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Wyoming Basin Rapid Ecoregional Assessment Work Plan

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Executive Summary

The overall goal of the Rapid Ecoregional Assessments (REAs) being conducted for the Bureau of Land Management (BLM) is to provide information that supports regional planning and analysis for the management of ecological resources. The REA provides an assessment of baseline ecological conditions, an evaluation of current risks from drivers of ecosystem change, and a predictive capacity for evaluating future risks. The REA also may be used for identifying priority areas for conservation or restoration and for assessing the cumulative effects of a variety of land uses. There are several components of the REAs. Management Questions (MQs), developed by the BLM and partners for the ecoregion, identify the information needed for addressing land-management responsibilities. Conservation Elements (CEs) represent regionally significant aquatic and terrestrial species and communities that are to be conserved and (or) restored. Coarse-filter CEs include ecological communities and ecosystems and Fine-filter CEs include plant and animal species or assemblages of similar species. For each CE, key ecological attributes will be evaluated to determine CE status. The REA also will evaluate major drivers of ecosystem change [Change Agents (CA)] currently affecting or likely to affect the status of CEs in the future. The relationships between CAs and key ecological attributes will be summarized using conceptual models. The REA process is a two-phase process. Phase I (pre-assessment) includes developing and finalizing the lists of priority MQs, CEs, and CAs, and culminates in the REA work plan, which defines the process that will be used for conducting the assessment. Phase II (assessment) comprises three tasks related to the compilation, documentation, and analyses of datasets to address MQs and complete the ecoregional assessment. The purpose of the work plan for the Wyoming Basin REA is to document the selection process for, and final list of, MQs, CEs, and CAs developed during Phase I. The work plan also presents the overall assessment framework that will be used to assess the status of CEs and answer MQs.

The Wyoming Basin Ecoregion encompasses approximately 133,656 km^2 and includes portions of Wyoming, Colorado, Utah, Idaho, and Montana. The Wyoming Basin has some of the highest quality wildlife habitats remaining in the Intermountain West. The wide variety of vegetation types includes intermountain basins dominated by sagebrush shrublands interspersed with deciduous and conifer woodlands and montane or subalpine forests. The Wyoming Basin also supports ranching and agricultural operations that are important to the region's economy and vital to conserving habitats for wildlife. Fast-paced development of the region's abundant energy resources, including large natural gas reserves and areas of high wind-energy potential, is resulting in notable land-use change, including habitat loss and fragmentation.

Four Core MQs for each CE were identified for the Wyoming Basin REA as follows.

1. What and where are the key ecological attributes?
2. What and where are the CAs?
3. Where do the CAs overlap with the key ecological attributes?
4. How do the CAs affect the key ecological attributes?

In addition, several Integrated MQ themes were identified as follows.

1. Where are the priority areas?
2. Where are the potential areas for conservation?
3. Where are the potential areas for restoration or development?

4. Where do the CAs pose the greatest threats?

We selected 8 major biomes to represent coarse-filter CEs and 19 species or species assemblages to be included as fine-filter CEs.

We will address the four primary CAs—development, fire, invasive species, and climate change—required for the REA. In addition, we will evaluate insect pests and disease for particular CEs. Although grazing and off-highway vehicles were identified as important land uses, we determined that the data are insufficient for evaluating them for the entire ecoregion; thus, they will not be evaluated in the region-wide assessment. Fire risk will not be included in an index or model for the fire CA because it cannot be assessed readily; however, we will compile available fire data. Because available data are insufficient for mapping existing invasive species distributions, we will provide risk maps for selected species by using available invasive species models. For our analysis of climate change, we will develop "Reasonably Foreseeable Climate Scenarios," which will be compared to the historical and paleo periods for the region.

The work plan describes a generalized approach for addressing Core MQs and for assessing CAs and the status of CEs. A standardized key ecological attribute table will be used to summarize the attributes, indicators or predictor variables, metrics or models, and sources of data that will be used to evaluate the status of each CE. We organized the ecological attributes into three classes: amount and distribution of the CE, landscape structure, and landscape dynamics. For each CE, we will summarize the relevant variables, metrics, and data sources used to quantify the potential effects of the CAs on the CE in a standardized CA table. We describe the approach for creating a region-wide development index that is designed to evaluate the cumulative effects of development on CEs, highlight the development index as a part of the methodology outlined in the assessment framework, and provide two examples of how the overall development index can be applied to a coarse-filter (sagebrush steppe biome) and a fine-filter [pygmy rabbit (*Brachylagus idahoensis*)] CE. This work plan will serve as the template for conducting the assessment in Phase II.

