as well as the leaves, flowers, and buds of associated plants. They also eat insects (e.g., ants, beetles, grasshoppers; Terres 1980). Insects are especially important in the diet of newly hatched broods. In southeastern Oregon, chicks ate primarily forbs and insects at one site, but mostly sagebrush at another site (Drut et al. 1994b). Over the fall, birds shift from consuming large amounts of forbs to eating mostly sagebrush (Wallestad 1975). See Schroeder et al. (1999) for greater detail on diet and food selection.

Reproduction

This species is a lek breeder; up to 400 males may display in an area 0.8 kilometers long. Clutch size averages around seven to eight but is highly variable; variation may reflect habitat quality and nutritional condition of female (Connelly et al. 2000). Incubation, by the female, lasts 25-27 days. Young are precocial, downy, tended by female, fly when 7-14 days old. Productivity generally is low; reported nest failure 36 percent (Montana) to 76 percent (Oregon) (see Gregg et al. 1993). Renesting rates after nest loss are variable, from less than 10 percent to more than 40 percent (Connelly et al. 2000). Females are sexually mature in 1 year, though some or many yearlings may not nest. Most sage-grouse live 3-6 years or less, but individuals up to 9 years of age have been recorded in the wild (Connelly et al. 2004).

Change Agent (CA) Effects

Declines in the 1920s and 1930s have been attributed to hunting, and declines in the 1960s and 1970s resulted primarily from loss, fragmentation, and degradation of sagebrush habitat (see USFWS 2010). Many of the recorded declines over the past several decades are the result of loss of leks, indicating either a direct loss of habitat or habitat function (USFWS 2010).

Connectivity among sage-grouse populations has declined since 1965 (USFWS 2010). The decline in connectivity was due to the loss of leks and reduced population size (Knick and Hanser, in press, cited by USFWS 2010). Small decreases in lek connectivity resulted in large increases in probability of lek abandonment. Historical leks with low connectivity were lost during this period, suggesting that current isolation of leks by distance (including habitat fragmentation) likely will result in future loss of isolated leks (Knick and Hanser).

Large losses of sagebrush shrubsteppe habitats due to agricultural conversion have occurred range wide but have been especially significant in the Columbia Basin of Washington, the Snake River Plain of Idaho, and the Great Plains. Conversion of sagebrush habitats to cropland continues to occur, but the current rate of conversion is unknown. Most areas suitable for agricultural production were converted many years ago. However, the current rate of conversion is likely to increase in the future if incentives for crop production for use as biofuels continue to be offered. Urban and exurban development also have direct and indirect negative effects on sage-grouse, including direct and indirect habitat losses, disturbance, and introduction of new predators and invasive plant species.

Given current trends in the Rocky Mountain west, urban and exurban development is expected to continue. Infrastructure such as powerlines, roads, communication towers, and fences continue to fragment sage-grouse habitat. These sources of fragmentation likely will increase into the future. Fragmentation of sagebrush habitats through a variety of mechanisms including those listed above has been cited as a primary cause of the decline of sage-grouse populations. The negative effects of habitat fragmentation on sage-grouse are diverse and include reductions in the following: lek persistence, lek attendance, winter habitat, recruitment, yearling annual survival, and female nest site choice. Habitat fragmentation is believed to be a primary cause of sage-grouse decline and in some areas has already led to population extirpation. Fragmentation is expected to continue into the foreseeable future and will continue to threaten the persistence of greater sage-grouse populations. [Abstracted from USFWS 2010].

Loss of sagebrush habitat to wildfire has been increasing in western areas of the greater sage-grouse range for the past three decades. The change in fire frequency has been strongly influenced by the presence of exotic annual grasses and significantly deviates from extrapolated historical fire regimes. Restoration of these communities is challenging, requires many years, and may, in fact, never be achieved in the presence of invasive grass species. Greater sage-grouse are slow to recolonize burned areas even if structural features of the shrub community have recovered. Burned areas also inhibit sage-grouse dispersal. Fire frequency is likely to increase in the foreseeable future due to increases in cover of Bromus tectorum and the projected effects of climate change. [Abstracted from USFWS 2010].

Invasive plants negatively impact sage-grouse primarily by reducing or eliminating native vegetation that sage-grouse require for food and cover, resulting in habitat loss and fragmentation. A variety of non-native annuals and perennials (e.g., Bromus tectorum, Euphorbia esula) and native conifers (e.g., pinyon pine, juniper species) are invasive to sagebrush ecosystems. Nonnative invasives, including annual grasses and other noxious weeds, continue to expand their range, facilitated by ground disturbances such as wildfire, grazing, and infrastructure. Pinyon and juniper and some other native conifers are expanding and infilling their current range mainly due to decreased fire return intervals, livestock grazing, and increases in global carbon dioxide concentrations associated with climate change, among other factors. A large portion of the Great Basin is at risk of B. tectorum invasion or pinyon-juniper encroachment within the next 30 years. Approximately 80 percent of land in the Great Basin Ecoregion is susceptible to displacement by B. tectorum within 30 years, and approximately 35 percent of sagebrush in the Great Basin is at high risk of displacement by pinyon-juniper in 30 years. Bromus tectorum is widespread at lower elevations and pinyon-juniper woodlands tend to expand into higher elevation sagebrush habitats, creating an elevational squeeze from both low and high elevations. [Abstracted from USFWS 2010].

Livestock management and domestic grazing can seriously degrade sage-grouse habitat. Grazing can adversely impact nesting and brood-rearing habitat by decreasing vegetation concealment from predators. Grazing also has been shown to compact soils, decrease herbaceous abundance, increase erosion, and increase the probability of invasion of exotic plant species. Once plant communities have an invasive annual grass understory dominance, successful restoration is very difficult if not

impossible. Massive systems of fencing constructed to manage domestic livestock cause direct mortality to sage-grouse in addition to degrading and fragmenting habitats. Livestock management also can involve water developments that can degrade important brood-rearing habitat and or facilitate the spread of West Nile virus. Additionally, some research suggests there may be direct competition between sage-grouse and livestock for plant resources. However, although there are obvious negative impacts, some research suggests that under very specific conditions grazing can benefit sage-grouse. Similar to domestic grazing, wild horses and burros have the potential to negatively affect sage-grouse habitats by decreasing grass cover, fragmenting shrub canopies, altering soil characteristics, decreasing plant diversity, and increasing the abundance of invasive Bromus tectorum. [Abstracted from USFWS 2010].

Energy development is a significant risk to the greater sage-grouse in the eastern portion of its range (Montana, Wyoming, Colorado, and northeastern Utah), with the primary concern being the direct elimination of habitat, leks, and whole populations and fragmentation of some of the last remaining large expanses of habitat. Continued exploration and development of traditional and nonconventional fossil fuel sources in the eastern portion of the greater sage-grouse range is predicted to continue to increase over the next 20 years. Greater sage-grouse populations are predicted to decline 7-19 percent over the next 20 years due to the effects of oil and gas development in the eastern part of the range. Development of commercially viable renewable energy (wind, solar, geothermal, biomass) is increasing across the range. In Wyoming, where wind development is advancing and predicted to increase, the effects of both conventional and nonconventional and renewable sources may claim a substantial toll on sage-grouse habitats and geographic areas that were in the past considered refugia for the species. Renewable energy resources are likely to be developed in areas previously untouched by traditional energy development. Wind energy resources are being investigated in south-central and southeastern Oregon where large areas of relatively unfragmented sage-dominated landscapes are important for maintaining long-term connectivity within the sage-grouse populations. [Abstracted from USFWS 2010].

Under current climate-change projections, further invasion by *Bromus tectorum* into sage-grouse habitat is likely to occur, as is invasion by woody species, and fire frequency (as well as extent and severity) likely will continue to increase. Climate warming is also likely to increase the severity of West Nile virus (WNv) outbreaks and to expand the area susceptible to outbreaks into areas that are now too cold for the WNv vector. Climate change is thus likely to exacerbate the existing primary threats to greater sagegrouse of frequent wildfire and invasive nonnative plants, particularly *B. tectorum* as well as the threat posed by disease. [Abstracted from USFWS 2010].

Columbia Basin Distinct Population Segment: USFWS (2001) noted declines in the distribution and abundance of western sage grouse throughout the Columbia Basin, primarily attributed to the loss and degradation of native shrub steppe habitats. These impacts are likely due to a combination of factors including crop production, fire, military training, overgrazing by livestock, rural and suburban development, and dam construction. The Columbia Basin DPS of western sage grouse is also at increased risk from inbreeding depression and random environmental influences due to its small size and level of fragmentation. The fragmented, isolated nature of the Columbia Basin DPS is a concern.

A preliminary viability analysis conducted by the WSGWG (1998) indicates that neither subpopulation is likely viable over the long term (approximately 100 years). USFWS (2001) acknowledged that various state and Federal agencies in Washington and Oregon, and throughout the species' historical distribution, are actively managing the birds to try to improve their overall population status and/or attempting to restore them to currently unoccupied habitats.

Conceptual Diagram

Species and assemblages of species experience stress when faced with Change Agents. Some change agents, such as new rural or urban development including mines and landfills, directly remove the element. Other change agents such as roads and transportation corridors (railroads, power lines, solar arrays, oil pumping platforms and the like) fragment habitat (Debinski and Holt 2001). More dispersed human activities, such as recreation, hunting, logging, or ORV activities result in increases in road densities or disturbance via disrupted breeding, nesting, foraging, soil surface disturbance which affects biological soil crusts (Rosentreter and Eldridge 2002), or uprooting or damage to plants; but these dispersed activities are difficult to measure other than via mapping of roads.

Invasive plant species can have profound effects on ecosystems, and hence upon the species or assemblages occurring in those habitats. Invasive plant species directly compete with native species, and have been shown to completely remove the native ecosystem habitat (e.g. tamarisk) (Brussard et al. 2000). Fragmentation of shrub-steppe and grasslands by agriculture increases cover of annual grasses, total annual/biennial forbs, and bare ground, and decreases cover of perennial forbs and biological soil crusts, and reduces obligate insects (Quinn 2004) and obligate birds and small mammals (Vander Haegen et al. 2001). Fine fuels accumulating from alien annual grasses, such as *Bromus madritensis, Bromus tectorum*, and *Schismus* spp., are an important fuelbed component in many western ecosytems and can substantially increase the fire frequency (Chambers et al. 2007, Condon et al. 2011, Keeler-Wolf 2007), altering vegetation structure and composition, which in turn leads to alteration of faunal composition, species habitat, direct loss of habitat, and other impacts.

These stressors result in different levels of response depending on the degree of impact and how many stressors are acting on the same resource simultaneously. Responses include a reduction in species diversity and species genetic diversity with the fragmentation and loss of habitat (Vryanckx et al. 2011). Species can become less abundant as their habitats become fragmented or continually disturbed such that reproduction is less successful (Brussard et al. 2000). As native species become stressed, other more tolerant and opportunistic species may increase in abundance, further tipping the balance of food webs in both terrestrial and aquatic systems, and predator/prey dynamics. The indicators shown in the causal diagrams below measure the amount of stress or the type and magnitude of response to stress within each resource. See the Ecological Status Scorecard section for full explanation of each indicator (Figure B-22).

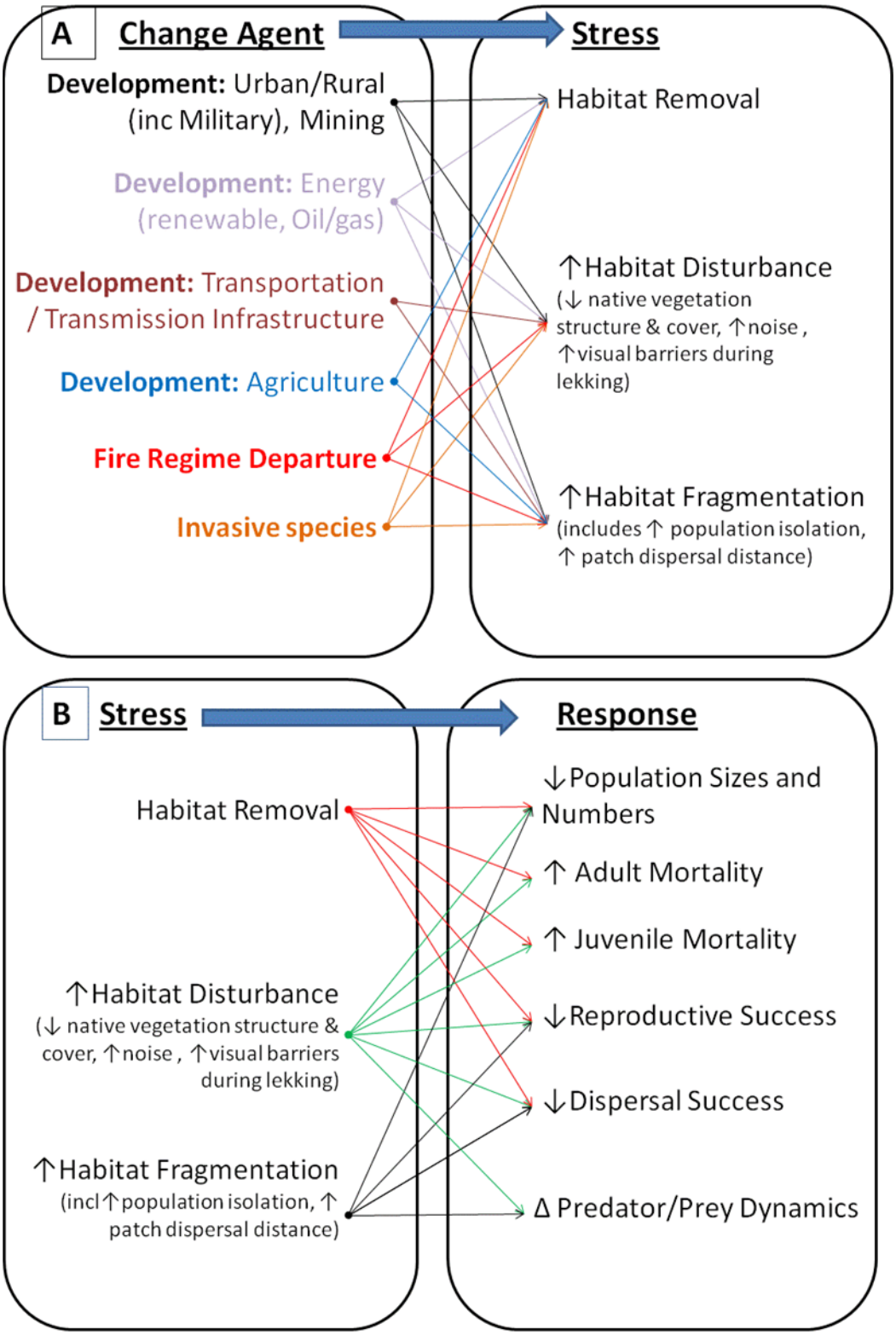

Figure B-22 (A and B). The conceptual model for Greater Sage Grouse (*Centrocercus urophasianus*) illustrates the effect of each Change Agent on the resource's ecological integrity. A. Change Agents are a source of different types of stressors. B. Different types of stressors invoke different responses.

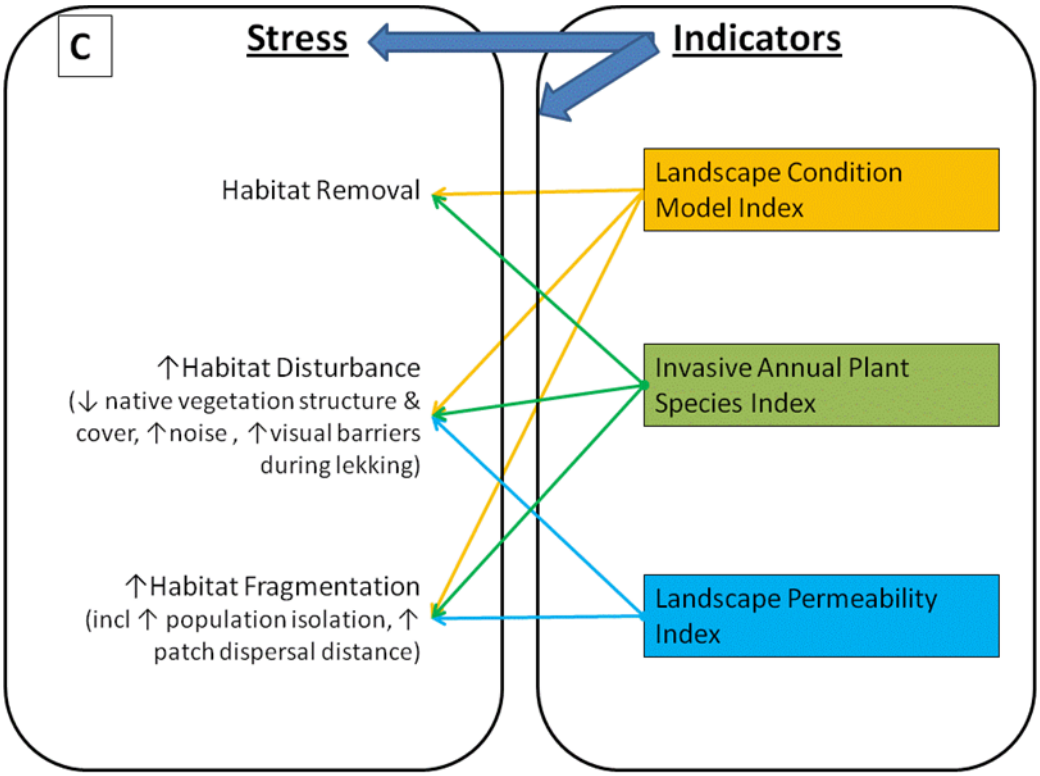

Figure B-22 (C). The conceptual model for Greater Sage Grouse (*Centrocercus urophasianus*) illustrates the effect of each Change Agent on the resource's ecological integrity. C. Indicators are metrics by which we can directly measure the amount of stress or response within each type of resource.

Ecological Integrity Criteria and Indicators

The Habitat Status Scorecard links conceptual models that describe the relationships between change agents and the habitat requirements of each species resource to spatial models that provide practical indicators of habitat status.

The conceptual model diagrams presented above in the discussion of Change Agent Effects indicate the stresses and responses expected at the scale of the habitat for the resource of concern. These stresses and responses were identified based on an assessment of the key habitat attributes for this resource type, based on the information presented in the Focal Resource Characterization section. Panel C of these diagrams, and Table B-23 below, identify a suite of indicators for assessing levels of stress and response. The indicators are organized by key ecological attributes (KEAs), which for species resources consist of pivotal habitat characteristics and primary ecological drivers. KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. The Habitat Status Scorecard (Table B-23) is designed to report on habitat status indicators by 4x4 km square units. The assessment indicators with justifications and definitions are presented in Table B-23, organized by Key Ecological Attributes.

Table B-23. Indicators used for habitat status assessment of Greater Sage Grouse (*Centrocercus urophasianus*).

Key Ecological Attribute	Indicator	Definition	Justification
Landscape Condition	Landscape Condition Index	This indicator is measured by intersecting the mapped area or habitat distribution map of the resource with the LCM layer and reporting the average LCM index value for the resource or habitat within each 5th level watershed, or 4x4 km square units for species. Landscape Condition Index is a 90x90m square unit resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. The results are a score for landscape condition from 0 to 1 with 1 being very high landscape condition and values close to 0 likely having very poor condition.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance.
Landscape Connectivity	Landscape Connectivity Index	This indicator provides a measure of relative landscape connectivity from the perspective of a given resource for each 270 m^2 grid cell that defines its distribution. The spatial index is derived from output of a CircuitScape model, which applies circuit theory to an algorithm that evaluates potential landscape connections across the individual resource distribution. The Landscape Condition Index surface (also a 90 m^2 grid rescaled to 270 m) for the ecoregion is used as a 'resistance surface' for CircuitScape to characterize relative landscape permeability among point locations established across the resources current distribution. Relative connectivity is measured as ‘current flow’ values per 270 m^2 grid cell. Highest current flow areas depict connectivity zones where high-levels of species movement might expect to be concentrated. Low current flow indicates barriers to movement in ecologically fragmented circumstances. The 270 m^2 permeability surface is overlaid on the distributions of each resource and average square unit values are calculated per 4 km^2 grid cell. The resulting index values range from 0 to 1, with 0 having no landscape connectivity (all barrier) and 1 having very high connectivity.	The relative degree of landscape connectivity affects the movement of individuals of a species, potentially constraining access to critical habitat resources.

Table B-23 (continued). Indicators used for habitat status assessment of Greater Sage Grouse (*Centrocercus urophasianus*).

Key Ecological Attribute	Indicator	Definition	Justification
Native Species Composition	Invasive Annual Cover Index	This indicator is measured using the mapped area or habitat distribution of the resource with an abundance map of introduced invasive annual plant species. The output is predicted percent cover of invasive annual species within each 5th level HUC. The Invasive Annual Cover Index is calculated by multiplying the invasive annual cover percent by 4 then subtracting the product from 1 to produce a normalized scale from 0 to 1 with 0 being 25% or greater cover of invasive annuals and 1 being invasive annuals absent.	Invasive annual plant species displace natural composition and provide fine fuels that significantly increase spread of catastrophic fire.

Each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest. The mean index scores of these indicators may then be averaged by each Key Ecological Attribute. Displaying the indicators with individual scores allows user to interpret which particular ecological attributes in a reporting area is driving the ecological status of the resource.

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Pygmy Rabbit (Brachylagus idahoensis)

Model Group: Basin Dry Land System > Semi-desert Shrub & Steppe

Focal Resource Characterization

Classification Comments

Formerly included in genus *Sylvilagus* (see Diersing 1984). Included in the genus *Brachylagus* by Jones et al. (1992) and Hoffmann (in Wilson and Reeder 1993). Another synonym is *Lepus*

idahoensis. The Washington State (Columbia Basin) population is genetically distinct from the remainder of the species, and is believed to have been isolated for at least 10,000 years, perhaps much longer (USFWS 2001).

Range

Oregon (Verts and Carraway 1998) to east-central California, east to western Utah, western Wyoming (Campbell et al. 1982), and southwestern Montana; isolated population in east-central Washington. Range apparently decreased in eastern Washington during the last 3,000 years as the extent of sagebrush-dominated steppe diminished (Lyman 1991). Within its range the distribution is not continuous but patchy, primarily in areas of Great Basin big sagebrush (*Artemisia tridentata*)-dominated plains and alluvial fans where plants occur in tall and dense clumps, and the soil is relatively deep and friable (Orr 1940; Green and Flinders 1980a,b; Weiss and Verts 1984). Also reported to frequent areas in Idaho supporting greasewood (*Sarcobatus* spp.) (Davis 1939).

Occurrences

Number of occurrences not known, but all states tracking the species have ranks of S1 to S3. In Oregon, Weiss and Verts (1984) found only 51 occupied sites among 211 potentially suitable sites.

Population

Washington population estimated at fewer than 30 animals (USFWS 2003); no population estimates available from other states.

Habitat

This rabbit generally occurs in dense stands of big sagebrush growing in deep loose soils. It is highly dependent on sagebrush for food and shelter throughout the year. Unlike most other rabbits, it digs burrows, which are around 7.6 cm in diameter; a burrow may have multiple entrances. Pygmy rabbits occasionally use of burrows abandoned by other species and may occur in areas of shallower or more compact soils if these sites support sufficient shrub cover (USFWS 2010). Microhabitat for nesting is poorly known; burrows have been excavated, but no nests have been found (Green and Flinders 1980b).

In southwestern Wyoming, pygmy rabbits selectively used dense and structurally diverse stands of sagebrush that accumulated a relatively large amount of snow; the subnivean environment provided access to a relatively constant supply of food and provided protection from predators and thermal extremes (Katzner and Parker 1997).

Phenology

Activity occurs throughout the year. Pygmy rabbits may be active at any time of day or night, but most activity is crepuscular.

Ecology

Predators include: weasels, coyotes, owls, and likely other carnivorous mammals and birds.

Mobility

In southwestern Wyoming, winter home range size was 548-18,464 sq m (mean 2568 sq m and 10,204 sq m in two different years) (Katzner and Parker 1997). In Washington, mean home range

size was 0.7 hectares in males. 0.3 hectares in females; a small number had much larger home ranges; 95 percent of males had home ranges smaller than or equal to 20.2 hectares (Gahr 1993).

Food

Big sagebrush is the primary food source, particularly in winter, but grasses (particularly native bunch-grasses, such as Agropyron spp. and Poa spp.) and forbs also are eaten in spring and summer (Green and Flinders 1980b, Lyman 1991).

Reproduction

Breeding period extends from spring to early summer. Gestation lasts probably about 27-30 days (Green and Flinders 1980a). Adult females produce 2-3 litters per year, with 4-8 young per litter (Reid 2006).

Change Agent (CA) Effects

The loss and degradation of habitat through fire, grazing, invasion of exotic annuals, energy development, and agricultural conversion (Whisenant 1990, Knick and Rotenberry 1995, 1997) are probably the most significant factors contributing to pygmy rabbit population declines. Sagebrush cover is critical to pygmy rabbits; sagebrush eradication is detrimental (Holochek 1981). Fragmentation of sagebrush communities also poses a threat to populations of pygmy rabbits (Weiss and Verts 1984) because dispersal potential is limited. Protecting of old-growth sagebrush shrublands is the most effective and practical means of conserving pygmy rabbits at the present (NDW 2012).

Under current climate-change projections, further invasion by *Bromus tectorum* into sagebrush habitat is likely to occur, as is invasion by woody species, and fire frequency (as well as extent and severity) likely will continue to increase. Climate change is thus likely to exacerbate the existing primary threats such as frequent wildfire and invasive nonnative plants, particularly *B. tectorum*.

Conceptual Diagram

Species and assemblages of species experience stress when faced with Change Agents. Some change agents, such as new rural or urban development including mines and landfills, directly remove the element. Other change agents such as roads and transportation corridors (railroads, power lines, solar arrays, oil pumping platforms and the like) fragment habitat (Debinski and Holt 2001). More dispersed human activities, such as recreation, hunting, logging, or ORV activities result in increases in road densities or disturbance via disrupted breeding, nesting, foraging, soil surface disturbance which affects biological soil crusts (Rosentreter and Eldridge 2002), or uprooting or damage to plants; but these dispersed activities are difficult to measure other than via mapping of roads.

Invasive plant species can have profound effects on ecosystems, and hence upon the species or assemblages occurring in those habitats. Invasive plant species directly compete with native species, and have been shown to completely remove the native ecosystem habitat (e.g. tamarisk) (Brussard et al. 2000). Fragmentation of shrub-steppe and grasslands by agriculture increases cover of annual grasses, total annual/biennial forbs, and bare ground, and decreases cover of perennial forbs and biological soil crusts, and reduces obligate insects (Quinn 2004) and obligate birds and small mammals (Vander Haegen et al. 2001). Fine fuels accumulating from alien annual grasses, such as

Bromus madritensis, Bromus tectorum, and *Schismus* spp., are an important fuelbed component in many western ecosytems and can substantially increase the fire frequency (Chambers et al. 2007, Condon et al. 2011, Keeler-Wolf 2007), altering vegetation structure and composition, which in turn leads to alteration of faunal composition, species habitat, direct loss of habitat, and other impacts.

These stressors result in different levels of response depending on the degree of impact and how many stressors are acting on the same resource simultaneously. Responses include a reduction in species diversity and species genetic diversity with the fragmentation and loss of habitat (Vryanckx et al. 2011). Species can become less abundant as their habitats become fragmented or continually disturbed such that reproduction is less successful (Brussard et al. 2000). As native species become stressed, other more tolerant and opportunistic species may increase in abundance, further tipping the balance of food webs in both terrestrial and aquatic systems, and predator/prey dynamics. The indicators shown in the causal diagrams below measure the amount of stress or the type and magnitude of response to stress within each resource. See the Ecological Status Scorecard section for full explanation of each indicator (Figure B-23).

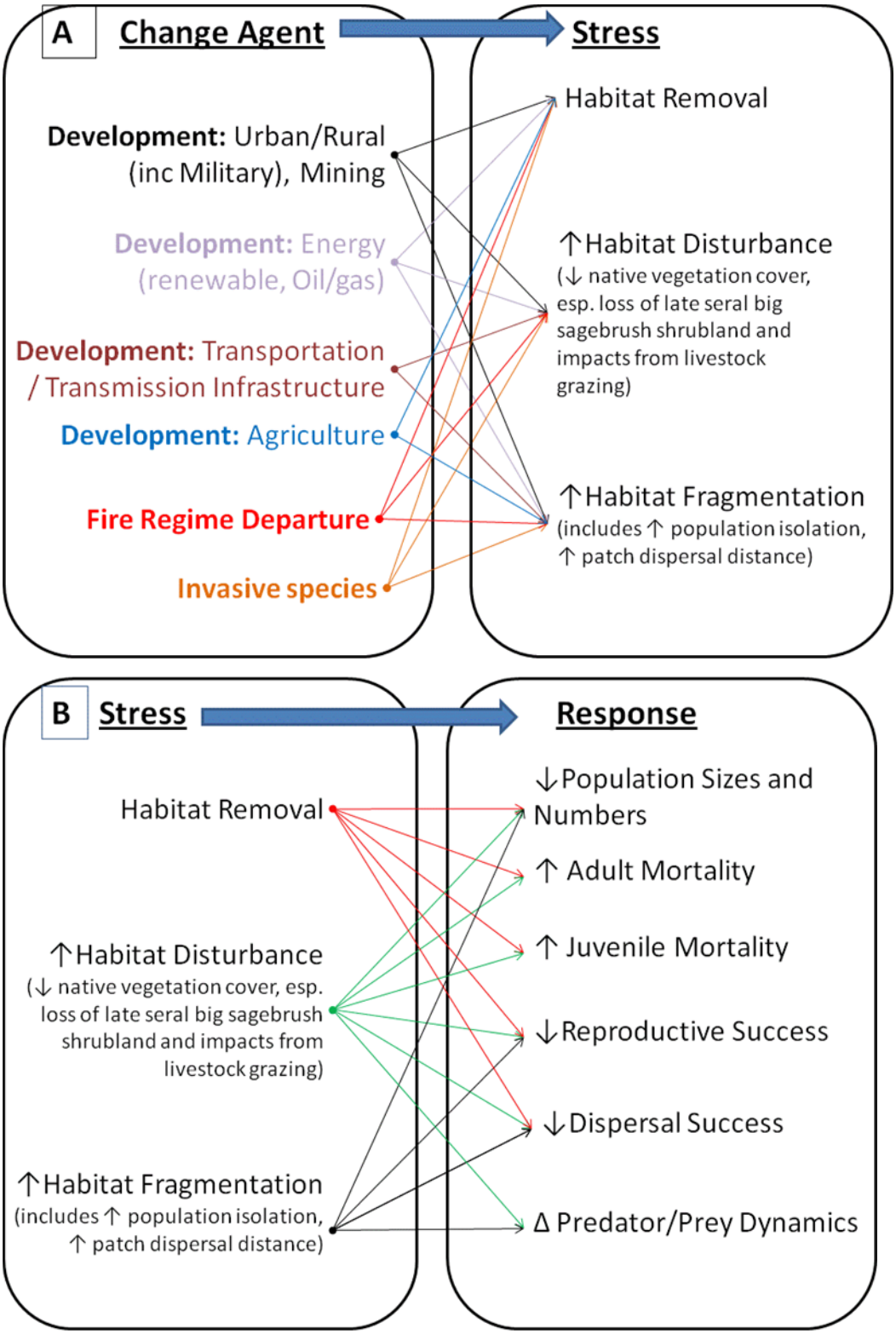

Figure B-23 (A and B). The conceptual model for Pygmy Rabbit (*Brachylagus idahoensis*) illustrates the effect of each Change Agent on the resource's ecological integrity. A. Change Agents are a source of different types of stressors. B. Different types of stressors invoke different responses.

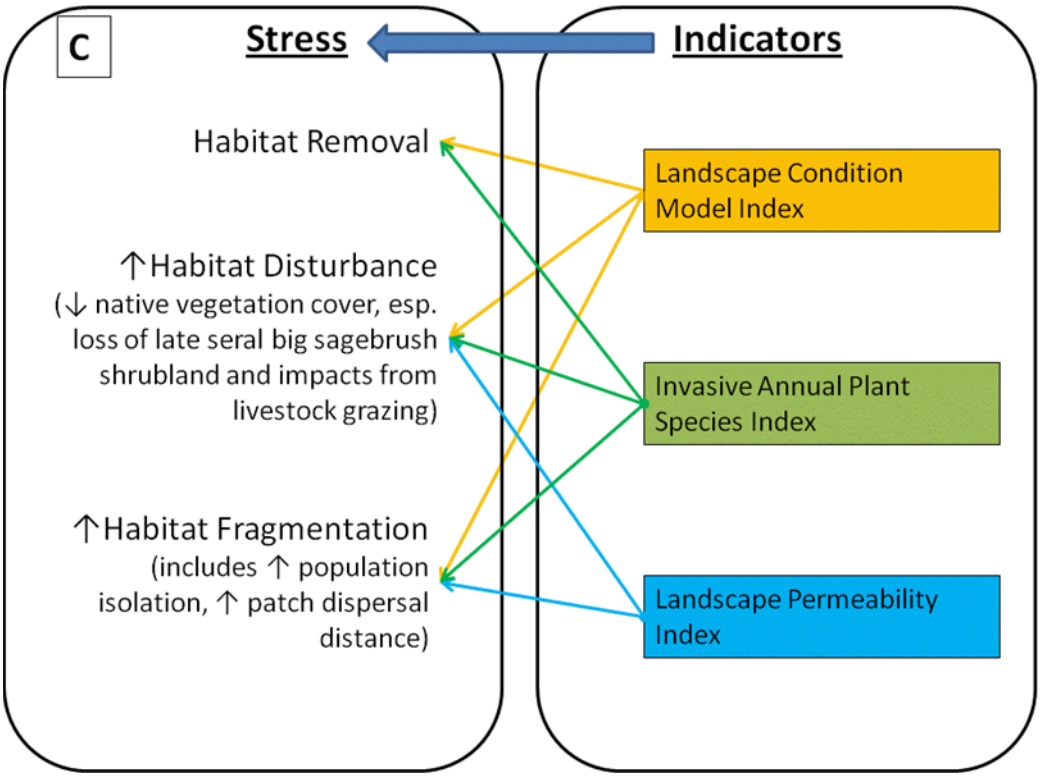

Figure B-23 (C). The conceptual model for Pygmy Rabbit (*Brachylagus idahoensis*) illustrates the effect of each Change Agent on the resource's ecological integrity. C. Indicators are metrics by which we can directly measure the amount of stress or response within each type of resource.

Ecological Integrity Criteria and Indicators

The Habitat Status Scorecard links conceptual models that describe the relationships between change agents and the habitat requirements of each species resource to spatial models that provide practical indicators of habitat status.

The conceptual model diagrams presented above in the discussion of Change Agent Effects indicate the stresses and responses expected at the scale of the habitat for the resource of concern. These stresses and responses were identified based on an assessment of the key habitat attributes for this resource type, based on the information presented in the resource Characterization section. Panel C of these diagrams, and Table B-24 below, identify a suite of indicators for assessing levels of stress and response. The indicators are organized by key ecological attributes (KEAs), which for species resources consist of pivotal habitat characteristics and primary ecological drivers. KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. The Habitat Status Scorecard (Table B-24) is designed to report on habitat status indicators by 4x4 km square units. The assessment indicators with justifications and definitions are presented in Table B-24, organized by Key Ecological Attributes.

Table B-24. Indicators used for habitat status assessment of Pygmy Rabbit (*Brachylagus idahoensis*).

Key Ecological Attribute	Indicator	Definition	Justification
Landscape Condition	Landscape Condition Index	This indicator is measured by intersecting the mapped area or habitat distribution map of the resource with the LCM layer and reporting the average LCM index value for the resource or habitat within each 5th level watershed, or 4x4 km square units for species. Landscape Condition Index is a 90x90m square unit resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. The results are a score for landscape condition from 0 to 1 with 1 being very high landscape condition and values close to 0 likely having very poor condition.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance.
Native Species Composition	Invasive Annual Cover Index	This indicator is measured using the mapped area or habitat distribution of the resource with an abundance map of introduced invasive annual plant species. The output is predicted percent cover of invasive annual species within each 5th level HUC. The Invasive Annual Cover Index is calculated by multiplying the invasive annual cover percent by 4 then subtracting the product from 1 to produce a normalized scale from 0 to 1 with 0 being 25% or greater cover of invasive annuals and 1 being invasive annuals absent.	Invasive annual plant species displace natural composition and provide fine fuels that significantly increase spread of catastrophic fire.

Each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest. The mean index scores of these indicators may then be averaged by each Key Ecological Attribute. Displaying the indicators with individual scores allows user to interpret which particular ecological attributes in a reporting area is driving the ecological status of the resource.

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Appendix C: Methods for Two Spatial Models used to Gauge Ecological Integrity

This appendix provides explanation and results summarized in the main report. Contributing analyses include the treatment of potential fire and hydrologic regime effects, spatial models for landscape condition and invasive plant species distributions and effects. The methodology discussed here was developed and further documented in Comer et al. (2013); the BLM Rapid Ecoregional Assessment of the Central Basin and Range Ecoregion.

Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. So for example, these measures address the degree of landscape fragmentation or other anthropogenic impacts (such as invasive species) in the landscapes supporting a given focal resource. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance from source.

Landscape Condition

Ecological condition commonly refers to the state of the physical, chemical, and biological characteristics of natural ecosystems, and their interacting processes. Many human land uses affect ecological condition, (e.g., through vegetation removal or alteration, stream diversion or altered natural hydrology, introduction of non-native and invasive species, etc.). Landscape condition assessments commonly apply principles of landscape ecology with mapped information to characterize ecological condition for a given area (e.g., USEPA 2001, Sanderson et al. 2002). Since human land uses – such as built infrastructure for transportation or urban/industry, and land cover such as for agriculture or other vegetation alteration – are increasingly available in mapped form, they can be used to spatially model inferences about ecological stress and ecological condition.

Maps of this nature can be particularly helpful for identifying relatively unaltered landscape blocks, or for making inferences about the relative ecological integrity of natural habitats on the ground. They can also be used for screening ecological reference sites; i.e., a set of sites where anthropogenic stressors range from low to high. Ecological condition within reference sites is often further characterized in the field to determine how ecological processes respond to specific stressors, but spatial models can provide a very powerful starting point to build upon (Faber-Langendoen et al. 2006). Knowledge from reference sites may then apply to surroundings for many types of environmental decisions.

The *Landscape Condition Model* used in this project builds on a growing body of published methods and software tools for ecological effects assessment and spatial modeling; all aiming to characterize relative ecological condition of landscapes (e.g., Knick and Rotenberry 1995, Forman and Alexander 1998, Trombulak and Frissel 1999, Theobald 2001, Seiler 2001, Sanderson et al. 2002, Riitters and Wickham 2003, Brown and Vivas 2005, Hansen et al. 2005, Leu et al. 2008, Comer and Hak 2009, Hak and Comer 2017, Theobald 2010, Rocchio and Crawford 2011). The intent of this modeling approach is to use regionally available spatial data to transparently express user knowledge regarding the relative effects of land uses on natural ecosystems and habitats. In these cases, the authors' expert

knowledge forms the basis of stressor selection, and relative weightings, but numerous examples from published literature have been drawn upon to parameterize the model for application in this ecoregion. Independent data sets were drawn upon for subsequent model evaluation. The current model applied to the Central Basin and Range ecoregion has been developed and evaluated for the entire western United States, and then customized for use within the ecoregion.

Each input data layer is summarized to a 90m grid and, *where the land use occurs*, given a **site impact score** from 0.05 to 0.9 (Table C-1) reflecting presumed ecological stress or impact. Values close to 1.0 imply relatively little ecological impact from the land use. For example, a given patch of 'ruderal' vegetation – historically cleared for farming, but recovering towards natural vegetation over recent decades, is given a Very Low (0.9) score for site impact as compared with irrigated agriculture (High Impact 0.3) or high-density urban/industrial development (Very High Impact 0.05). Certainly, there are some ecological values supported in these intensively used lands, but their relative condition is quite limited when compared with areas dominated by natural vegetation (Table C-1).

NOTE: While the categories of "introduced" plant species were included in these models their mapped locations were based on those found in SW ReGAP maps (Lowry et al. 2007), and should be presumed to reflect only the most severe centers of infestation. Lower abundances of invasive plant species should not be presumed to be reflected in this model (see subsequent discussion of invasive annual grass model). Similarly, effects of overgrazing, such as soil compaction and disturbance, were not available in mapped form, and therefore not at all represented.

A second model parameter – *again, for each data layer* – represents a **distance decay** function, expressing a decreasing ecological impact with distance away from the mapped location of each feature as applied to the Euclidian Distance value described above (Table C-1). Mathematically, this applies a function, based on the formula that characteristically describes a "bell curve" shape that falls towards plus/minus infinity. Those features given a high decay score (approaching 1.0) result in a map surface where the impact value dissipates within a relatively short distance. Those features given a low decay score (approaching 0.0) create a map surface where the per-pixel impact value dissipates more gradually with distance away from the impacting feature. Values for each layer will approach 1.0, symbolizing negligible impact, at the distance listed in the right-hand column of Table C-1.

The result is a map surface indicating relative scores between 0.0 and 1.0 (Figure C-1). This provides one composite view of the relative impacts of land uses across the entire study area. Darker green areas indicate apparently least impact and orange to red areas most impact.

Landscape Condition (2010 and 2025): Landscape condition of each focal resource was measured using these landscape condition models, one reflecting land use *circa* 2012 and the second reflecting mapped forecasts of land use *circa* 2025. This indicator is measured by intersecting the mapped area of the focal resource with the LCM layer and reporting the proportional area impacted within each reporting unit (i.e., watershed or 4km^2 pixel grid cell) of the study area. The average per-pixel score provides a relative index for landscape condition resulting with a score from 0 to 1 with 1 being very high landscape condition and values close to 0 likely having very poor condition.

Table C-1. Ecological stressor source, site-impact scores, and distance decay scores implemented for the landscape condition model

Stressor Category	Ecological Stressor Source	Site Impact Score	Presumed Relative Stress	Distance Decay Score	Impact Approaches Negligible
Transportation	Dirt roads, 4-wheel drive	0.70	Low	0.5	200m
	Local, neighborhood and connecting roads	0.50	Medium	0.5	200m
	Secondary and connecting roads	0.20	High	0.2	500m
	Primary Highways with limited access	0.05	Very High	0.1	1000m
	Primary Highways without limited access	0.05	Very High	0.05	2000m
Urban and Industrial Development	Low Density Development	0.60	Medium	0.5	200m
	Medium Density Development	0.50	Medium	0.5	200m
	Powerline/Transmission lines	0.50	Medium	0.9	100m
	Oil /gas Wells	0.50	Medium	0.2	500m
	High Density Development	0.05	Very High	0.05	2000m
	Mines	0.05	Very High	0.2	500m
Managed and Modified Land Cover	Ruderal Forest & Upland	0.90	Very Low	1.0	0m
	Native Veg. with introduced Species	0.90	Very Low	1.0	0m
	Pasture	0.90	Very Low	0.9	100m
	Recently Logged	0.90	Very Low	0.5	200m
	Managed Tree Plantations	0.80	Low	0.5	200m
	Introduced Tree & Shrub	0.50	Medium	0.5	200m
	Introduced Upland grass & forb	0.50	Medium	0.5	200m
	Introduced Wetland	0.30	High	0.8	125m
	Cultivated Agriculture	0.30	High	0.5	200m

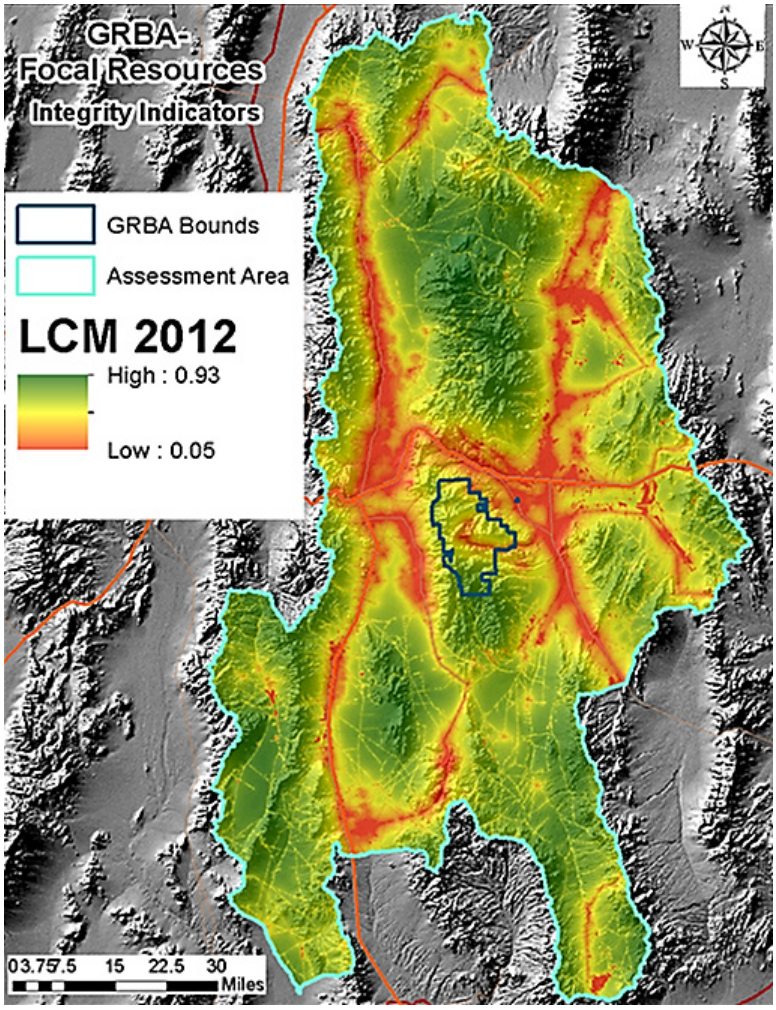

Figure C-1. Landscape Condition models (90 m) for the study area reflecting ~2012 conditions.

Invasive Plant Models

Spatial models of invasive species assemblages (Invasive Annual Grasses and Invasive Woody Riparian) were developed for the BLM REA in the Central Basin and Range ecoregion using Maximum Entropy (Maxent v3.3.3e, Phillips, et al. 2006) to represent the potential of the ecoregion to experience invasive encroachment. These models do not represent the actual distribution or estimate of cover, but are rather a representation of the biophysical settings where invasive species from these two categories have a high potential to occur. See Comer et al. (2012) for more detailed explanations of models.

The model for the GRBA area was derived from the BLM model developed for the combined extent of both Central Basin and Range and Mojave Desert ecoregions.

Invasive Annual Grasses

The Invasive Annual Grass model is comprised of five separate continuous models representing separate thresholds of absolute cover. All training and validation data were acquired from the July

2011 update of the LANDFIRE publicly available sample points. A total of 7,031 samples (across Mojave and Great Basin ecoregions) were identified as having an invasive annual grass component within the overall species composition of the sample site. A total of 25 separate species were identified within the sample sites, of which 77% of the total samples were comprised of Cheatgrass (*Bromus tectorum*) (Table C-2). Samples were aggregated for this functional grouping of invasive species because there tends to be inadequate samples to model them individually.

Table C-2. Invasive Annual Grasses present with the combined Great Basin and Mojave region.

Invasive Grass Species	Sample Count
Aegilops cylindrica	2
Avena barbata	5
Avena fatua	3
Bromus diandrus	27
Bromus hordeaceus	8
Bromus hordeaceus ssp. hordeaceus	2
Bromus japonicus	3
Bromus madritensis	603
Bromus rubens	335
Bromus tectorum	5,388
Echinochloa crus-galli	1
Eragrostis cilianensis	5
Hordeum murinum	7
Hordeum murinum ssp. leporinum	11
Hordeum vulgare	2
Poa annua	3
Polypogon monspeliensis	1
Schismus arabicus	5
Schismus barbatus	580
Secale cereale	8
Sorghum bicolor	1
Taeniatherum caput-medusae	5
Triticum aestivum	20
Vulpia myuros	5

Table C-2 (continued). Invasive Annual Grasses present with the combined Great Basin and Mojave region.

Invasive Grass Species	Sample Count
Zea mays	1
Grand Total	**7,031**

The majority of sample points are comprised of a single species of annual grass, but 375 points contain between 2-7 species per sample site. The final sample total includes 6,622 samples plots with the majority of the samples in the Category 1 and Category 2 levels of density (Table C-3).

Table C-3. Sample size per percent cover category.

Invasive Annual Grass Category	Sample Count	Minimum Cover (%)	Maximum Cover (%)	Average Cover (%)
1- less than 5%	3,674	0.02	5	2.62
2 – 5-15%	1,434	5.20	15	10.82
3 – 15-25%	635	15.50	25	21.03
4 – 25-45%	554	27.00	45	34.62
5 – greater than 45%	325	49.90	100	64.30
Grand Total	**6,622**	**–**	**–**	**–**

Independent spatial layers used in the Maxent analysis consist of both continuous and thematic feature types. Landforms, Surficial Lithology, climatic Ombrotype and Thermotype were extracted from the existing USGS national data layers (Sayre et al 2009). All others variables were derived from either the 10m Digital Elevation Model (rescaled to 30m), or the updated soils map as described in the sensitive soils results of the REA reports. No new remotely-sensed imagery, which would be required to fully map the current distribution of invasive plants, was used for these models. This is why they should be considered models of the potential distribution; but not confirmed, actual distribution and abundance. Proportionally, the Category 1 points are evenly distributed throughout the both ecoregions.

In order to maximize the number of samples applied to the model, a two part modeling approach was utilized to determine the model performance. In addition to the final models which consist of all available sample points, a separate analysis was performed utilizing a series of 10 replicate models with random withholding of 10% of total samples for model validation. The average AUC score from the receiver operating characteristics (ROC) score was used to determine the model validity.

Final models for each density categories where compiled from the five independent models using the threshold where occurrence equal training sensitivity and specificity (Table C-4). This value in all

model categories was the most restrictive threshold value. The final composite model is comprised of each individual model layered in order of lowest percent coverage to highest percent coverage with each increasing percent cover layer superseding all underlying data values (Figure C-2).

Table C-4. Maximum entropy thresholds.

Annual Grass Category	Threshold
1- less than 5%	0.479
2 – 5-15%	0.470
3 – 15-25%	0.449
4 – 25-45%	0.434
5 – greater than 45%	0.390

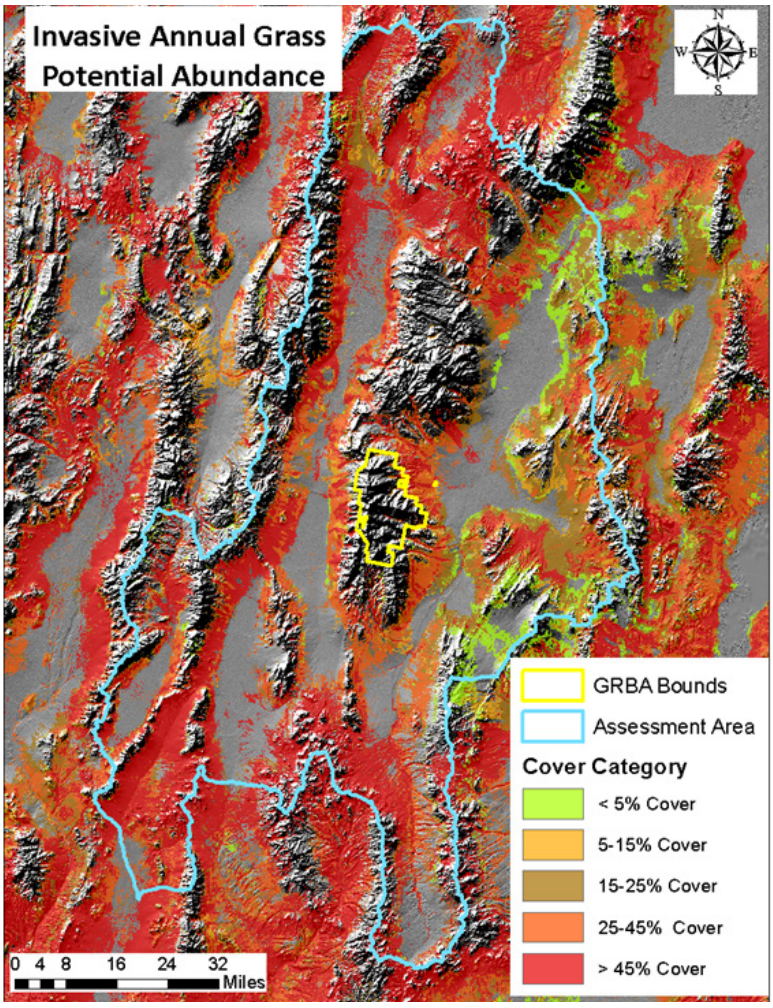

Figure C-2. Invasive annual grass potential for the study area.

Overall model performance was acceptable with ranges in AUC score from 0.69 to 0.806 and with standard deviations ranging from 0.014 to 0.029. The composite model performance as such was not defined beyond the component inputs.

The variable contribution to individual models was constant across the majority of the cover class with Thermotype and recent fire patch distance comprising 42-55% of the model explanation. While we did not perform future projection of invasive potential, the importance of the thermotype variable suggests the potential to forecast invasive grass potential at finer scales.

The variable contribution to individual models was constant across the majority of the cover class with Thermotype and recent fire patch distance comprising 42-55% of the model explanation. While we did not perform future projection of invasive potential, the importance of the thermotype variable suggests the potential to forecast invasive grass potential at finer scales.

Invasive Plant Effects: Current invasive effects for each focal resource were assessed within the study area for each applicable focal resourtce using this spatial model. This indicator is measured by intersecting the mapped area of the focal resource with the composite invasive plant layer and reporting the proportional area impacted within each reporting unit (i.e., watershed or $4km^2$ pixel grid cell) of the study area. The proportional impact score provides a relative index from 0 to 1 with 1 being very limited invasive presence and values close to 0 likely having very severe proportional impact from invasives.

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Appendix D: Focal Resource Location and Indicator Scores

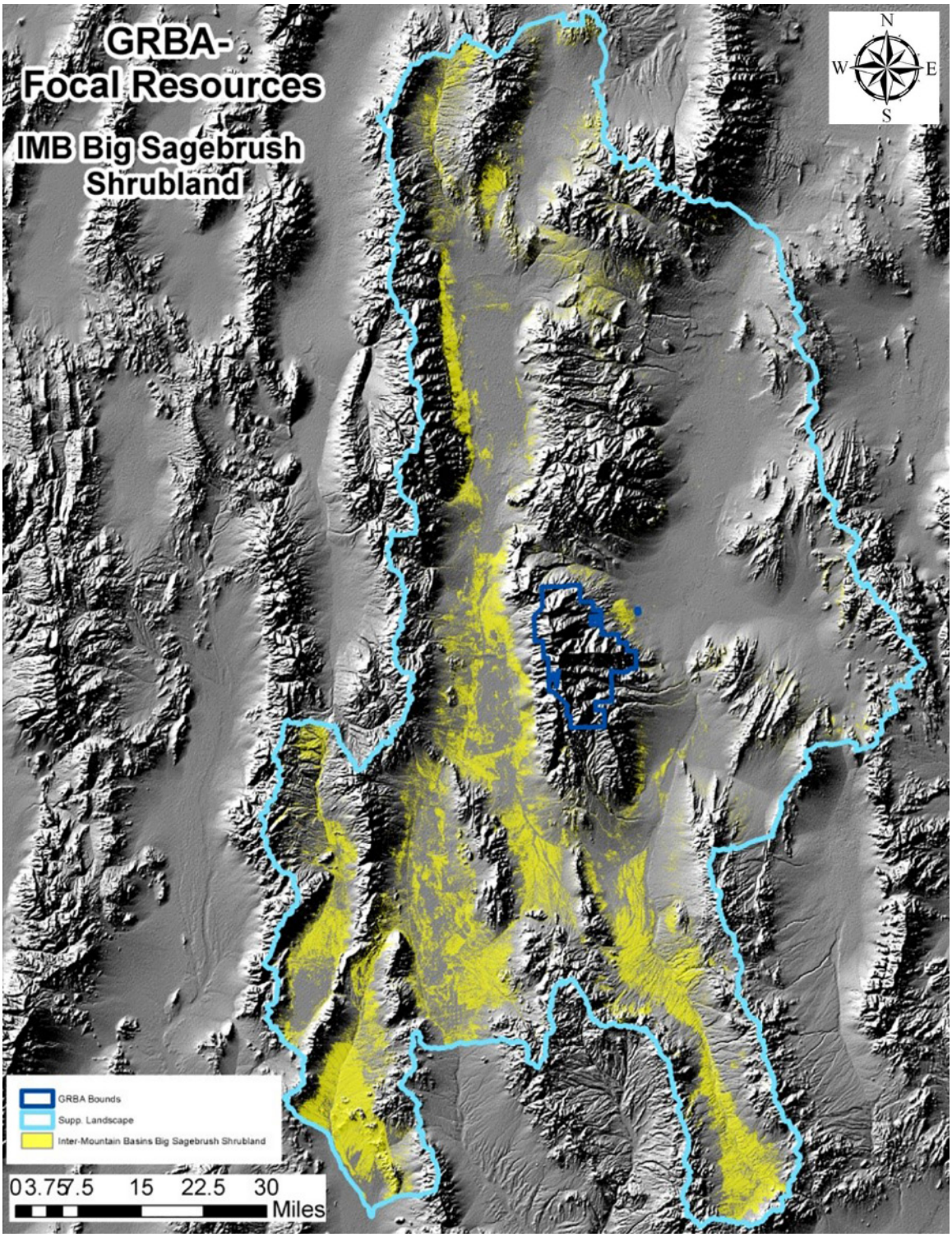

Figure D-1. Map showing IMB big sagebrush shrubland habitat in the Great Basin.

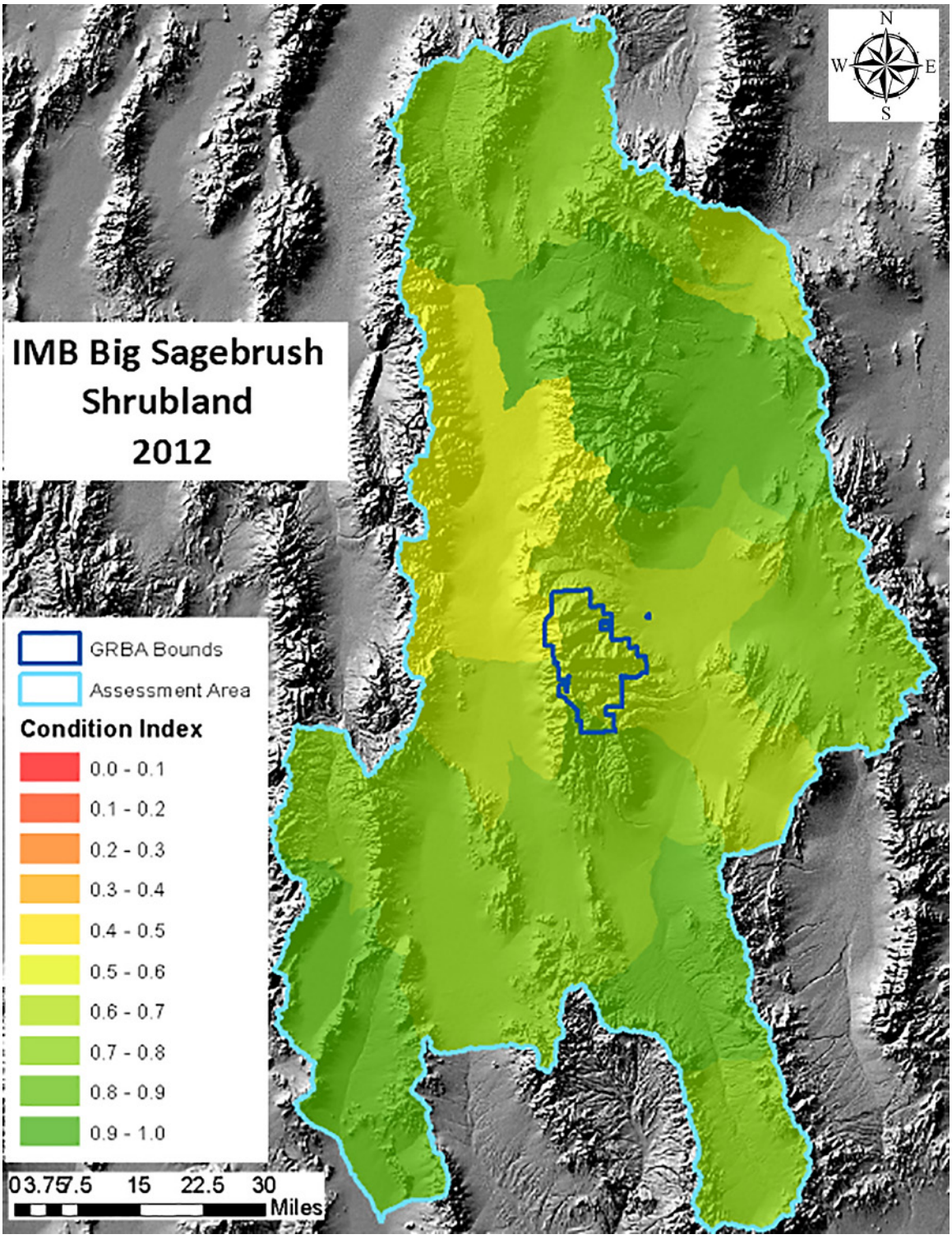

Figure D-2. Map showing modeled 2012 IMB big sagebrush shrubland condition index in the Great Basin.

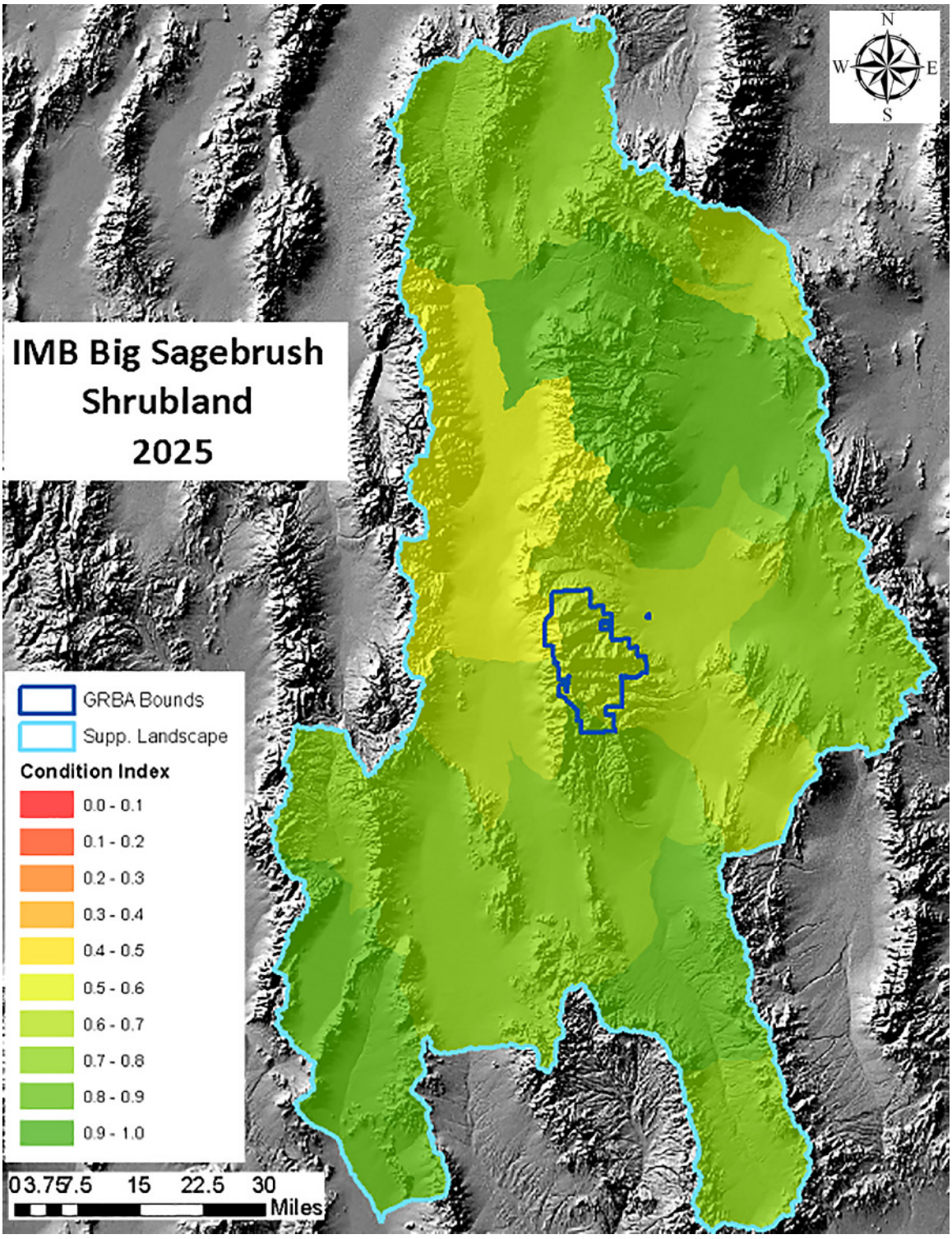

Figure D-3. Map showing modeled 2025 IMB big sagebrush shrubland condition index in the Great Basin.

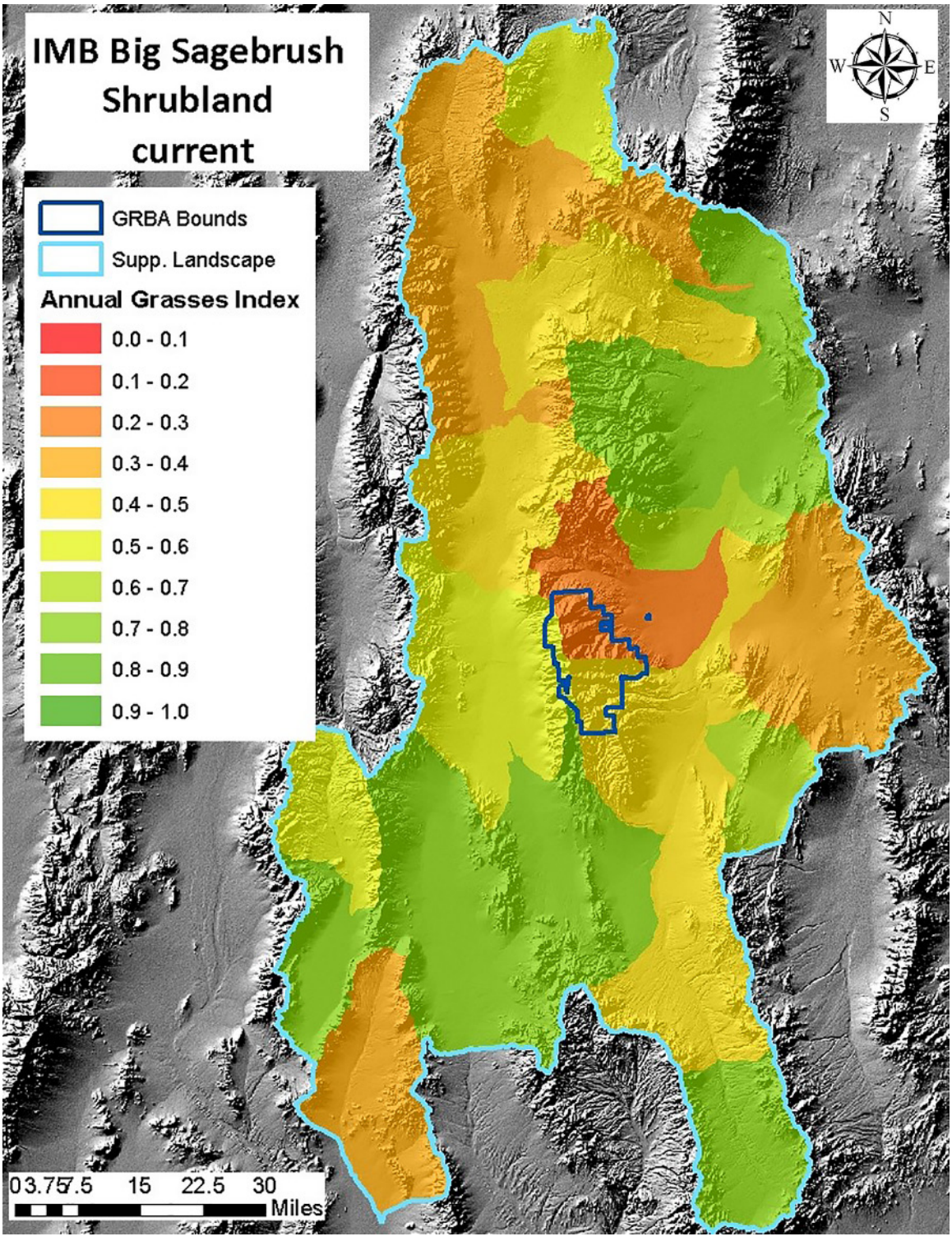

Figure D-4. Map showing current IMB big sagebrush shrubland annual grass index in the Great Basin.

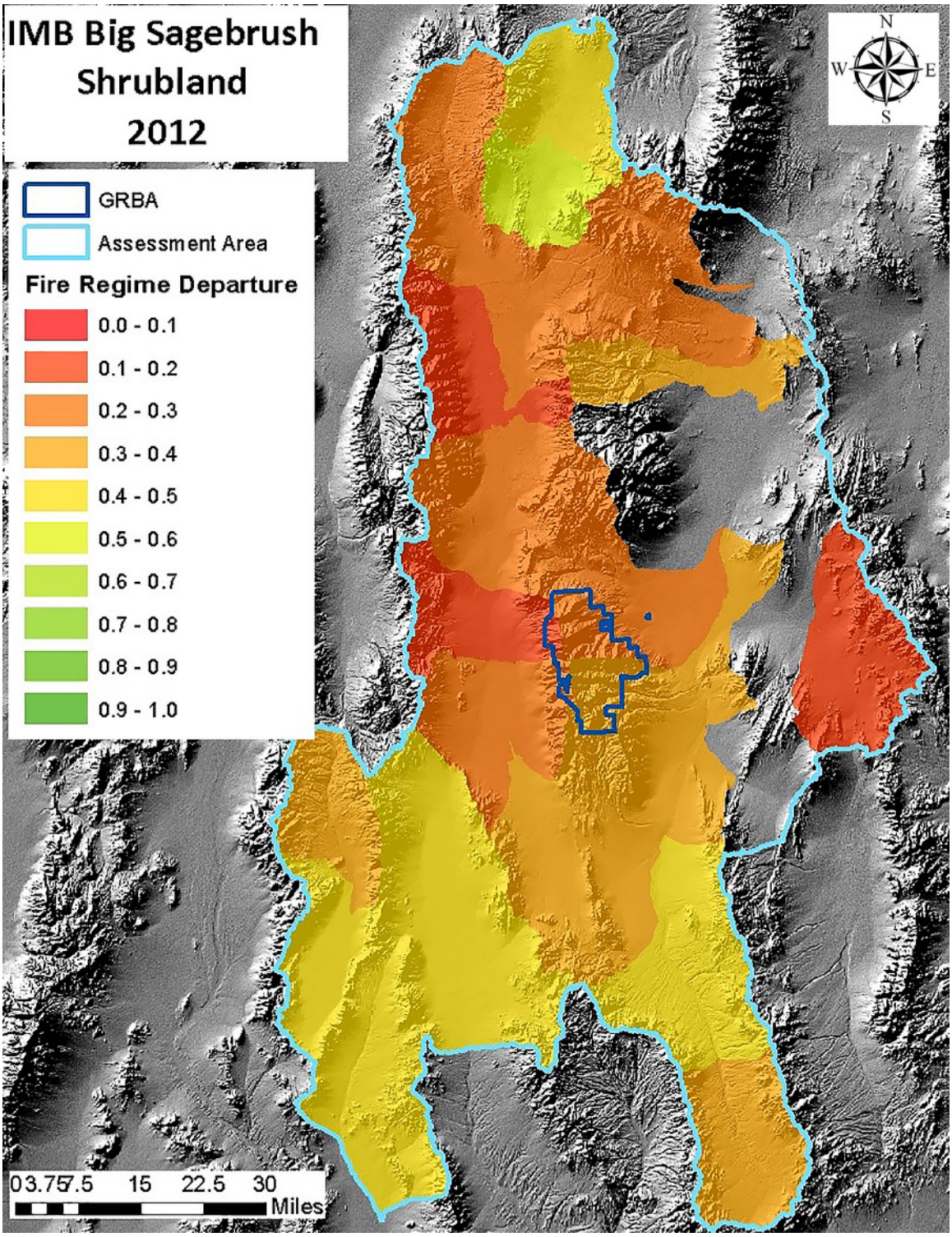

Figure D-5. Map showing modeled 2012 fire regime departure for IMB big sagebrush shrubland habitat in the Great Basin.

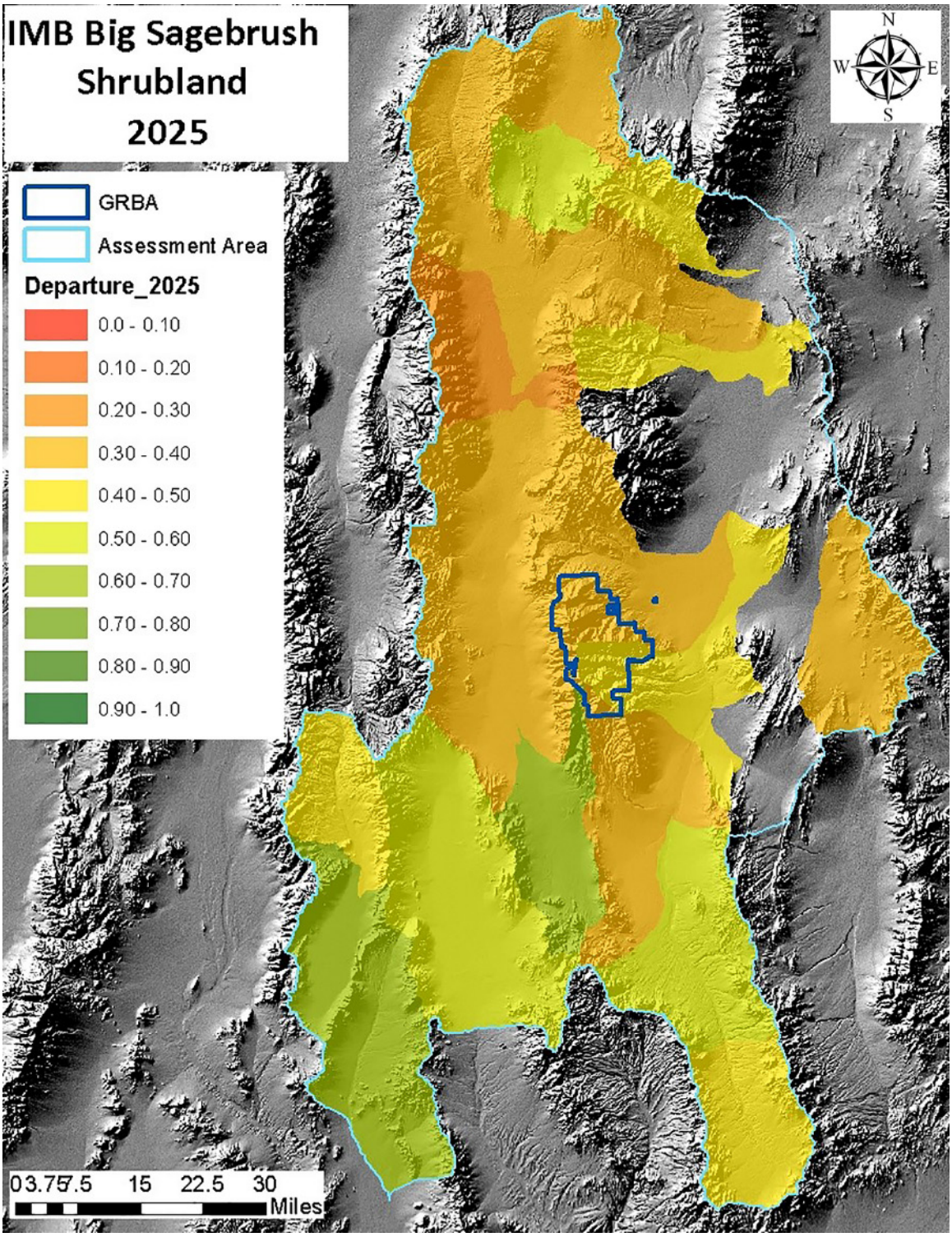

Figure D-6. Map showing modeled 2025 departure for IMB big sagebrush shrubland habitat in the Great Basin.

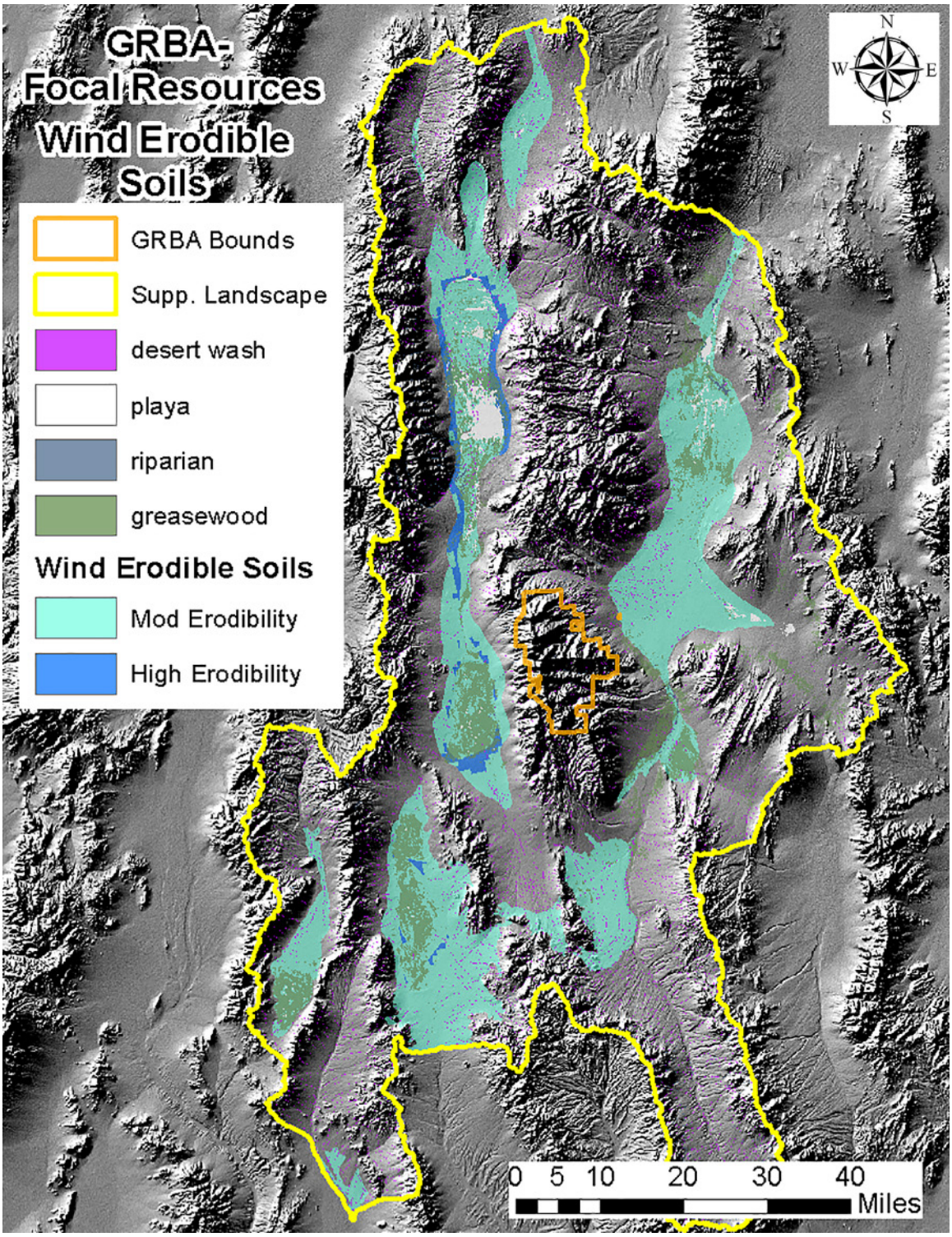

Figure D-7. Map showing Great Basin wind erodible soils.

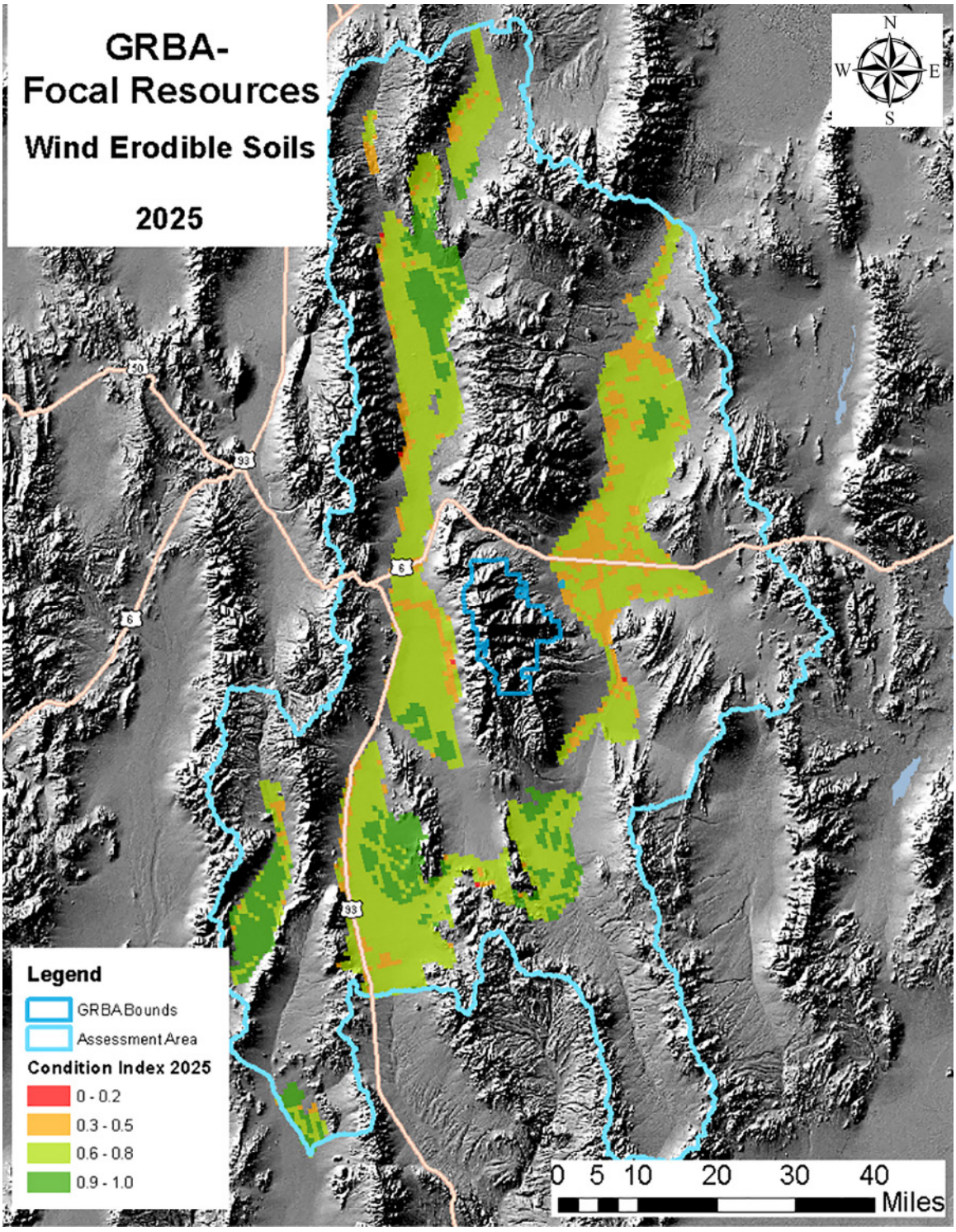

Figure D-8. Map showing modeled 2025 wind erodible soils in the Great Basin.

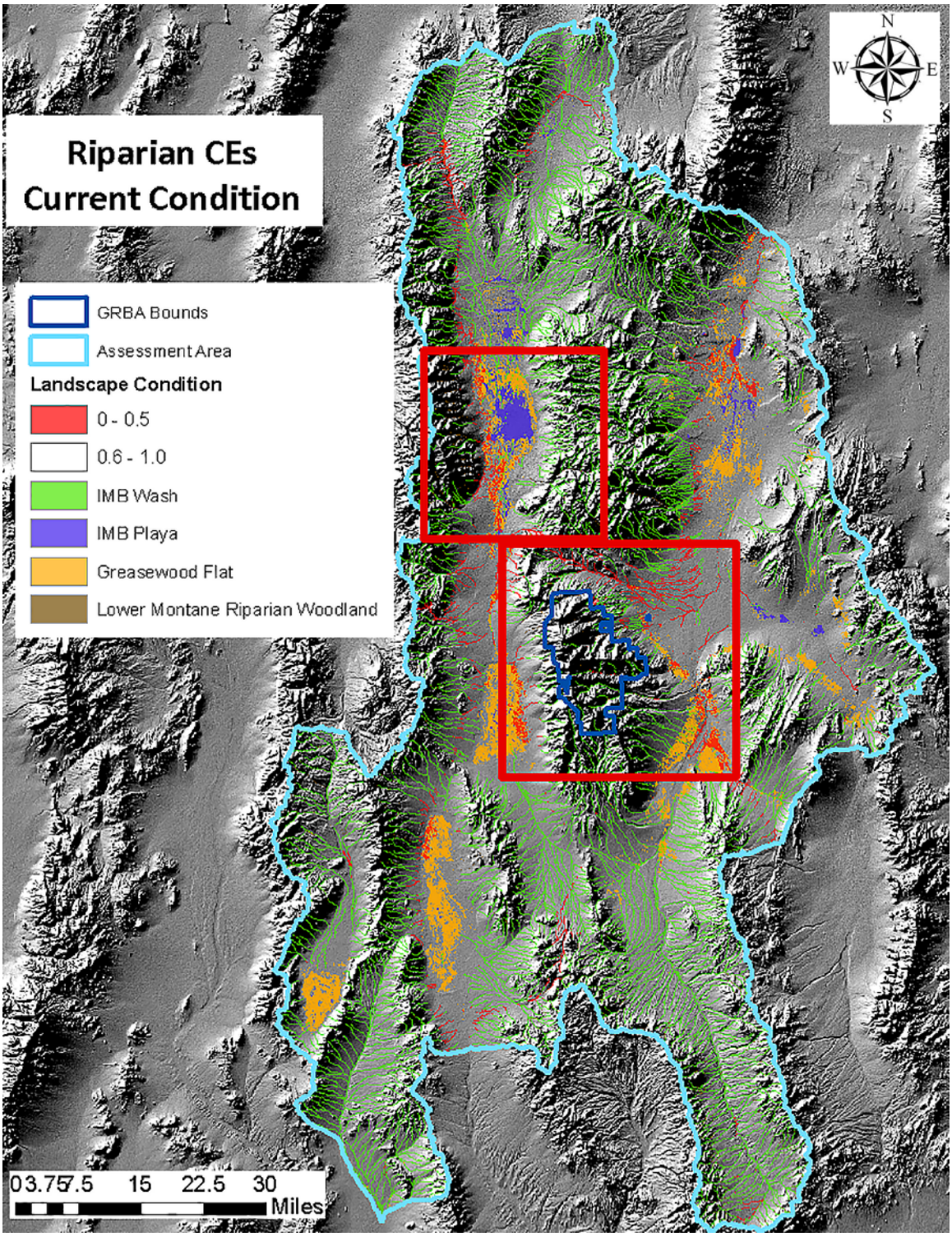

Figure D-9. Map showing current landscape condition in the Great Basin.

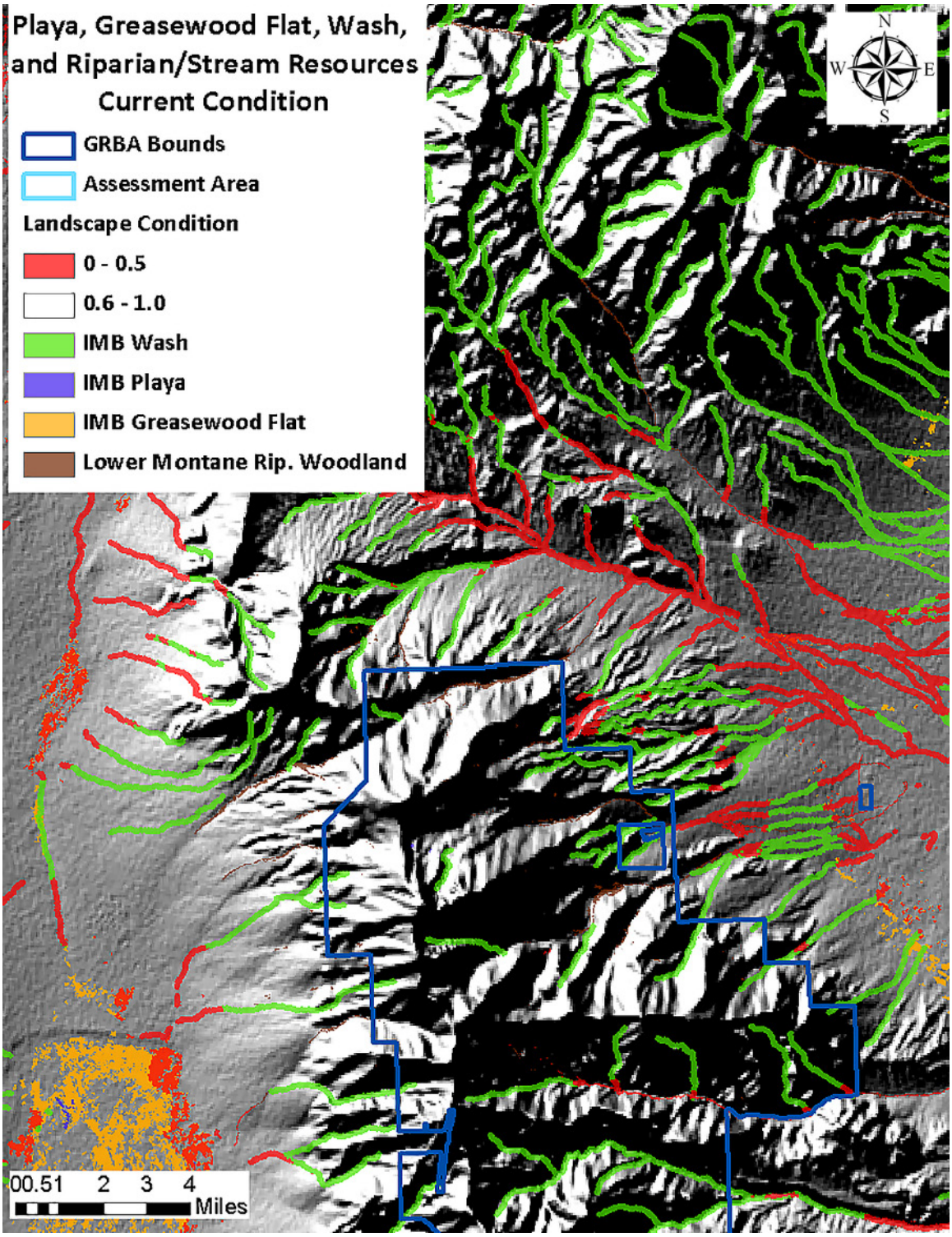

Figure D-10. Map showing current condition of playa, greasewood flat, wash and riparian/stream habitat in the Great Basin.

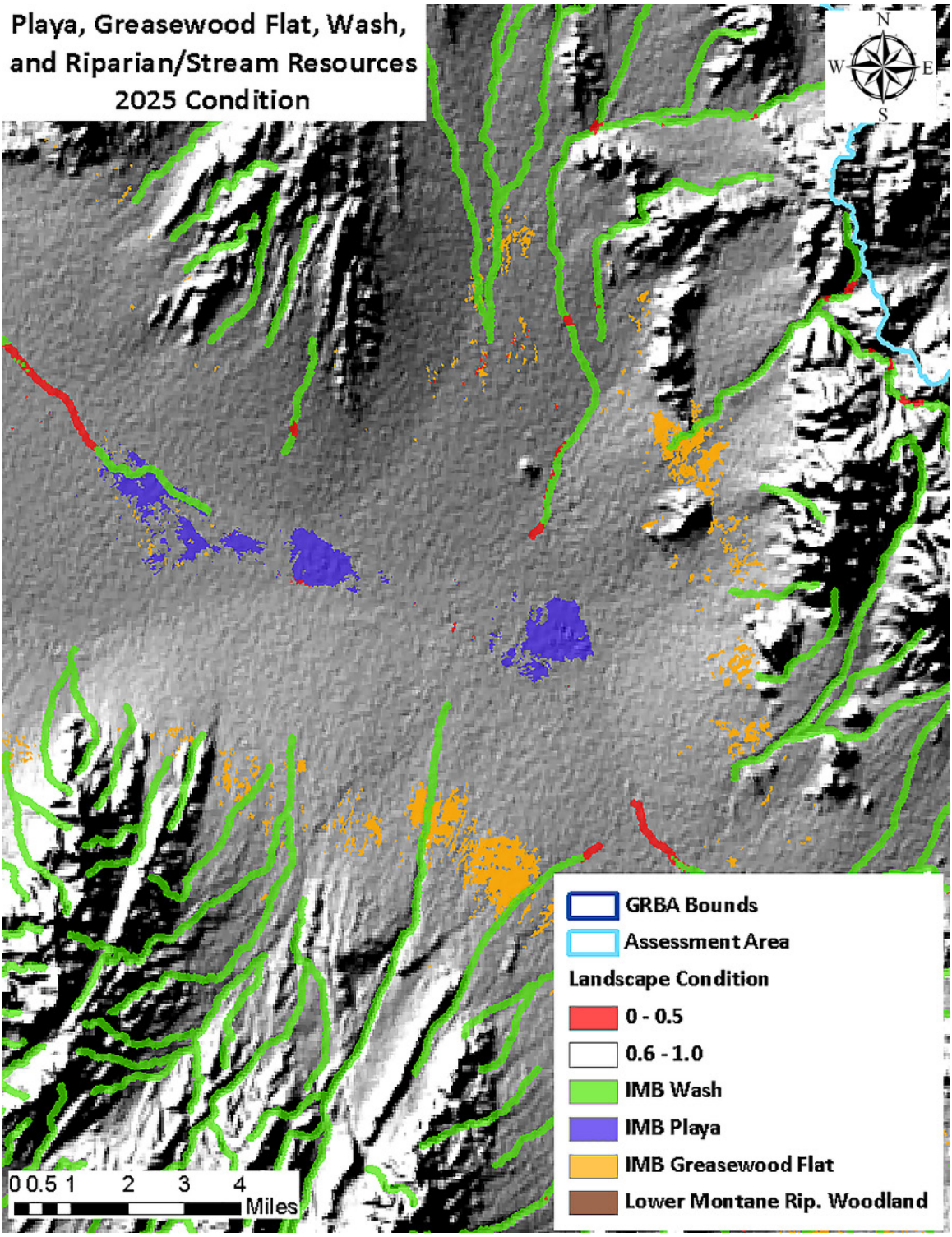

Figure D-11. Map showing modeled 2025 condition of playa, greasewood flat, wash and riparian/stream habitat in the Great Basin.

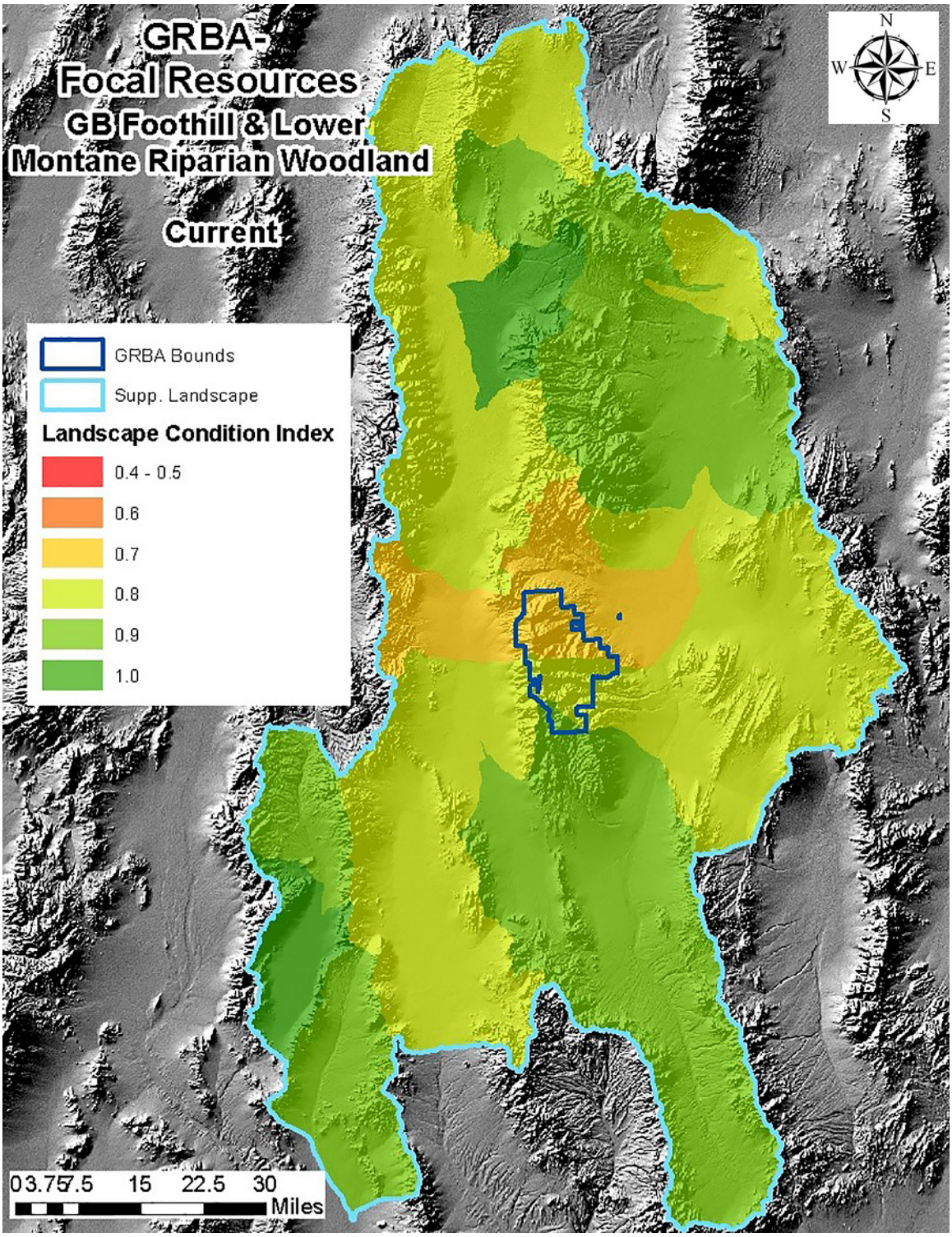

Figure D-12. Map showing current landscape index condition of Great Basin foothill and lower montane riparian woodland habitat.

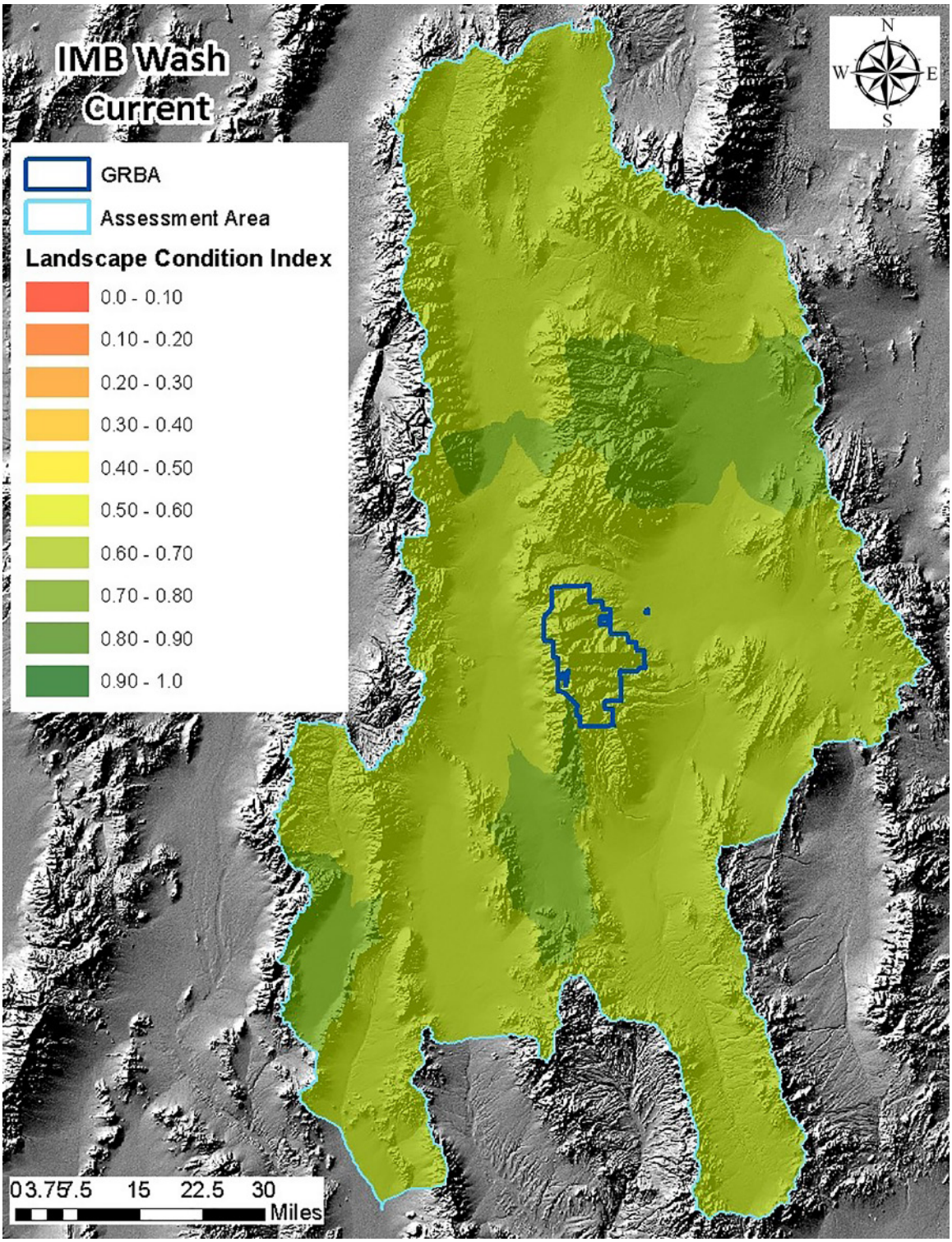

Figure D-13. Map showing current landscape index condition of Great Basin wash habitat.

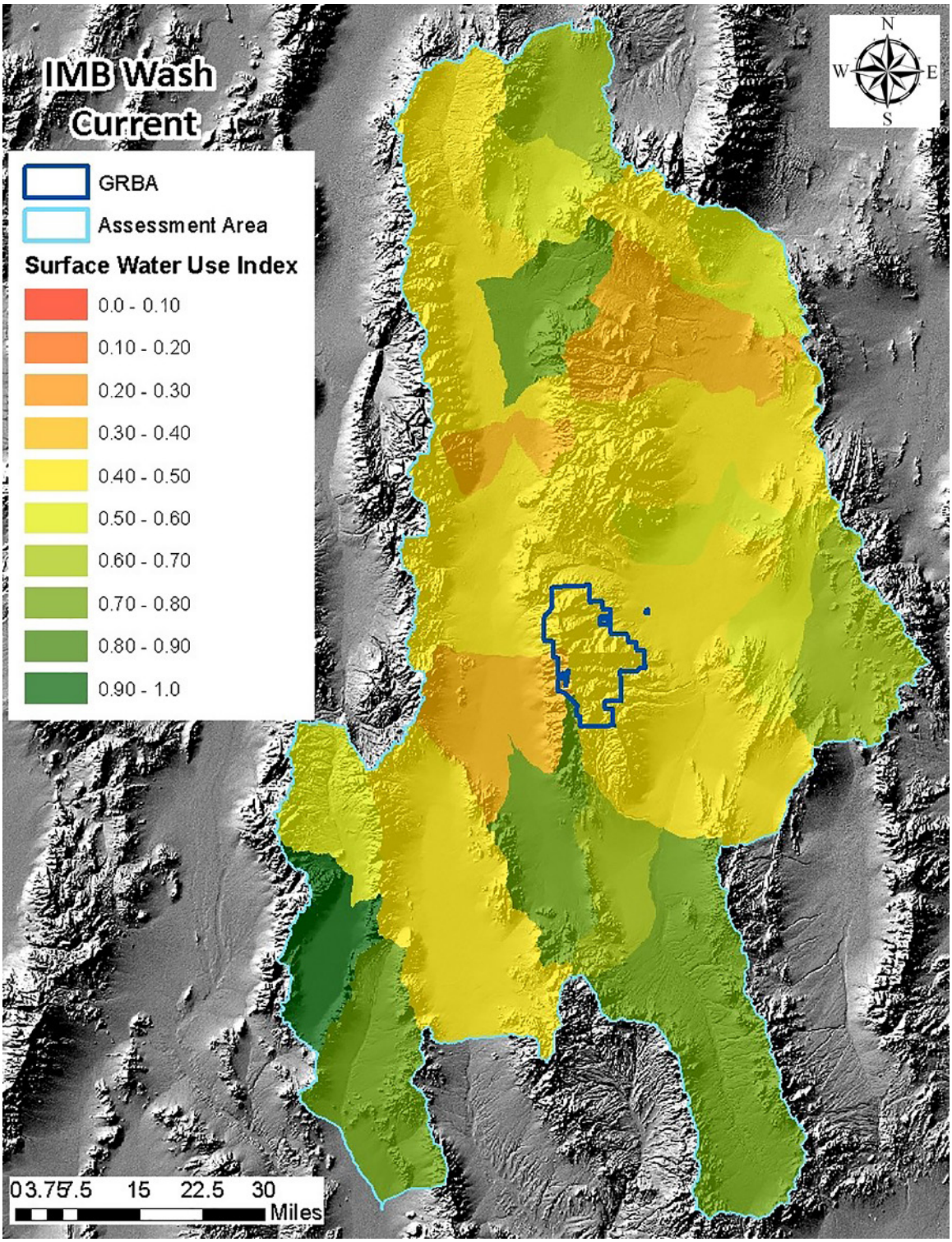

Figure D-14. Map showing current surface water use index of wash habitat in the Great Basin.

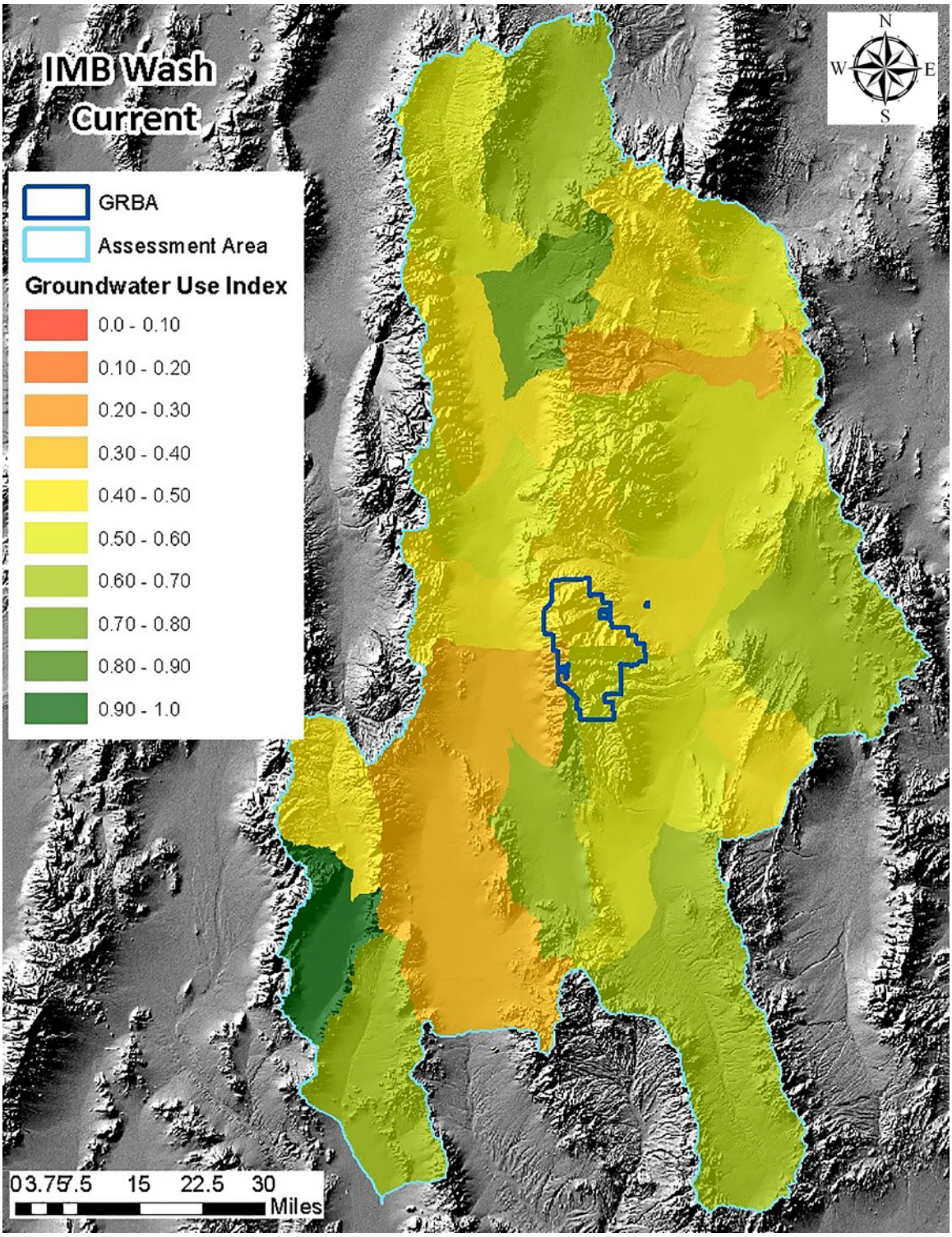

Figure D-15. Map showing current groundwater water use index of wash habitat in the Great Basin.

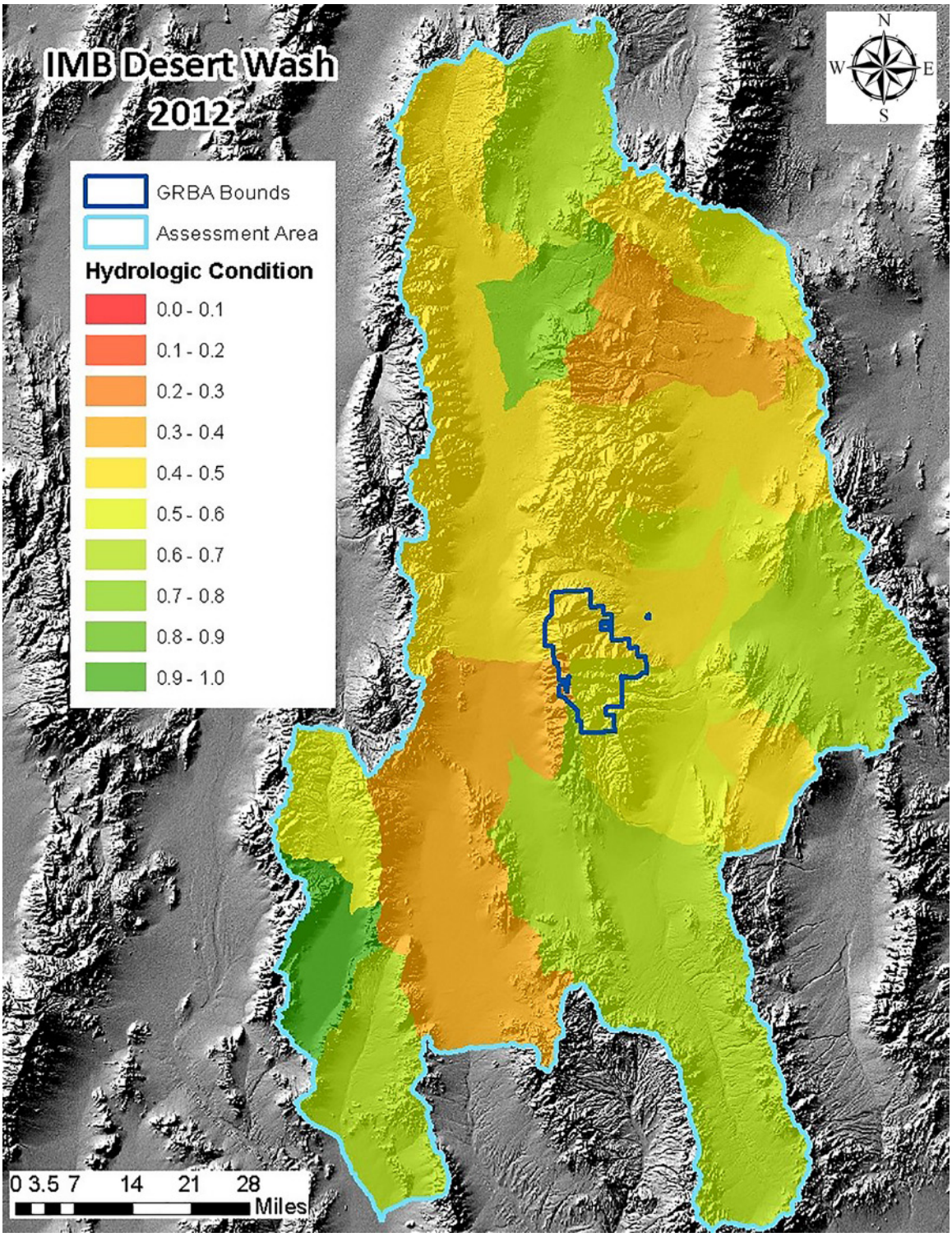

Figure D-16. Map showing modeled 2012 hyrolgic condition of wash habitat in the Great Basin.

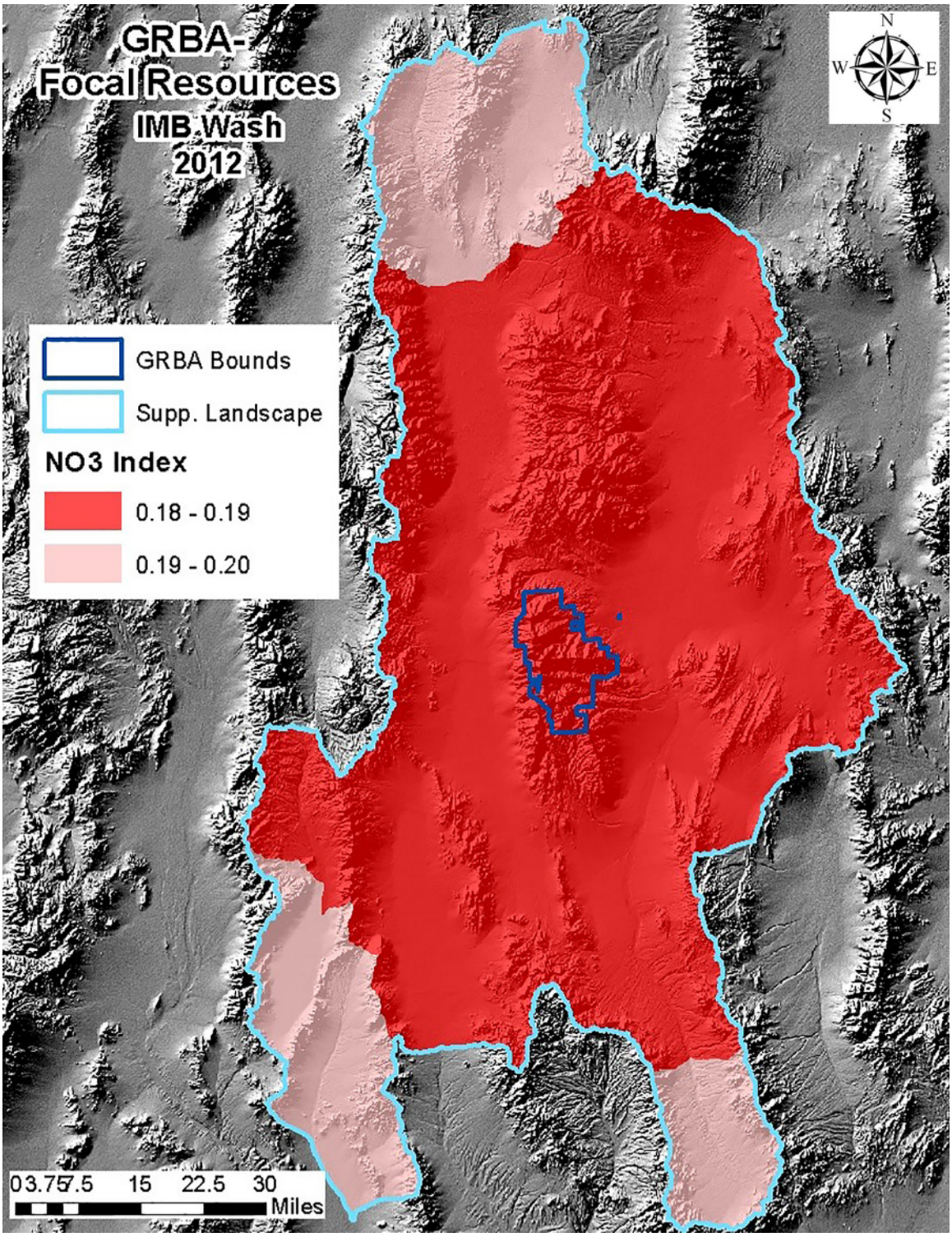

Figure D-17. Map showing modeled 2012 NO3 (nitrate) index of wash habitat in the Great Basin.

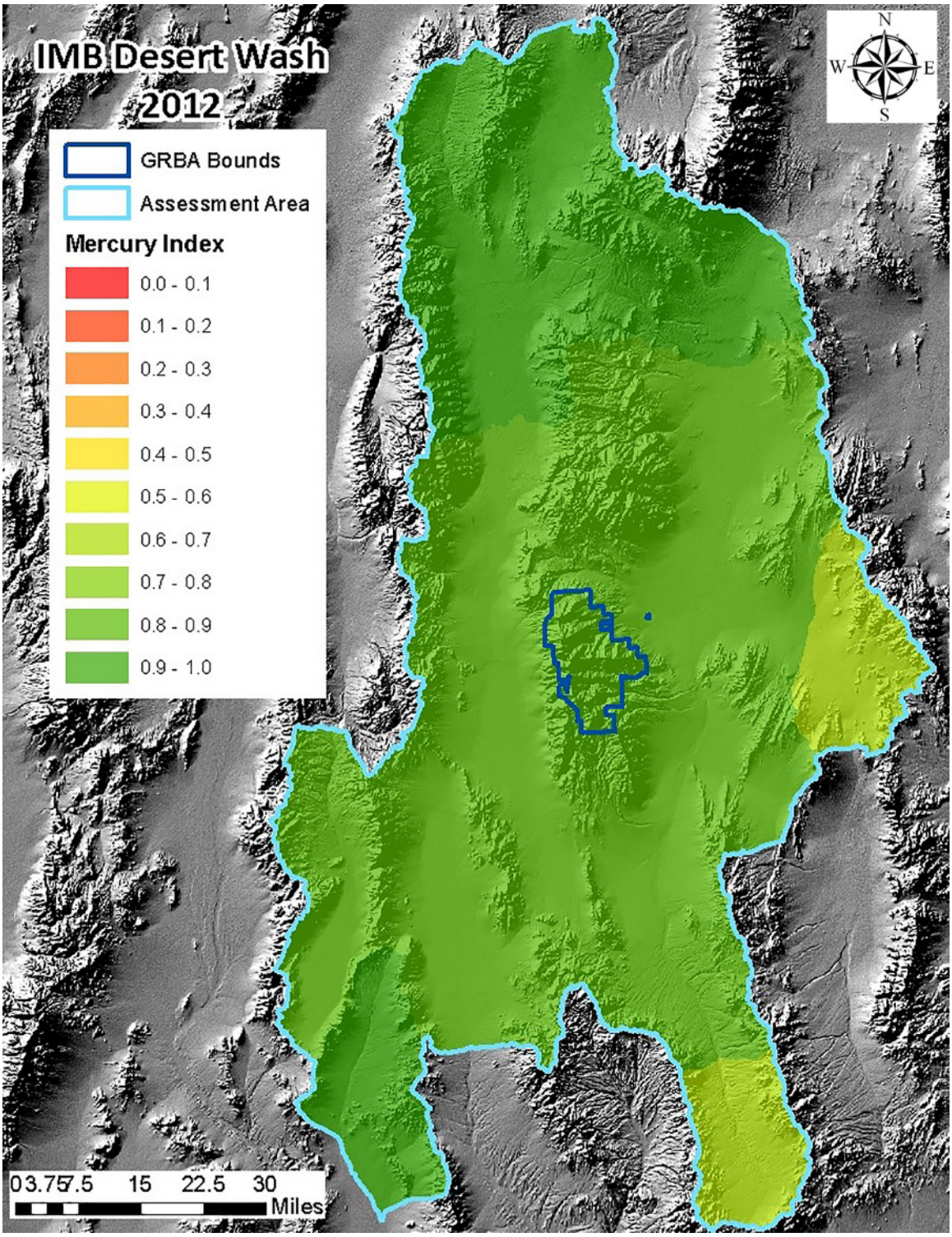

Figure D-18. Map showing modeled 2012 mercury index of wash habitat in the Great Basin.

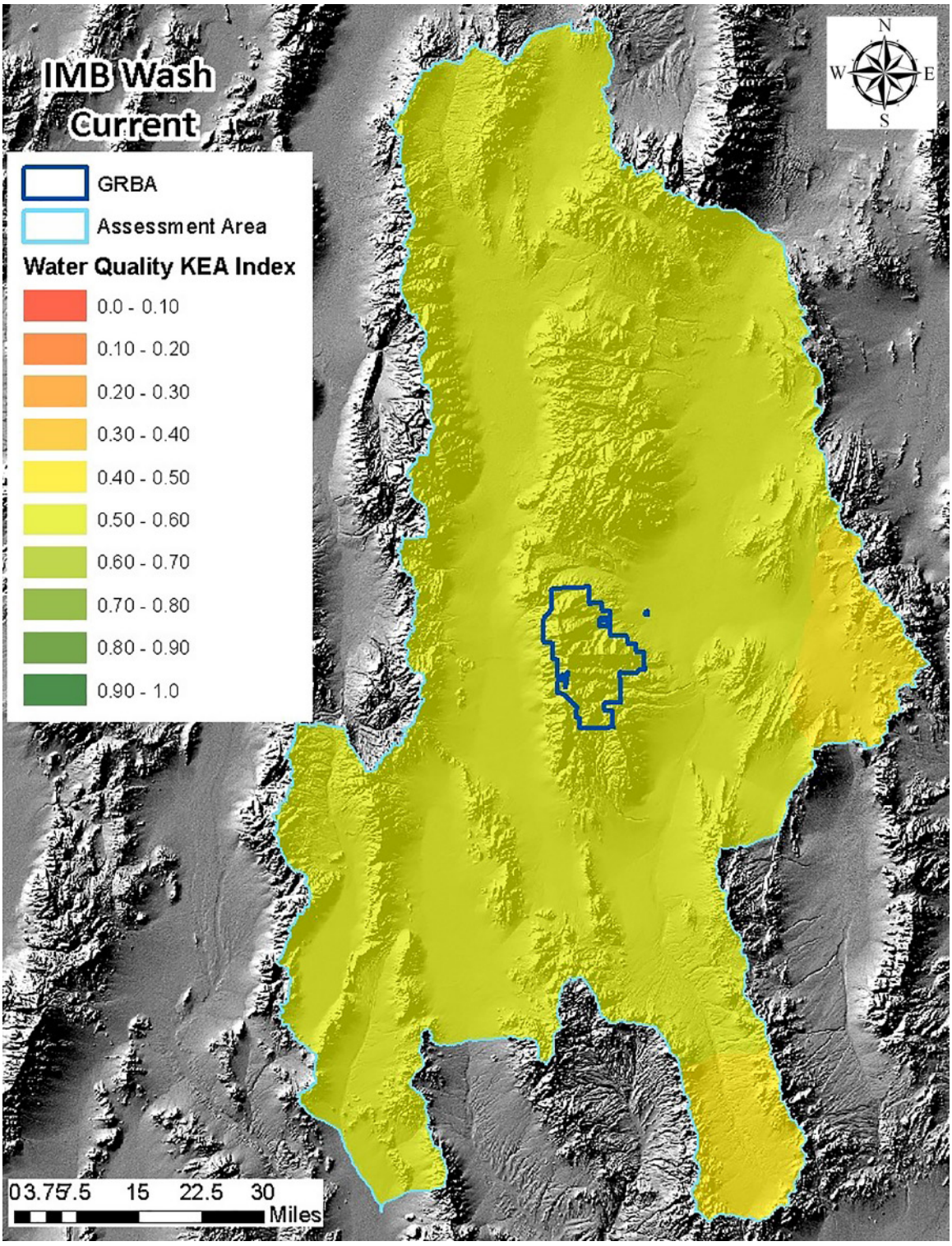

Figure D-19. Map showing current water quality KEA index of wash habitat in the Great Basin.

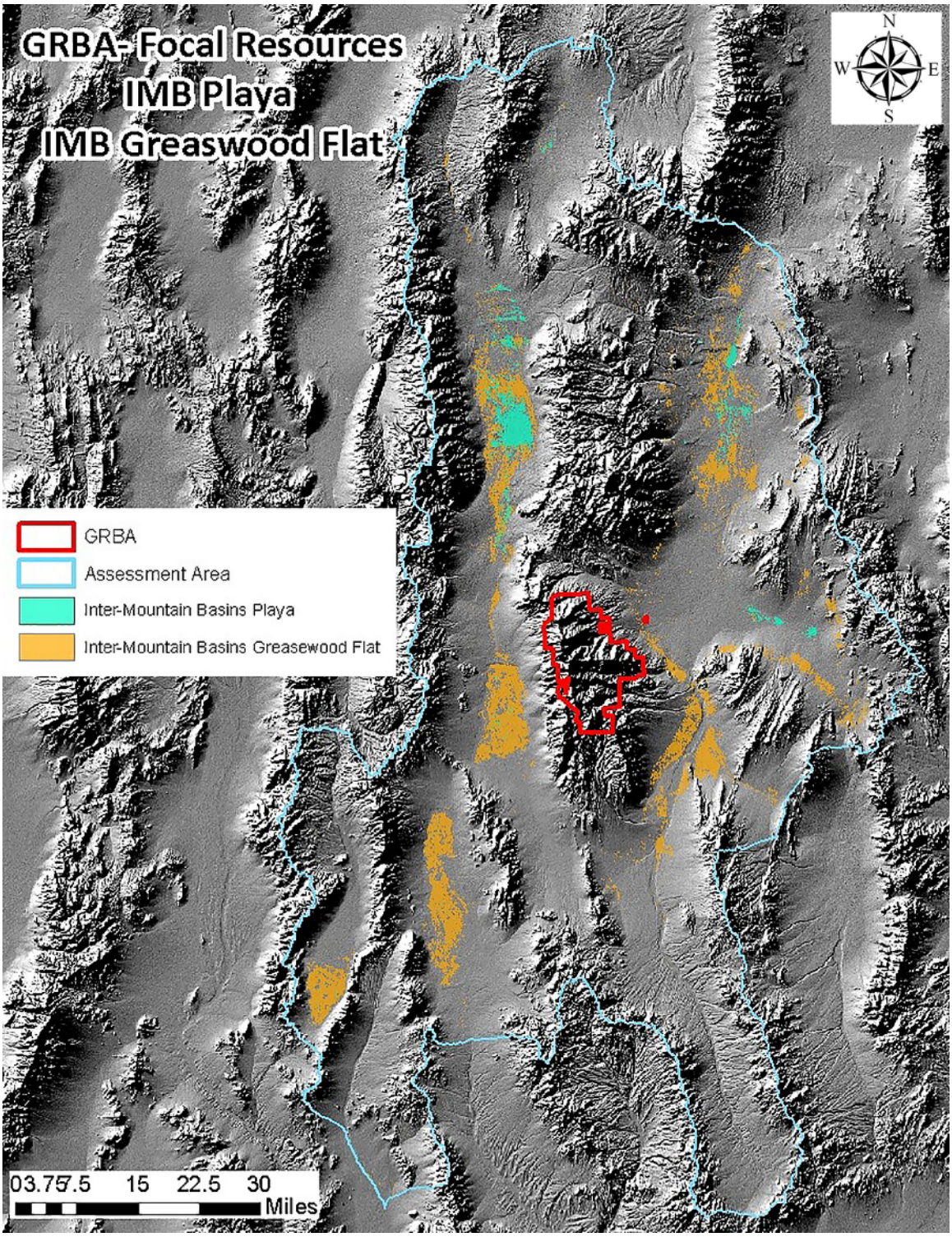

Figure D-20. Map showing IMB playa and IMB greasewood flat habbiats in the Great Basin.

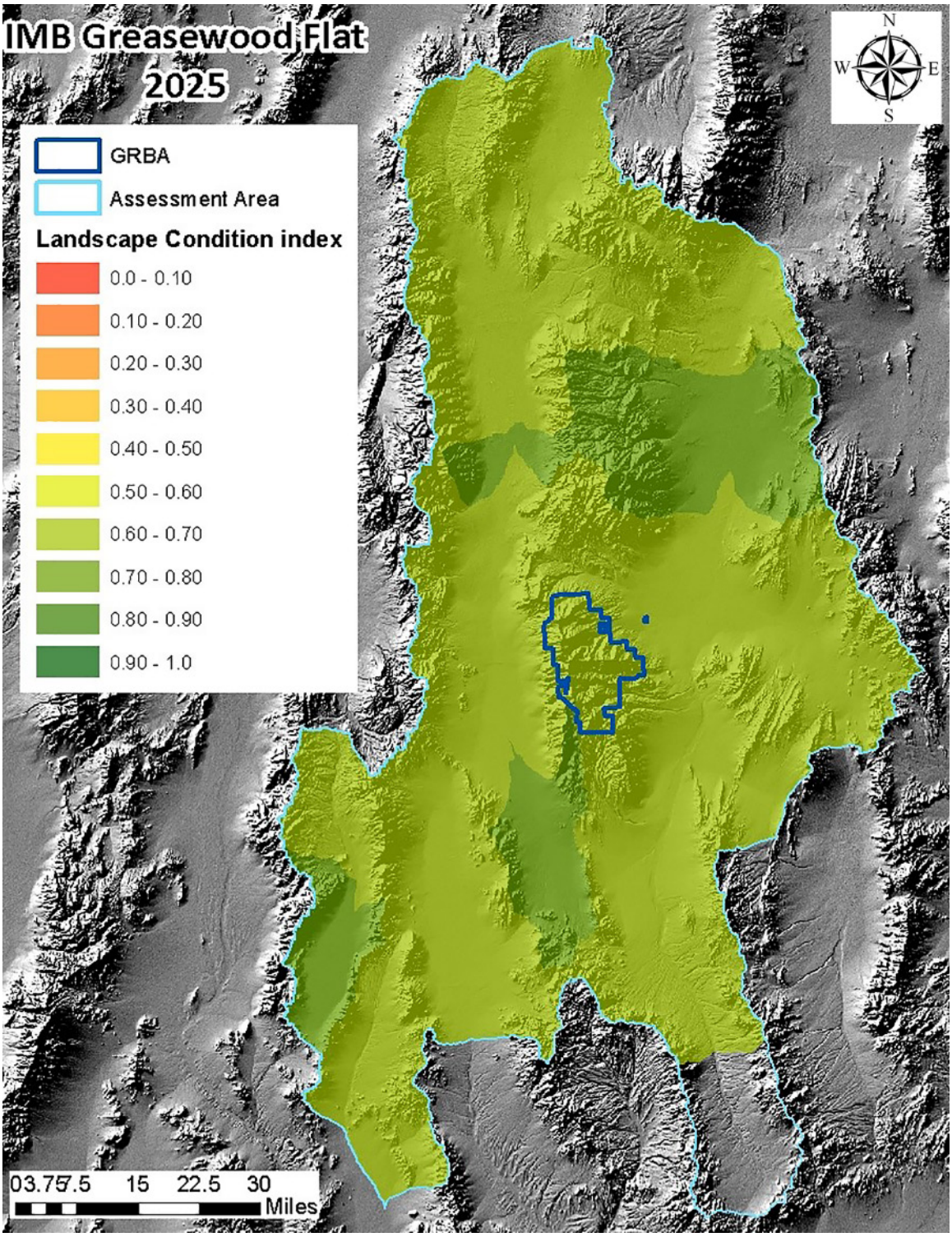

Figure D-21. Map showing modeled 2025 landscape condition index of IMB greasewood flat habbiat in the Great Basin.

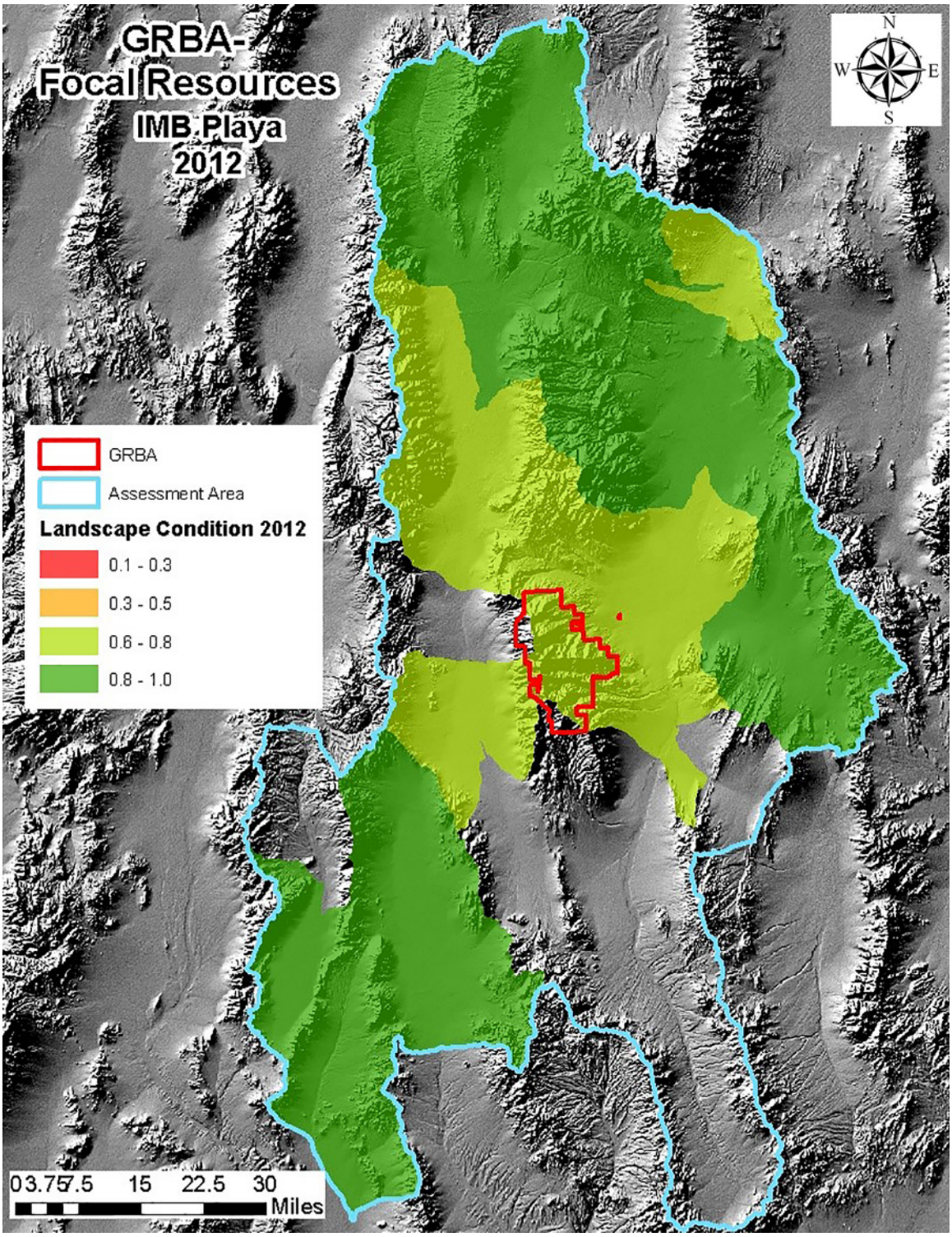

Figure D-22. Map showing modeled 2012 landscape condition index of IMB playa flat habbiat in the Great Basin.

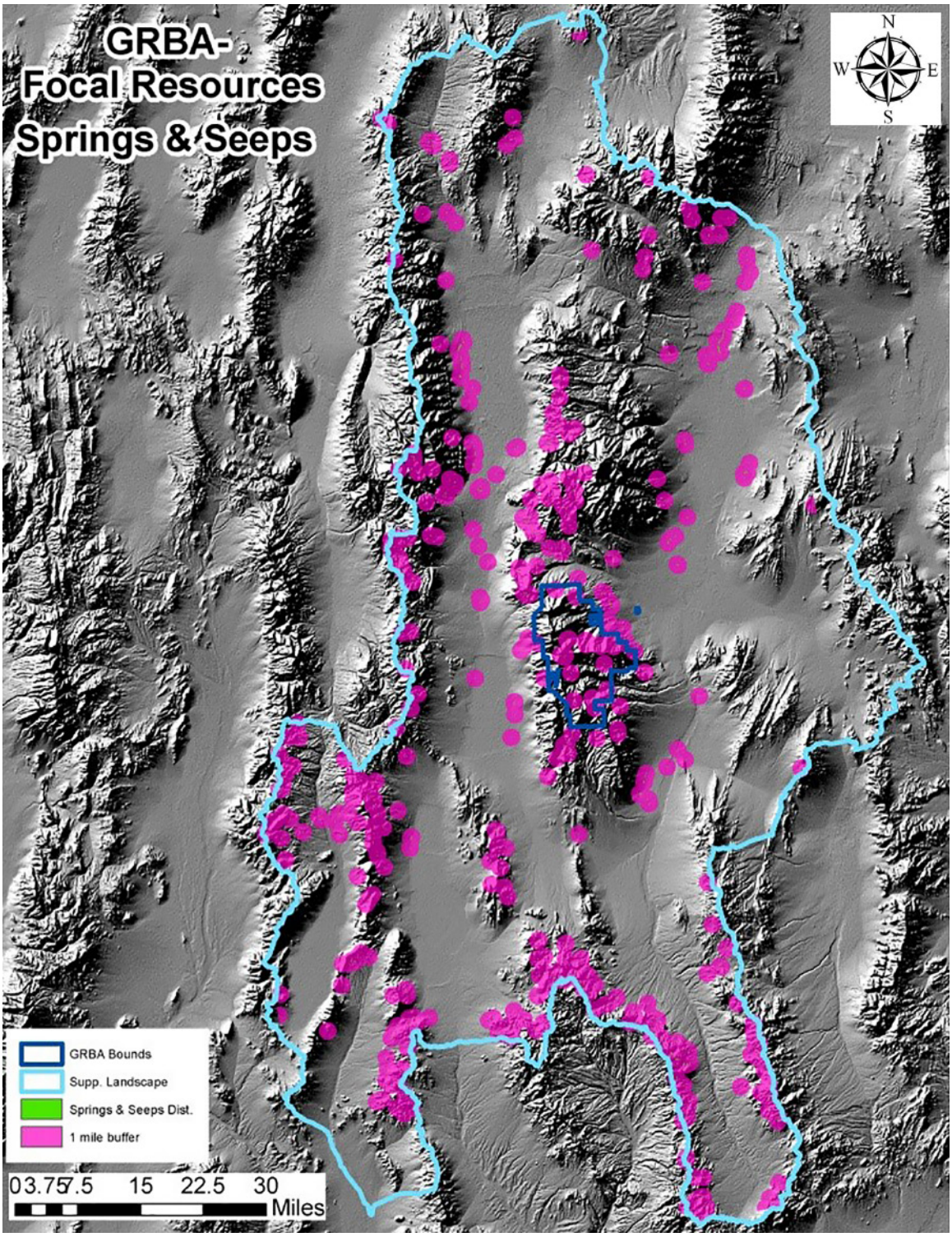

Figure D-23. Map showing seeps and springs in the Great Basin.

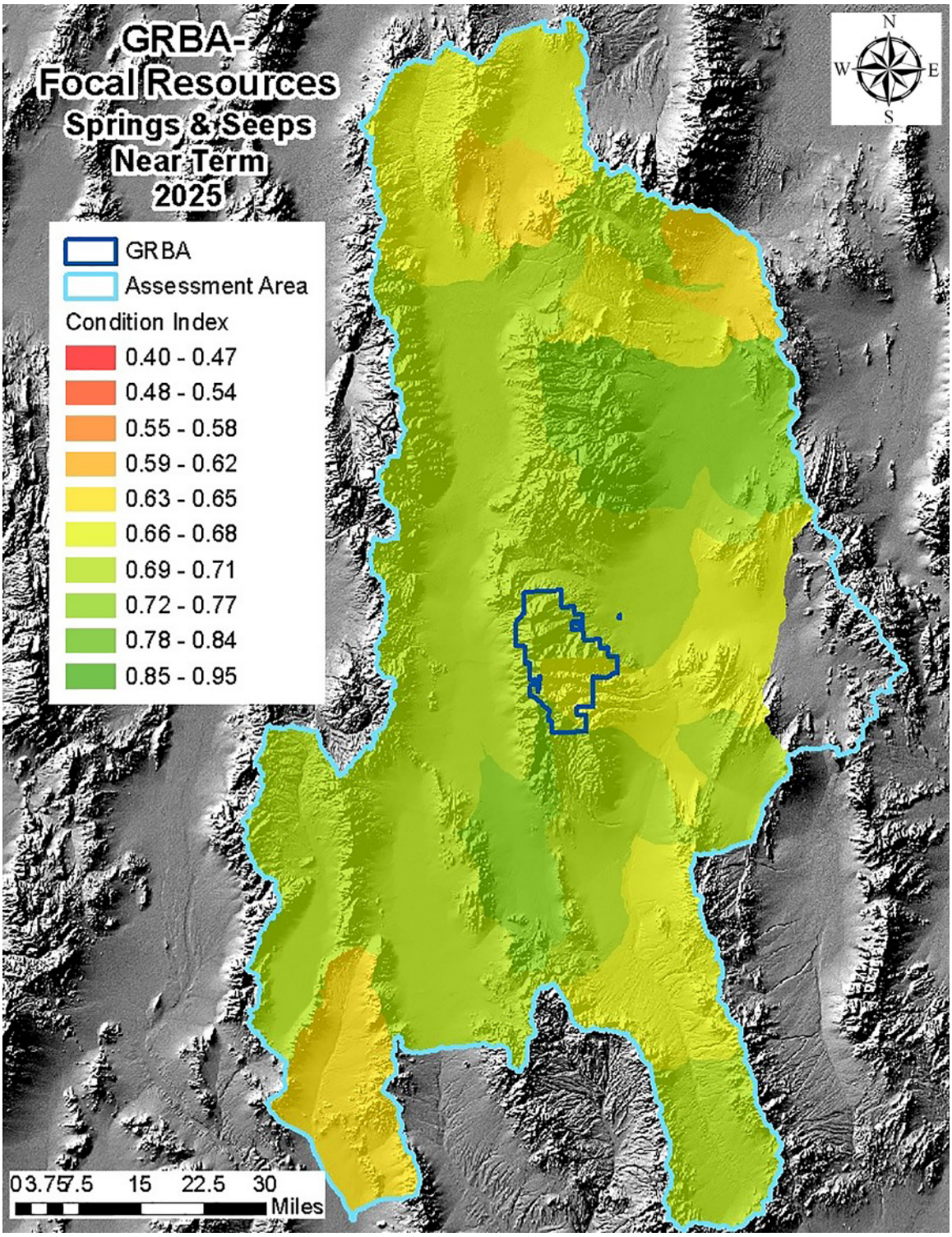

Figure D-24. Map showing the 2025 modeled condition index of seeps and springs in the Great Basin.

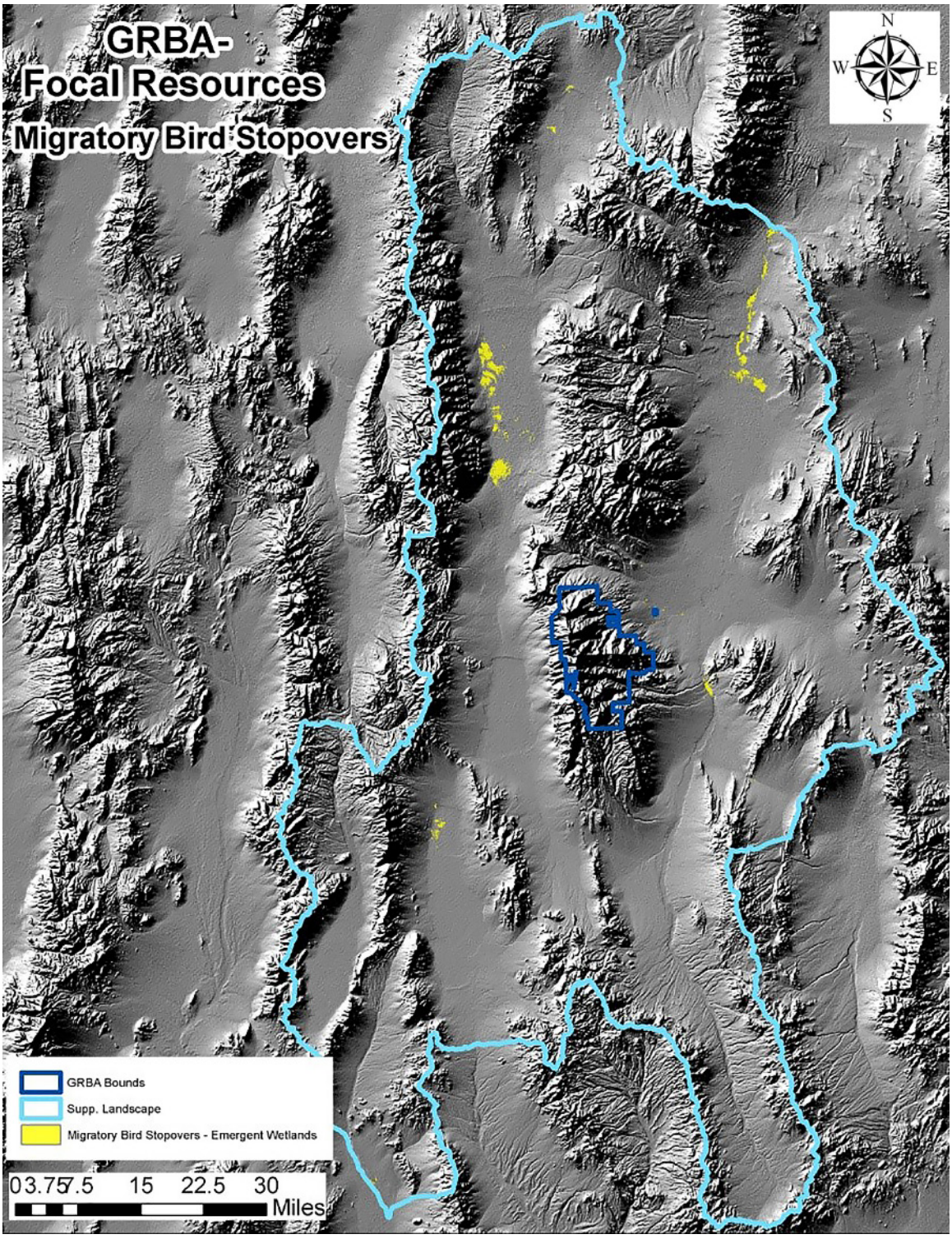

Figure D-25. Map showing the migratory bird stopovers in the Great Basin.

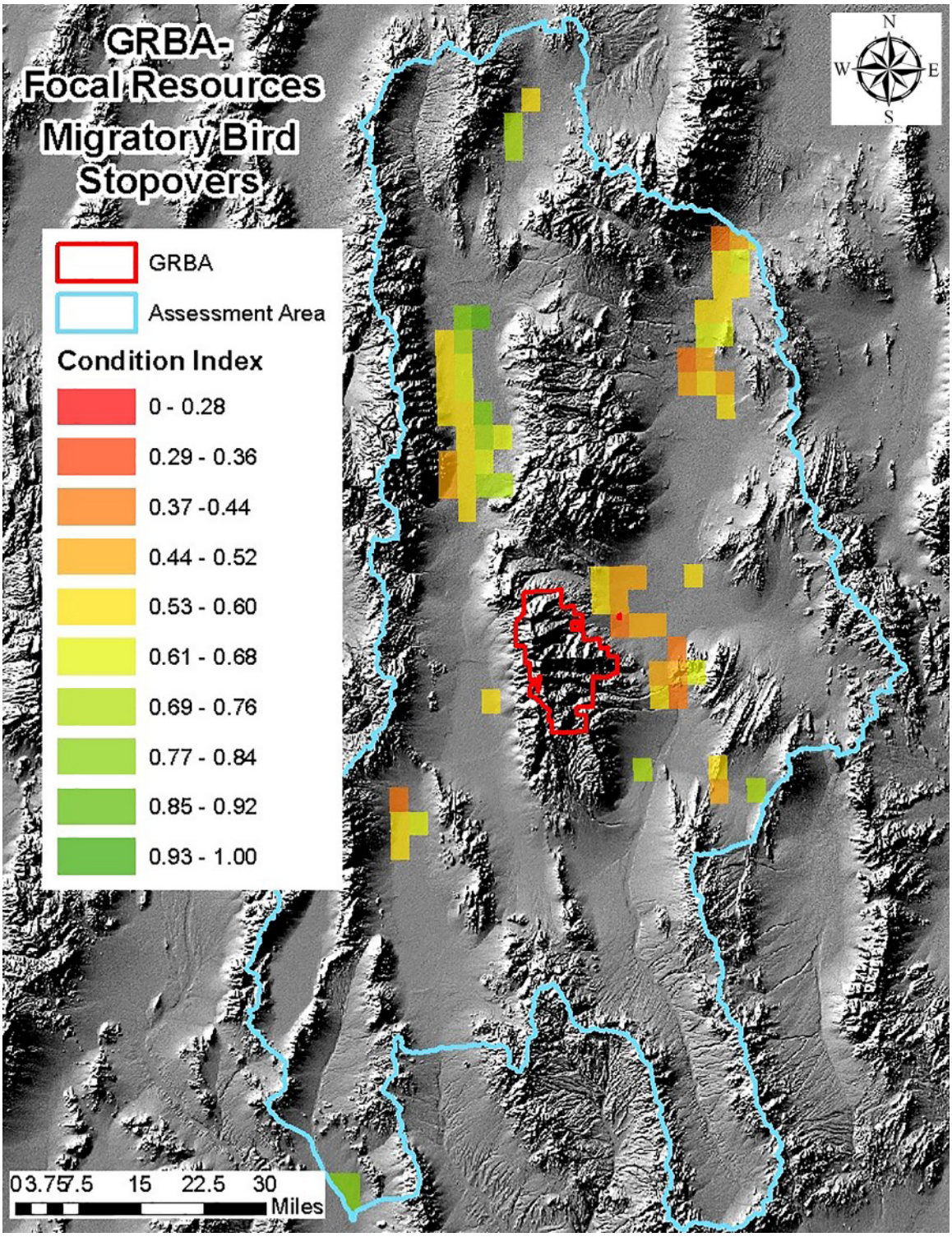

Figure D-26. Map showing the condition index of migratory bird stopovers in the Great Basin.

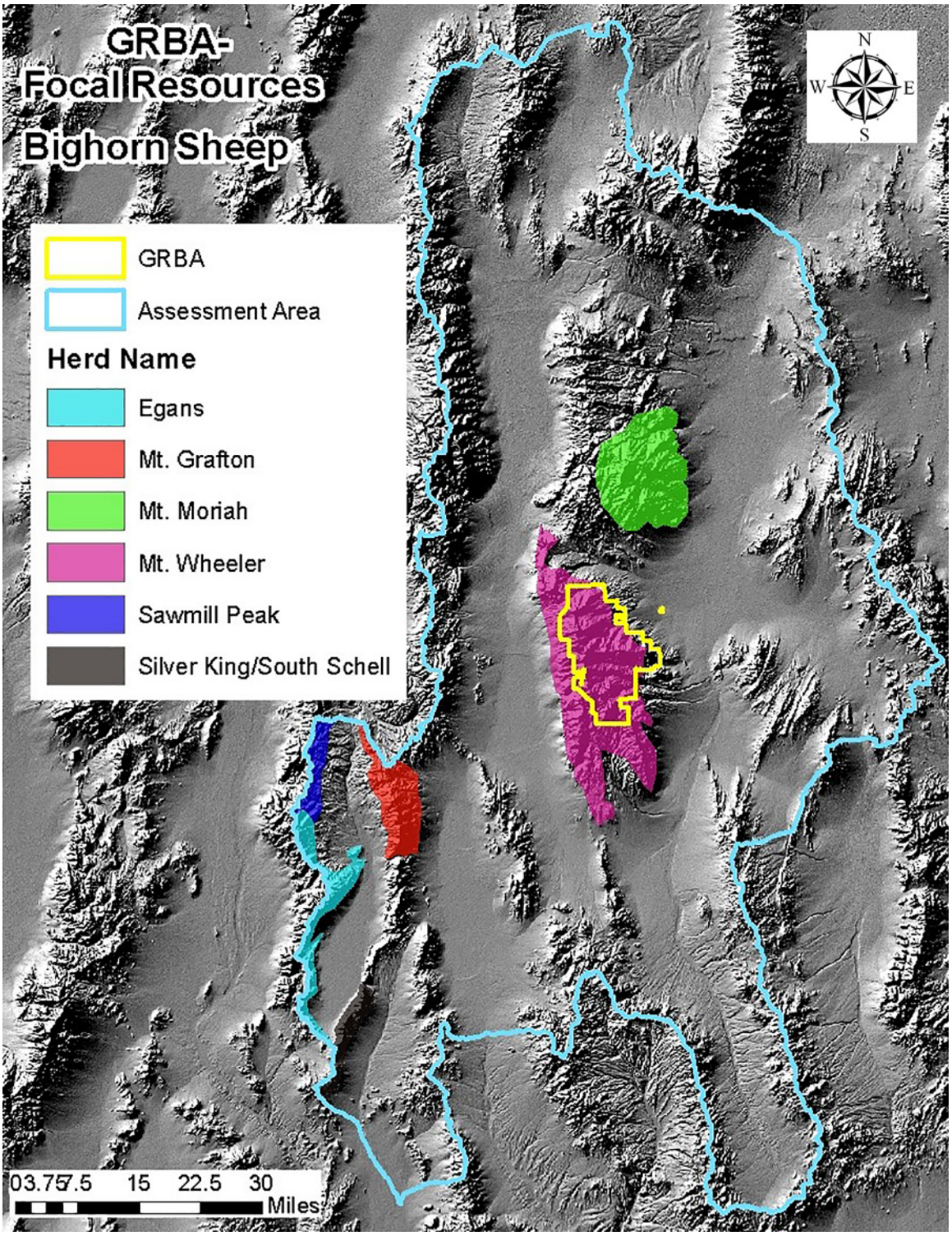

Figure D-27. Map showing bighorn sheep herd locations in the Great Basin.

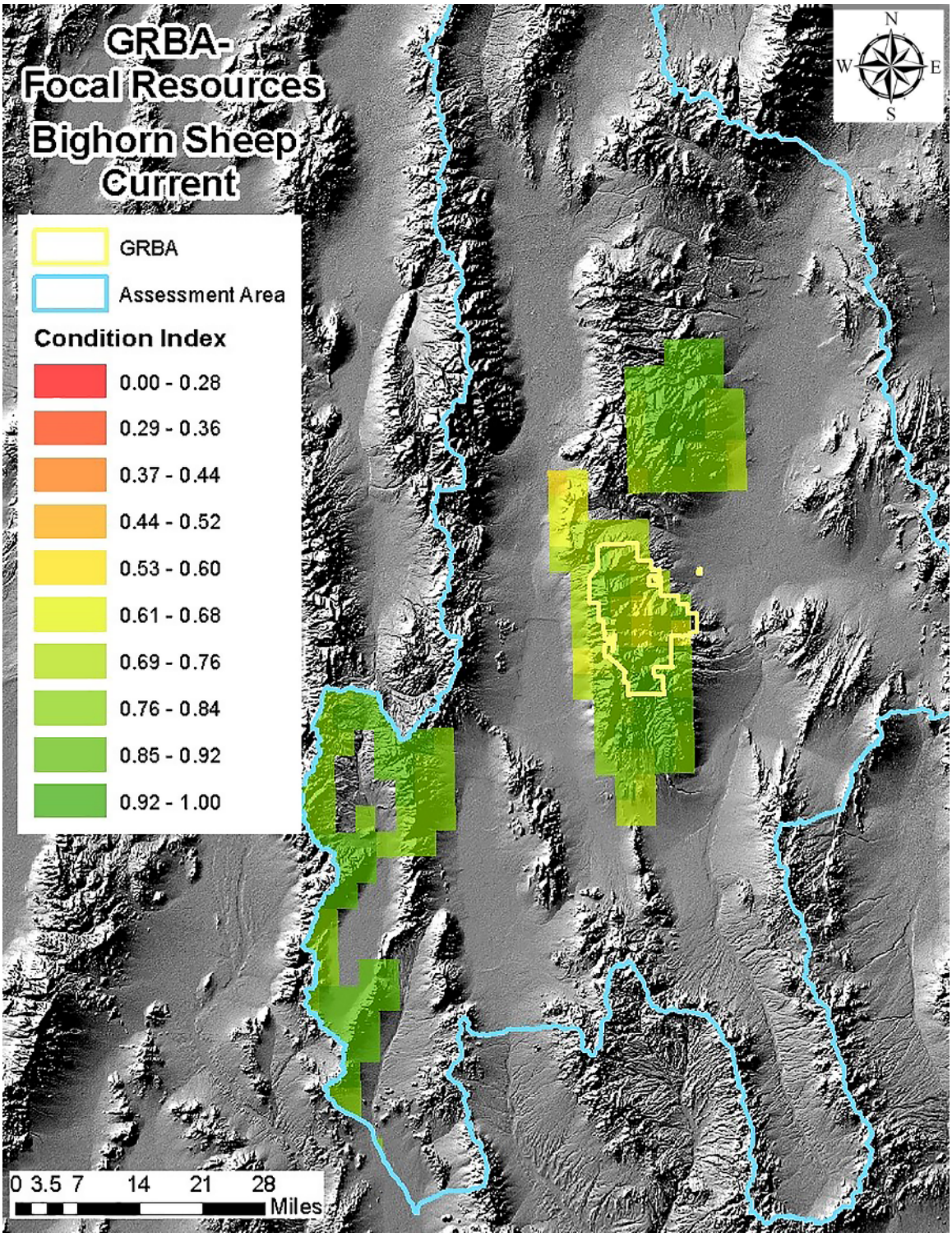

Figure D-28. Map showing the current bighorn sheep condition index in the Great Basin.

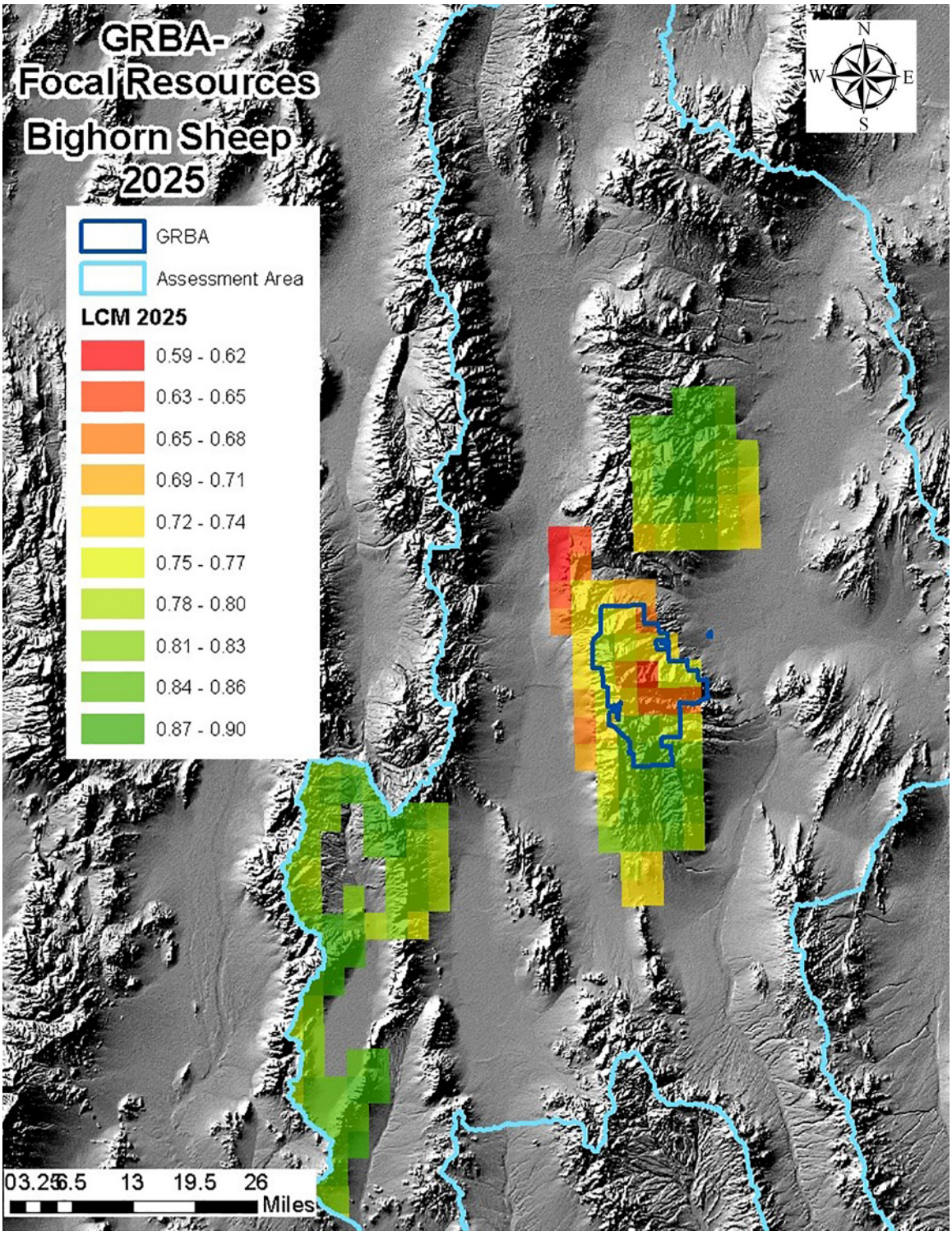

Figure D-29. Map showing the 2025 modeled LCM for bighorn sheep condition in the Great Basin.

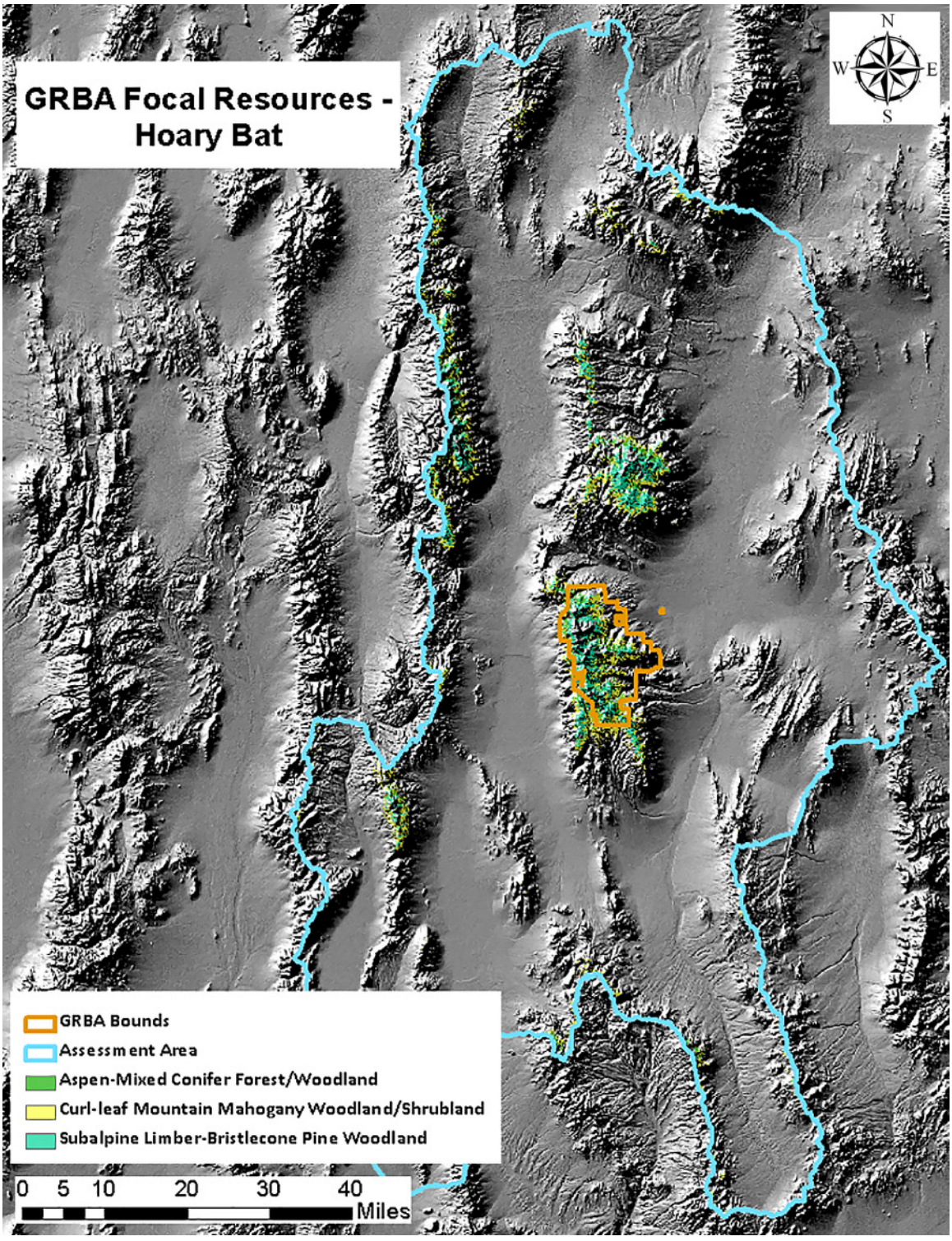

Figure D-30. Map showing habitat types amendable to the hoary bat in the Great Basin.

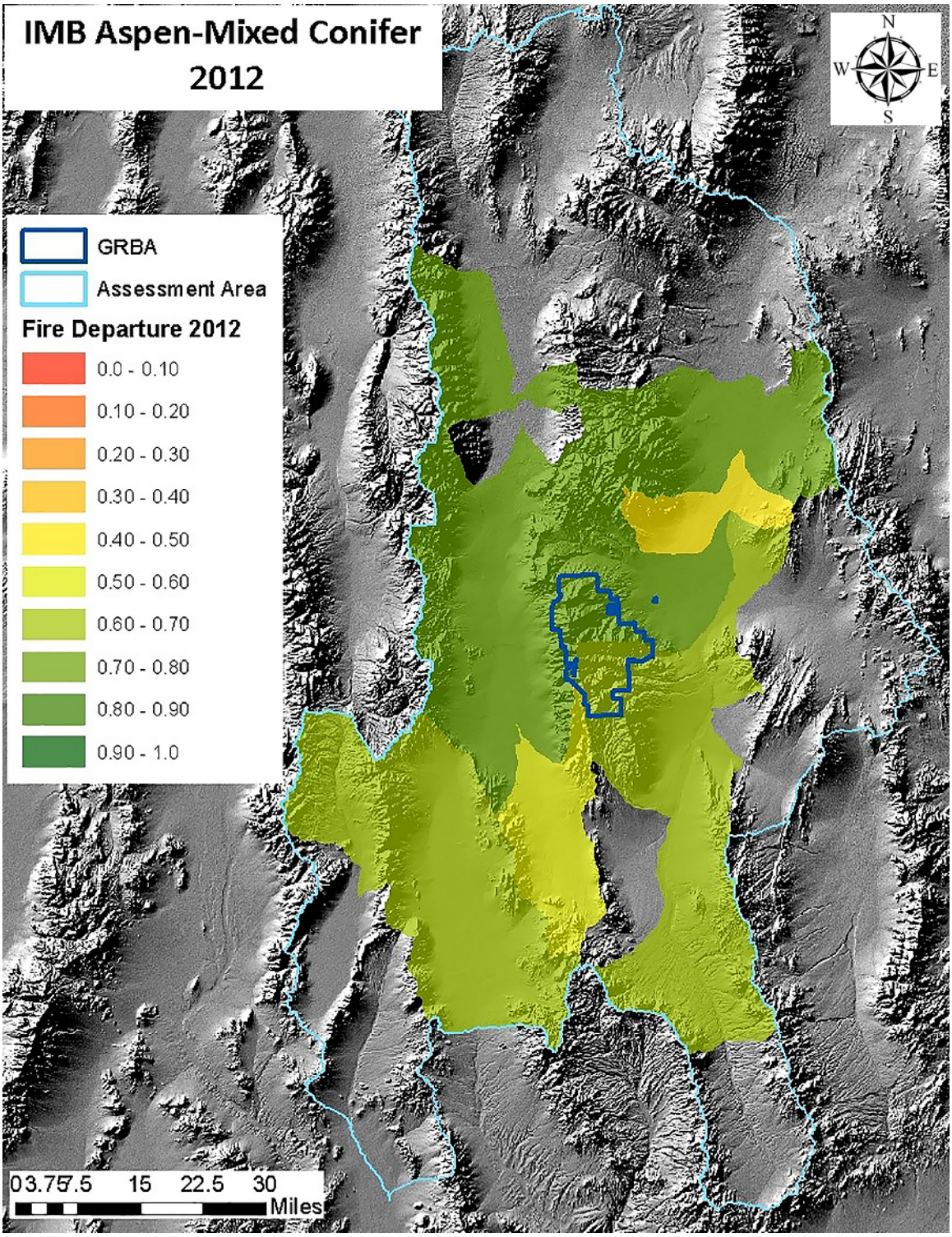

Figure D-31. Map showing 2012 modeled fire departure of aspen-mixed conifer habitat in the Great Basin.

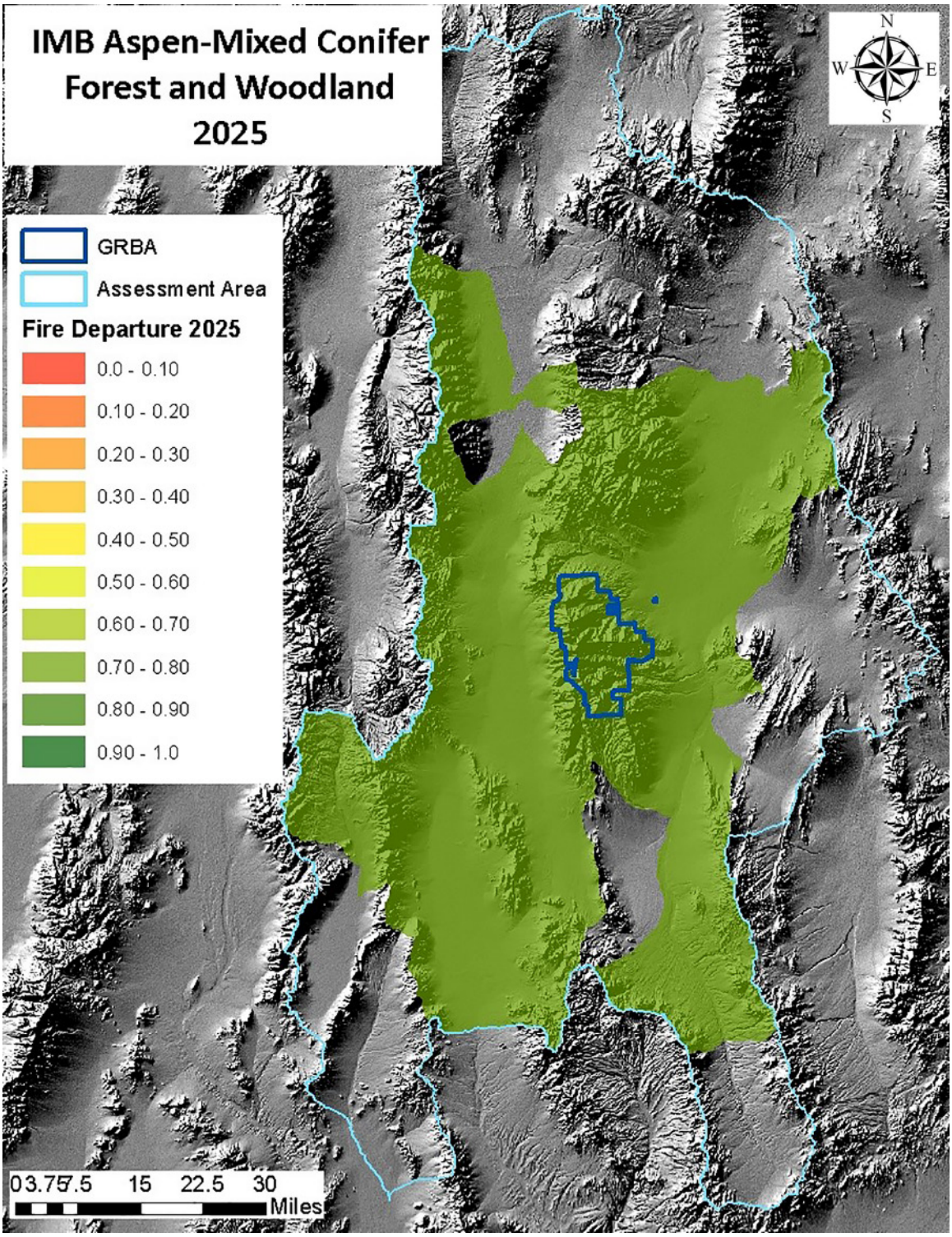

Figure D-32. Map showing 2025 modeled fire departure of aspen-mixed conifer habitat in the Great Basin.

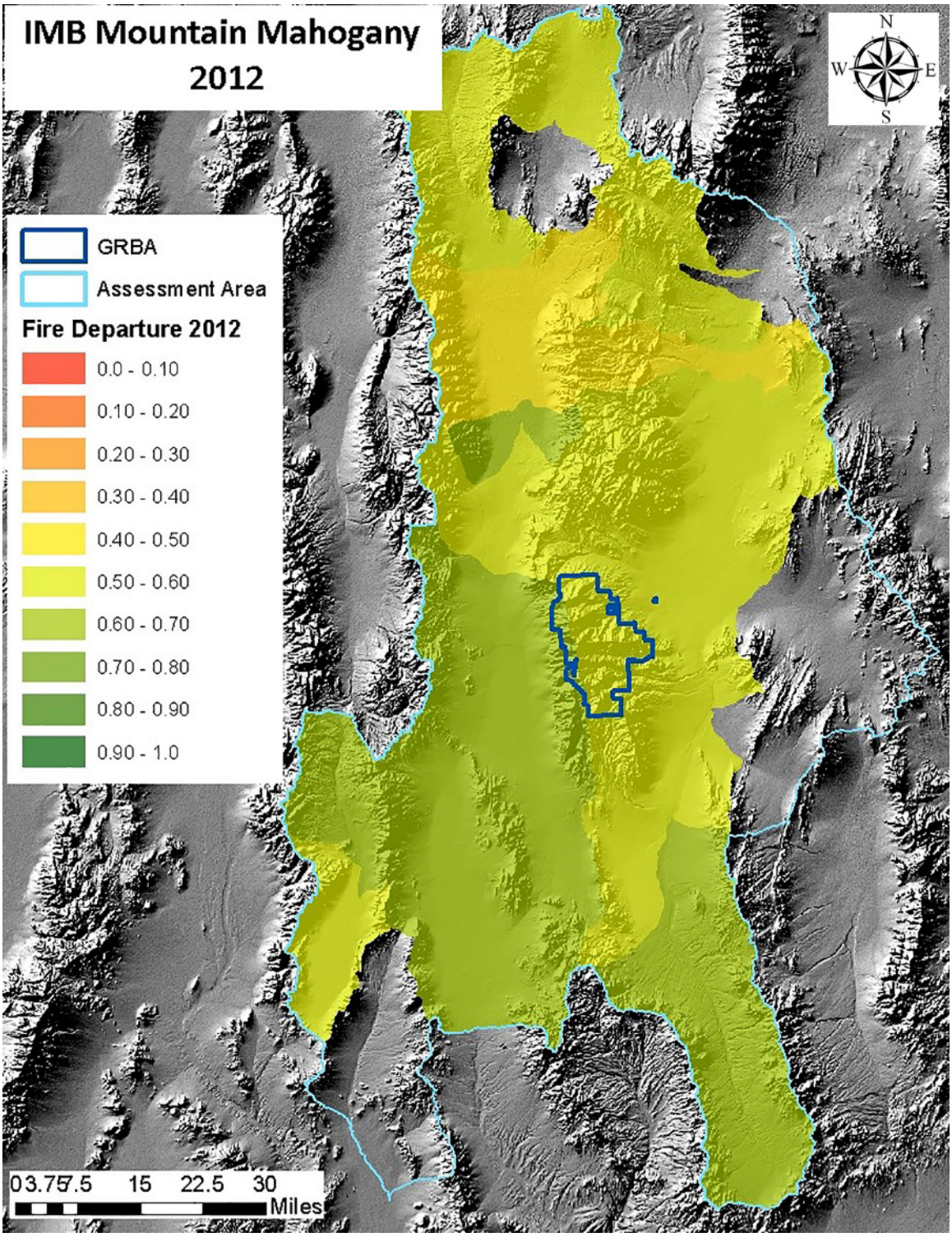

Figure D-33. Map showing 2012 modeled fire departure of mountain mahogany habitat in the Great Basin.

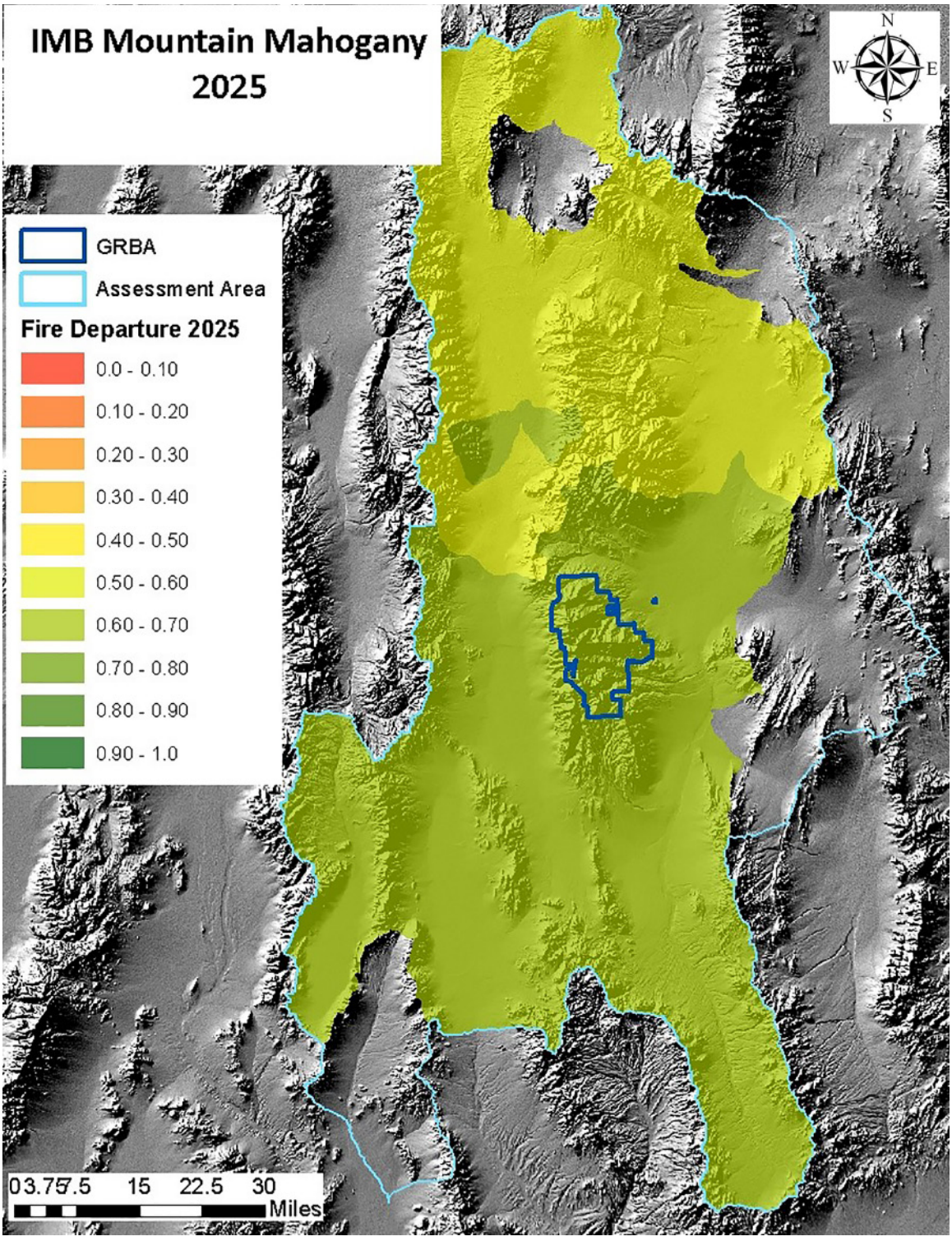

Figure D-34. Map showing 2025 modeled fire departure of mountain mahogany habitat in the Great Basin.

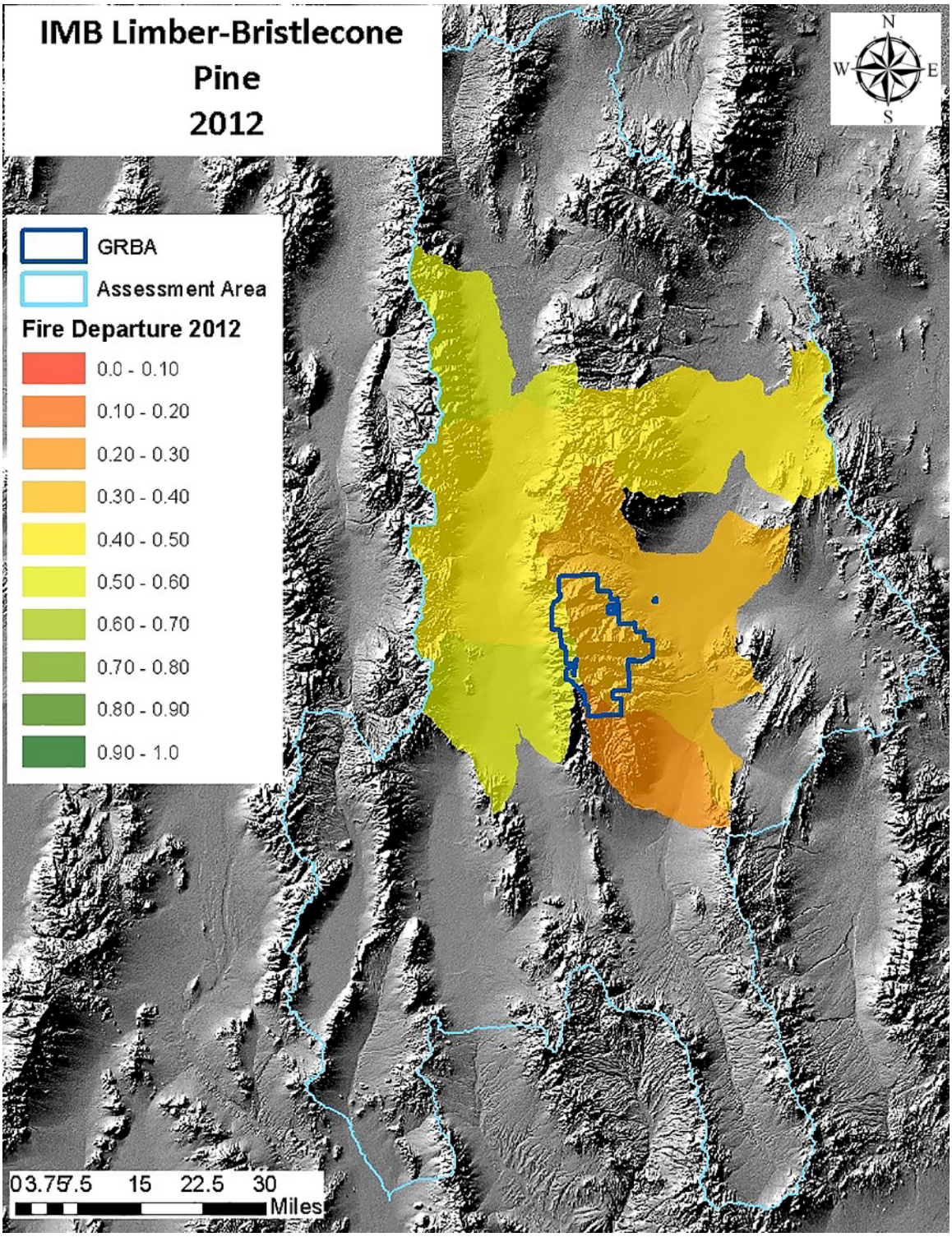

Figure D-35. Map showing 2012 modeled fire departure of limber-bristlecone pine habitat in the Great Basin.

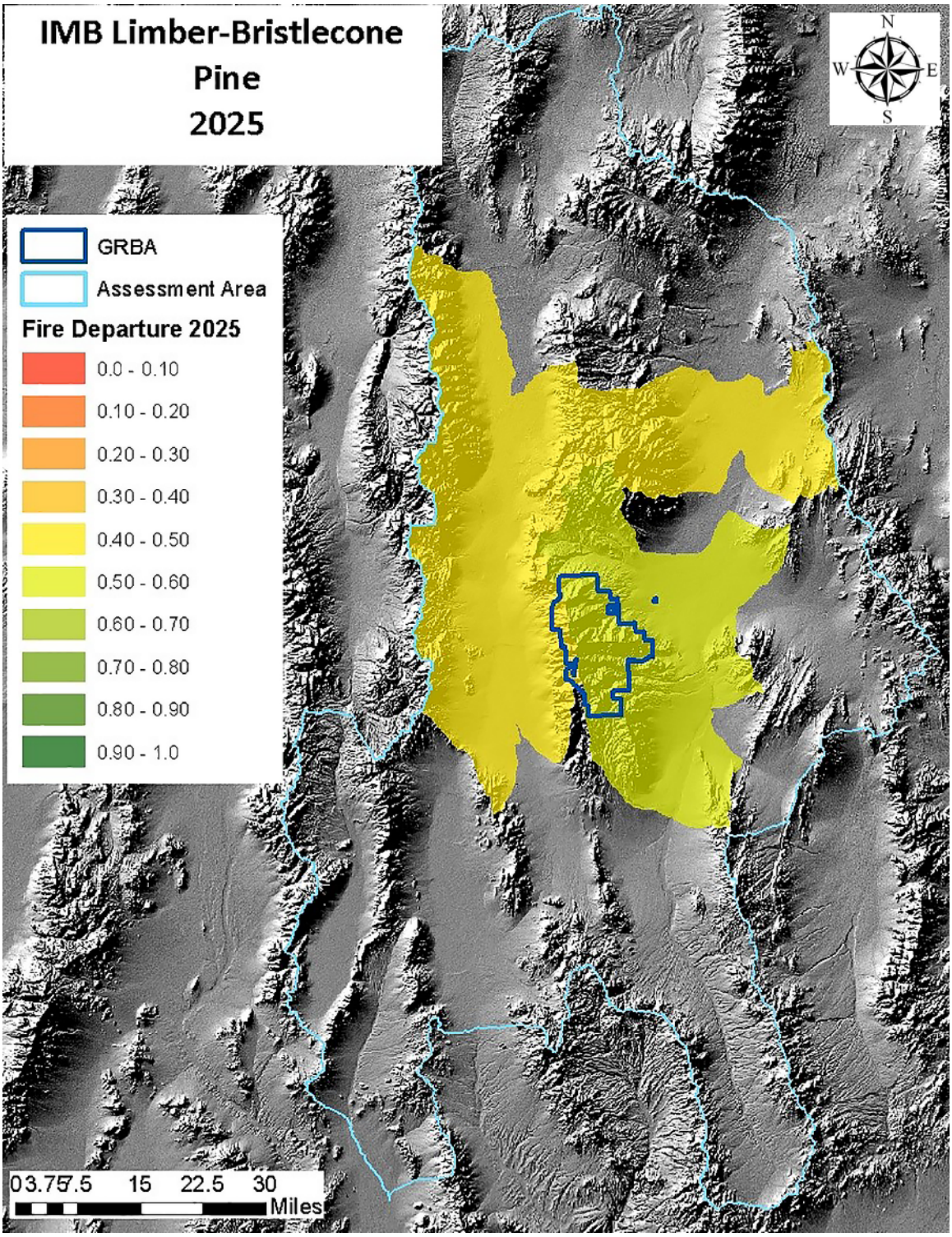

Figure D-36. Map showing 2025 modeled fire departure of limber-bristlecone pine habitat in the Great Basin.

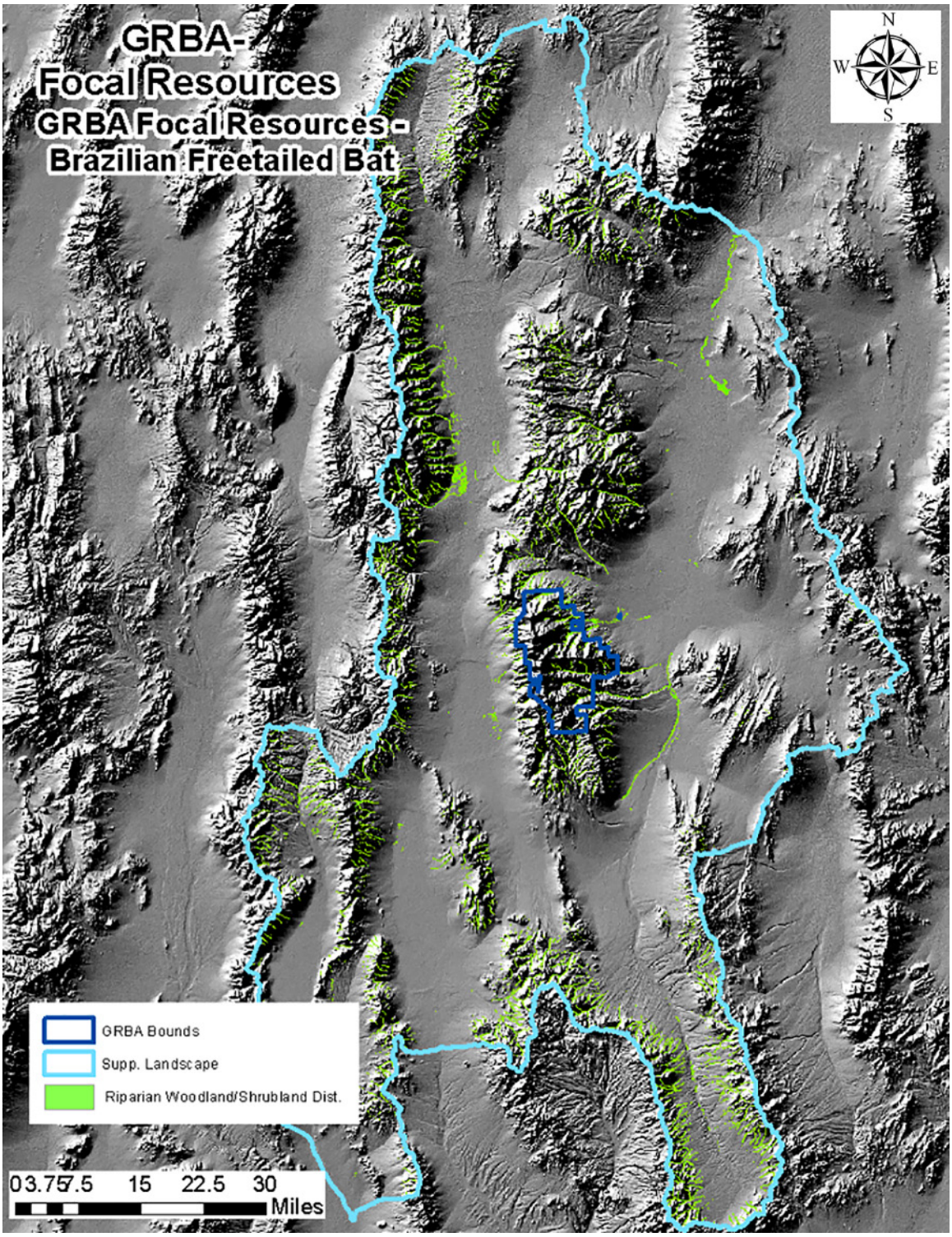

Figure D-37. Map showing potential Brazillian freetailed bat habitat in the Great Basin.

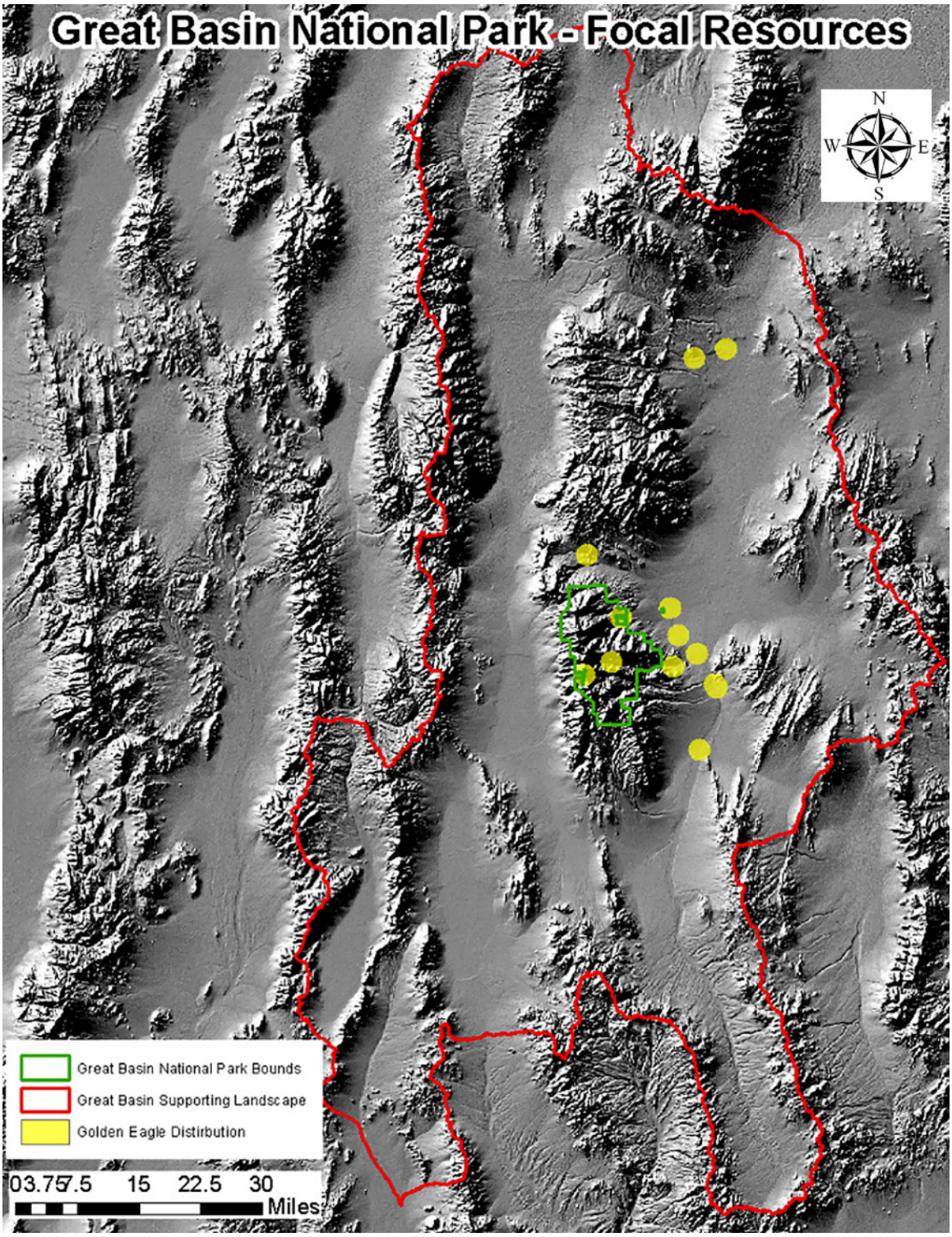

Figure D-38. Map showing golden eagle distribution in the Great Basin.

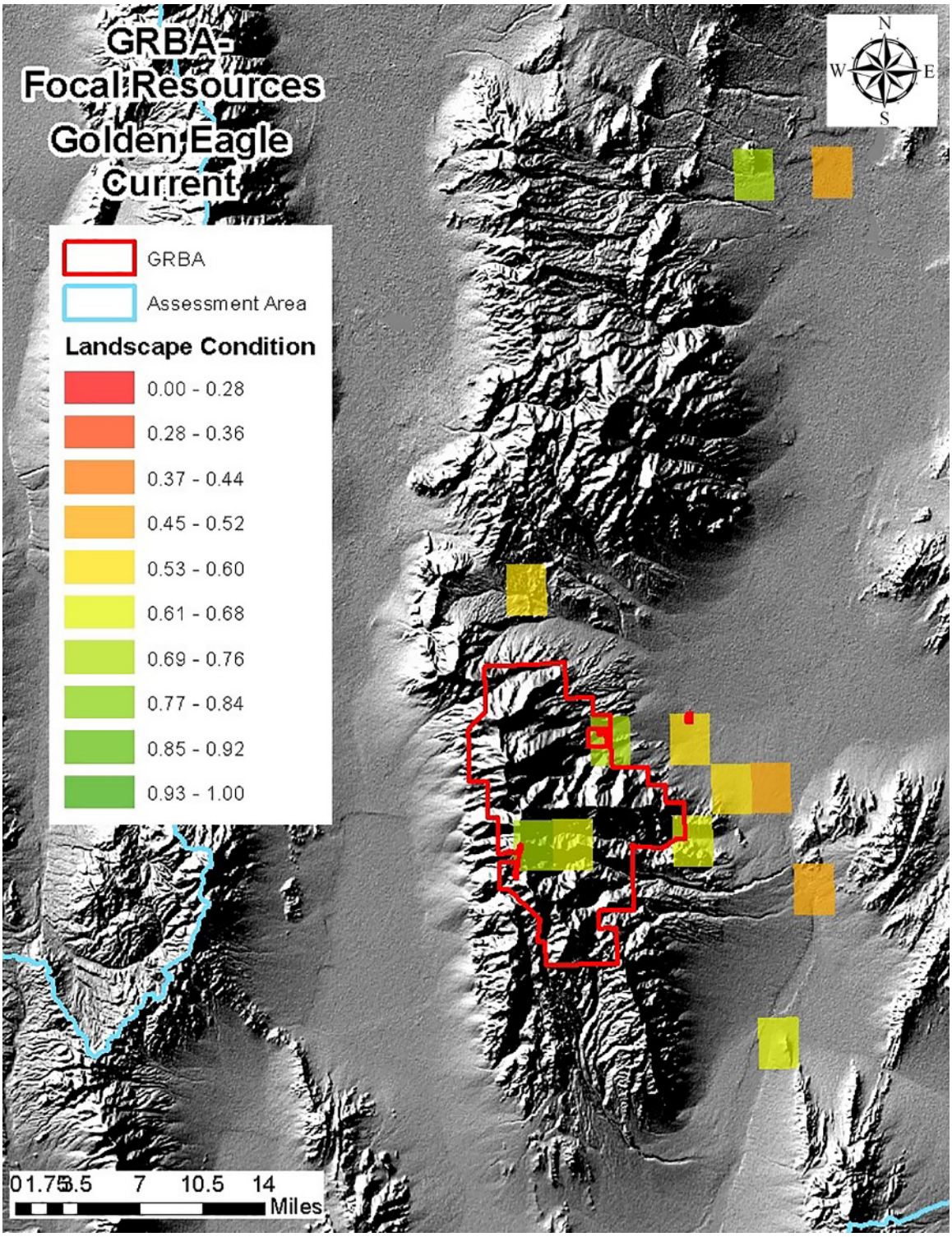

Figure D-39. Map showing current landscape condition of golden eagle in the Great Basin.

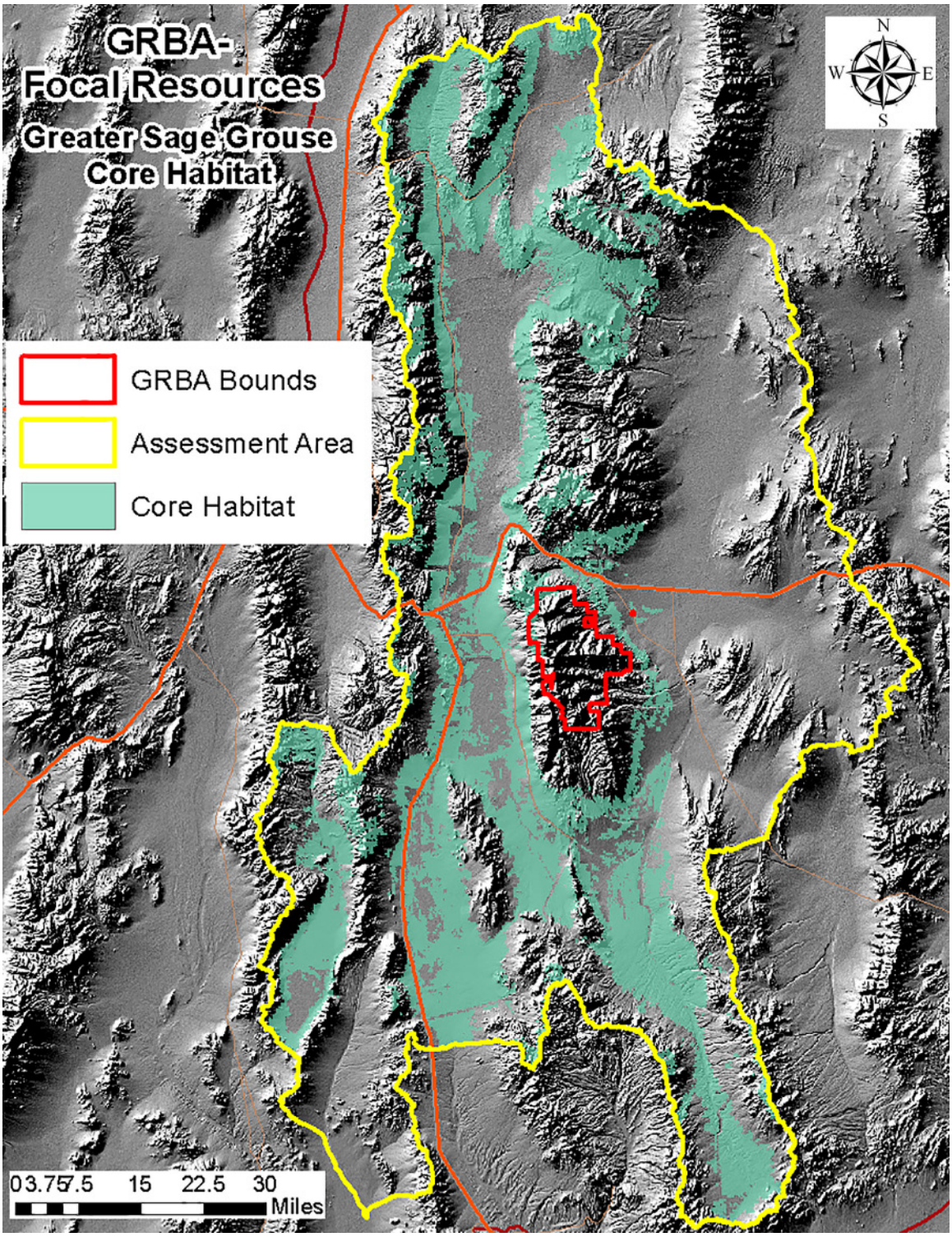

Figure D-40. Map showing core habitat for the greater sage grouse in the Great Basin.

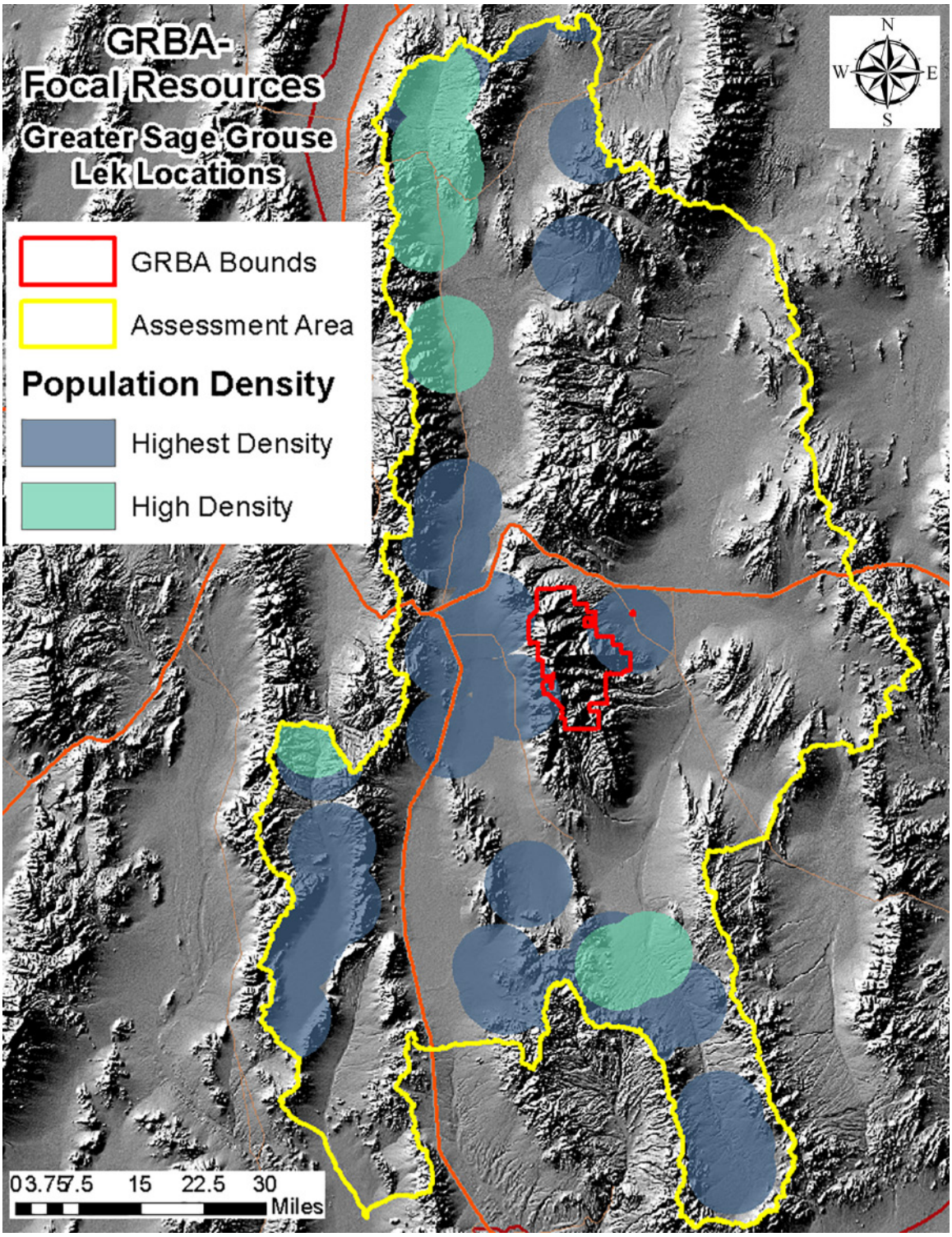

Figure D-41. Map showing lek locations for the greater sage grouse in the Great Basin.

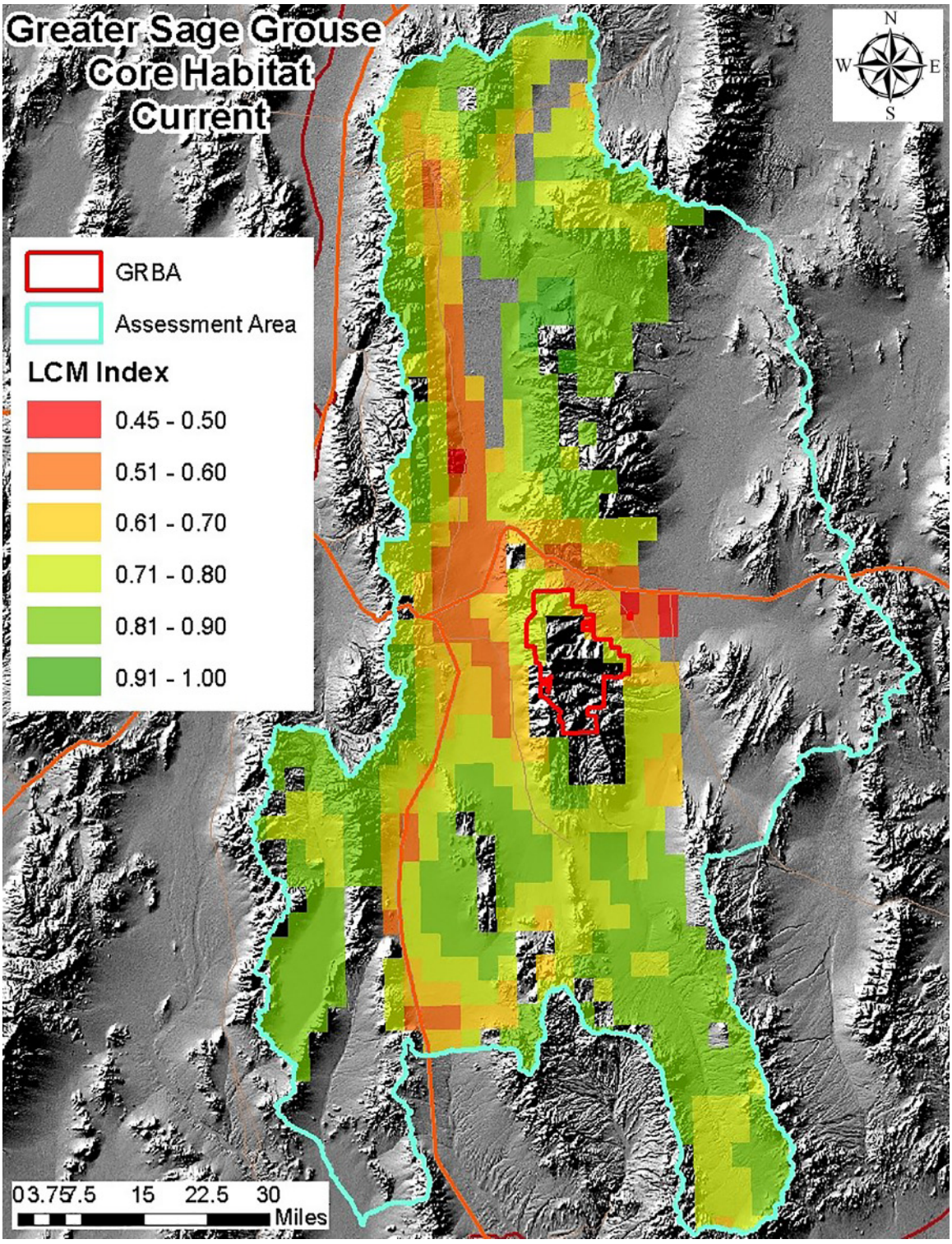

Figure D-42. Map showing the current LCM index for the greater sage grouse in the Great Basin.

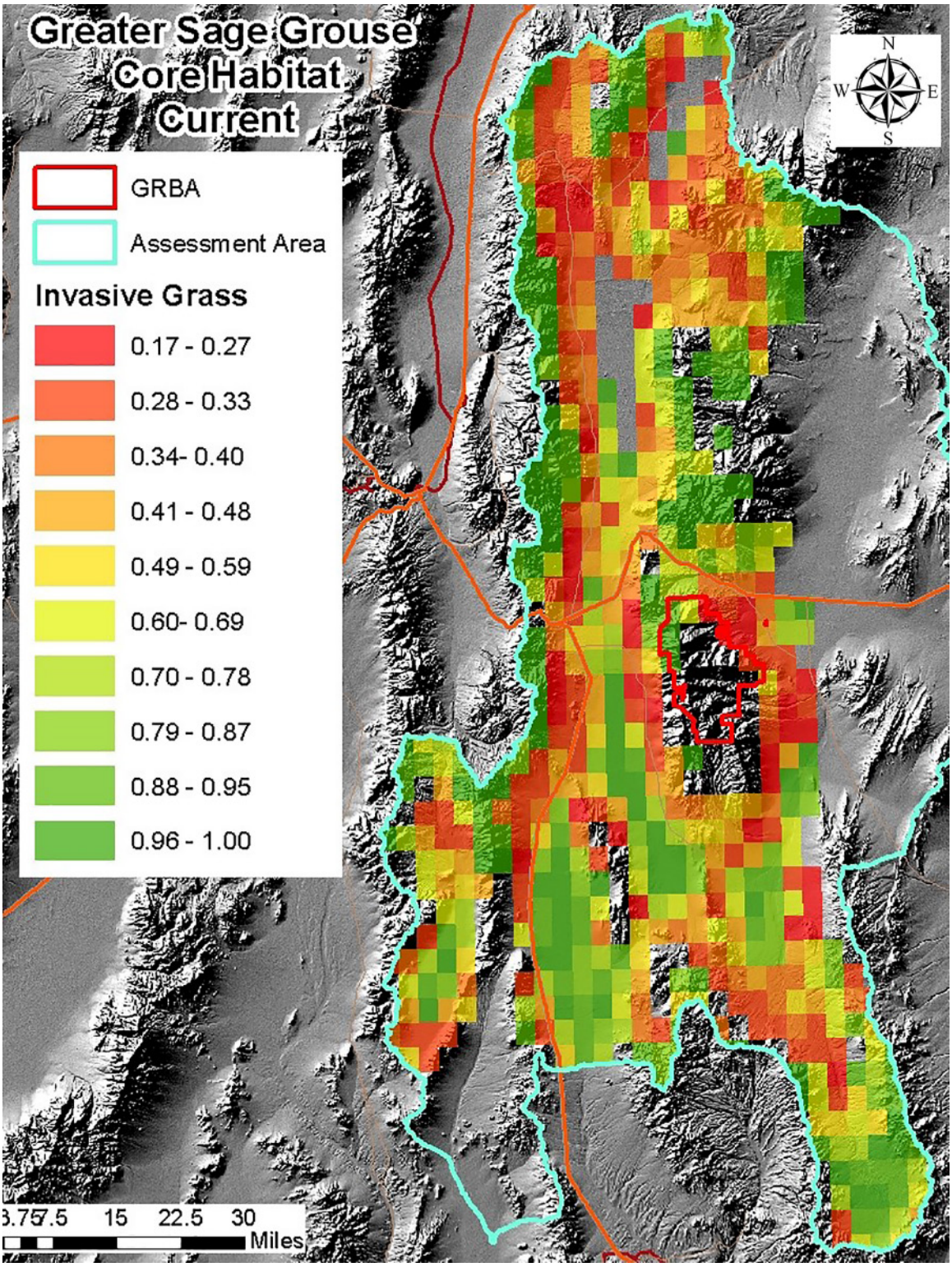

Figure D-43. Map showing the current invasive grass habitat in the Great Basin.

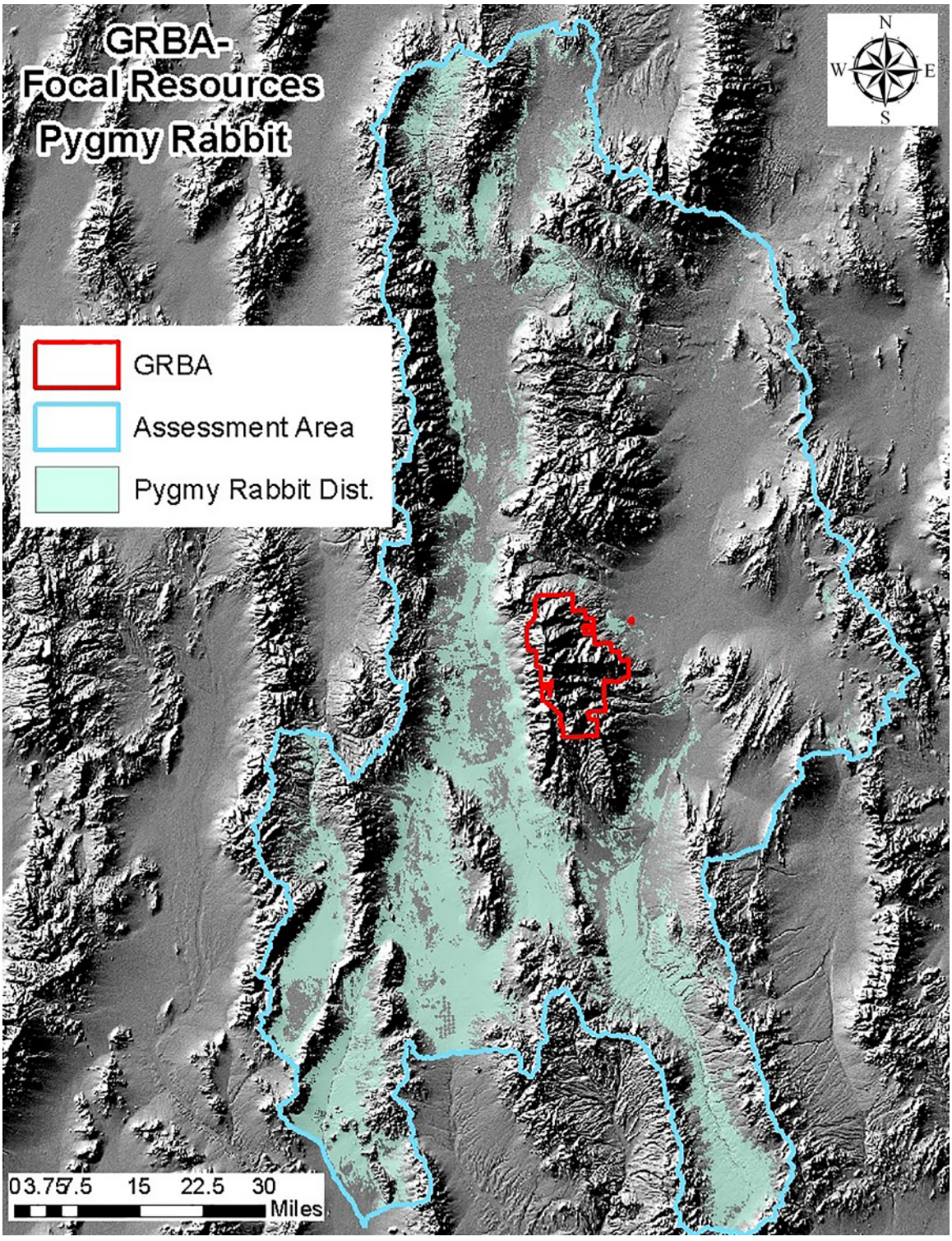

Figure D-44. Map showing the pygmy rabbit distribution in the Great Basin.

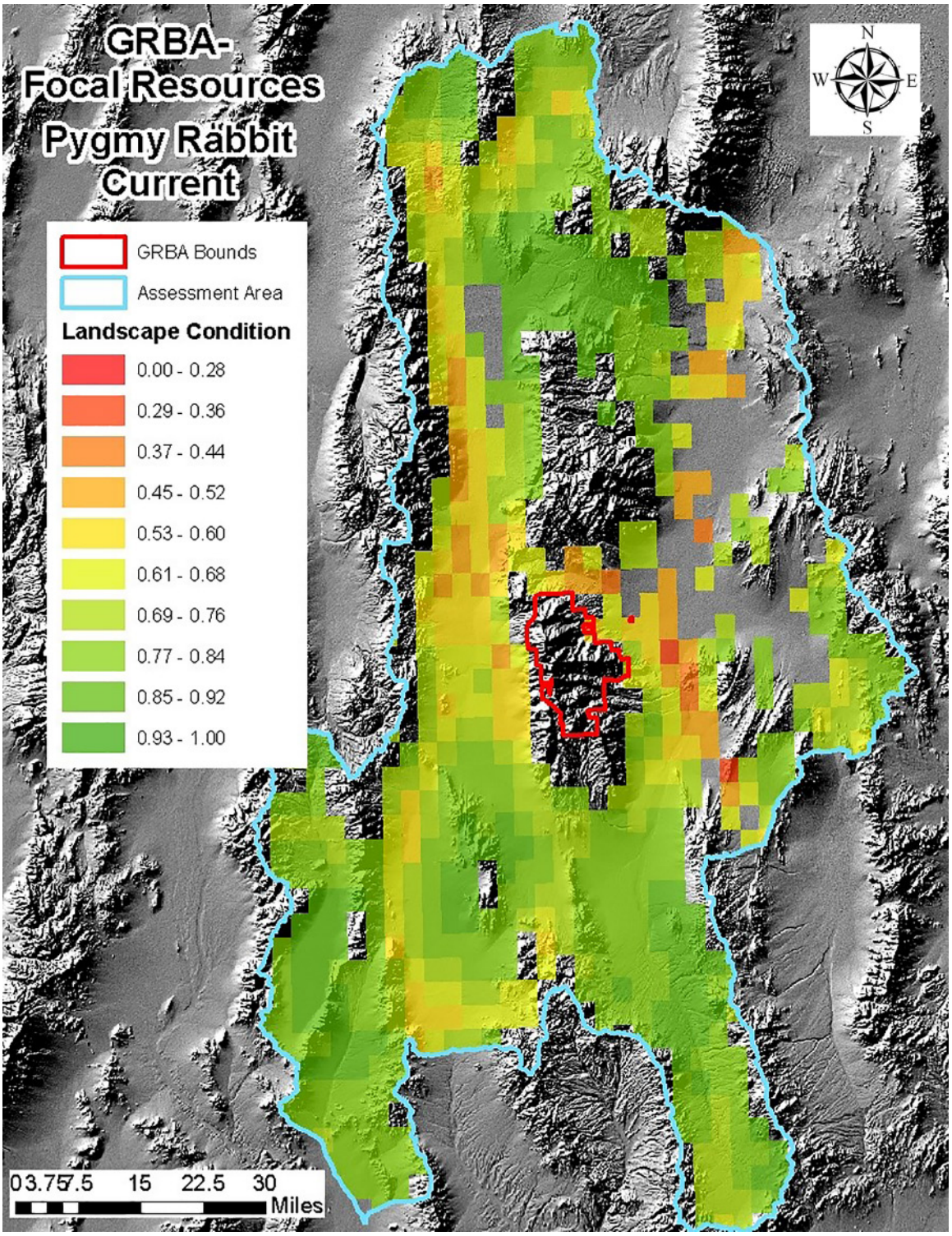

Figure D-45. Map showing the current landscape condition for pygmy rabbit in the Great Basin.

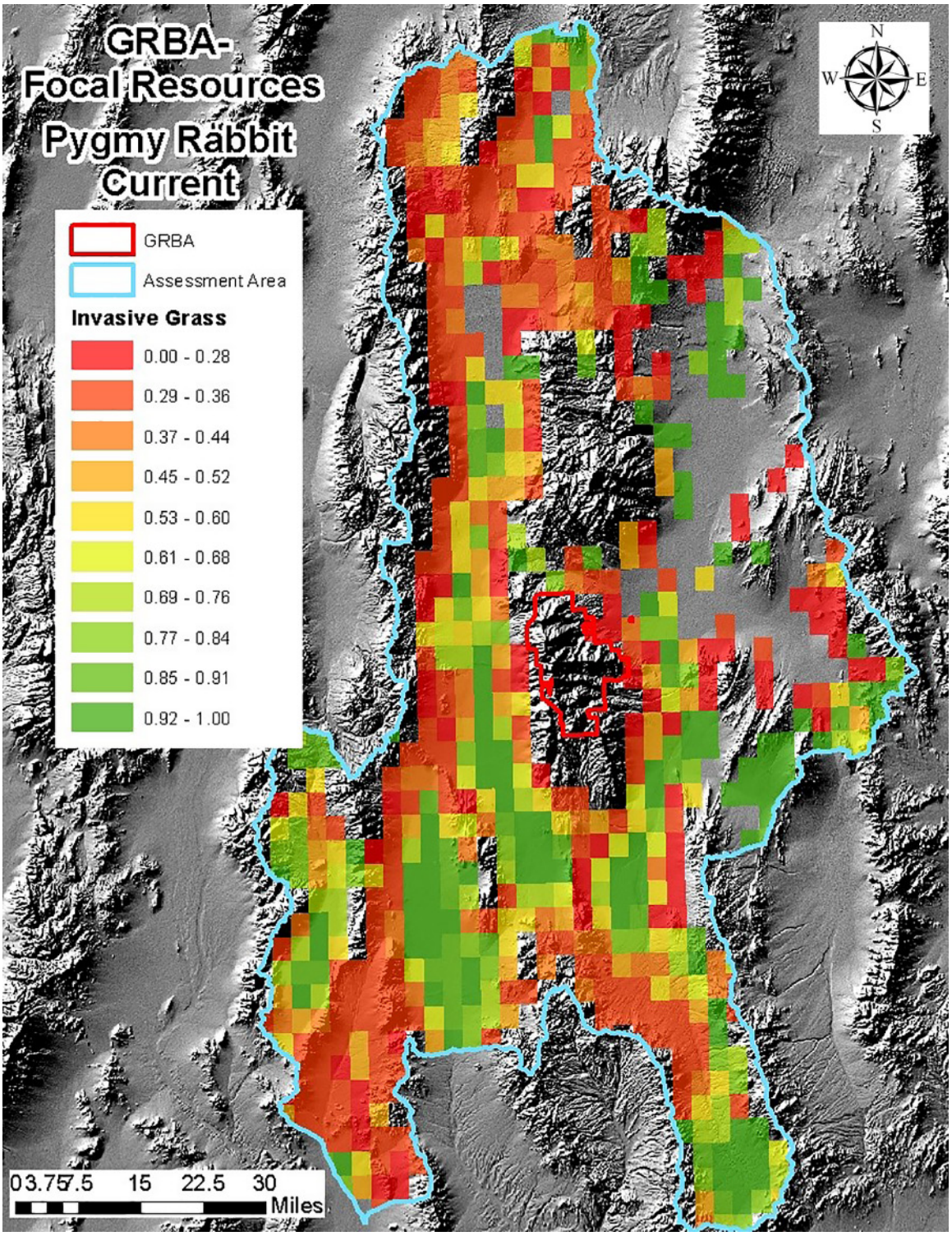

Figure D-46. Map showing the current invasive grass index for pygmy rabbit in the Great Basin.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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