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We thank Bob Means, Bureau of Land Management (BLM) Project Coordinator for the Wyoming Basin Rapid Ecoregional Assessment (REA), and the Wyoming Basin REA Management and Technical Teams, and stakeholders for their guidance in the development of this work plan and other materials. Reviews of this work plan and other materials were provided by Sean Finn, Kimberlee Foster, Jill Frankforter, Steven Hanser, Susan Phillips, Karen Prentice, Douglas Shinneman, George Soehn, and James Wolf. Tammy Fancher, Aaron Freeman, Catherine Jarnevich, Daniel Manier, and Abra Ziegler provided assistance in developing maps or contributed information for the work plan.

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Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
	Length	
kilometer (km)	0.6214	mile (mi)
	Area	
hectare (ha)	2.471	acre
square kilometer (km^2)	247.1	acre
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:
°C=(°F-32)/1.8

Abbreviations

AIM Assessment, Inventory, and Monitoring Program
AMT Assessment Management Team
BLM Bureau of Land Management
CA Change Agent
CE Conservation Element
COOP National Oceanic and Atmospheric Administration's National Weather Service Cooperative Observer Program
EVT Existing vegetation type
FAA Federal Aviation Administration
FRA Federal Railroad Administration
GIS Geographic Information System
HUC Hydrologic unit class
LANDFIRE Landscape Fire and Resource Management Planning
LHS Land health standards
MAXENT Maximum entropy model
MQ Management question
NHD National Hydrography Dataset
NWI National Wetlands Inventory
OHV Off-highway vehicle
PRISM Parameter-elevation regressions on independent slopes model
REA Rapid Ecoregional Assessment
ReGAP Regional Gap Analysis Program
RFCS Reasonably Foreseeable Climate Scenarios
SNOTEL Snowpack telemetry
T&E Threatened and Endangered
TIGER Topological Integrated Geographic Encoding and Referencing
USGS U.S. Geological Survey
WYNDD Wyoming Natural Diversity Database

Wyoming Basin Rapid Ecoregional Assessment Work Plan

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Introduction: Bureau of Land Management Rapid Ecoregional Assessments

Purpose of the Rapid Ecoregional Assessment

The overall goal of the Rapid Ecoregional Assessments (REAs) undertaken by the Bureau of Land Management (BLM) is to provide information that facilitates development of ecoregion-based conservation strategies across jurisdictional boundaries and to facilitate planning and analysis for the management of ecological resources. The REA provides an assessment of ecological conditions, an evaluation of risk from Change Agents (CAs), a predictive capacity for evaluating future risks from CAs, baseline information for long-term monitoring of ecoregional conditions, and guidance for adaptation and mitigation planning in response to climate change. The REA also may be used for identifying priority areas for conservation or restoration of native plant and animal communities, for assessing cumulative impacts as required by the National Environmental Policy Act, and for informing landscape-scale planning and decision-making for all resources and uses of public lands. Overall, the REA provides a vehicle for creating stronger, more effective and efficient collaboration and cooperation among all parties interested in regional land and resource management.

The BLM established the overall process and required components for the REA, which includes Management Questions (MQs), Conservation Elements (CEs; these are ecological resources of concern), and CAs for each ecoregion. Within these overall guidelines, however, there is flexibility to tailor the REA to the specific information priorities for a given ecoregion. We first provide an overview of the general REA guidelines. Sections that follow discuss the specific details pertaining to the Wyoming Basin REA.

Overview of the Rapid Ecoregional Assessment Process

An REA entails a two-phase process (table 1). Phase I (pre-assessment) comprises four tasks that culminate in a work plan for the REA. In Phase I, the lists of priority MQs, CEs, and CAs are developed and finalized. Phase I also includes the development of conceptual models that highlight important ecological attributes and functions, the identification of analytical approaches for the assessment, preliminary screening of datasets for use in the assessment, preliminary analyses, and the development of the REA work plan, which describes the assessment process. Phase II (assessment) comprises three

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[6] Cherokee Services Group, contracted to U.S. Geological Survey, Fort Collins, Colo.

tasks related to the compilation, documentation, and analyses of datasets to address MQs and complete the ecoregional assessment.

Table 1. Overview of Phase I (pre-assessment) and Phase II (assessment) tasks for the Rapid Ecoregional Assessment (REA).

Phase	Task	Task description
I. Pre-assessment	1	Refine Management Questions; select Conservation Elements and Change Agents; develop overall ecosystem conceptual model.
	2	Identify key ecological attributes and indicators for Conservation Elements; Identify potential methods, models, and tools to quantify attributes and indicators.
	3	Develop conceptual models for Conservation Elements; Identify existing data and conduct initial data screening and preliminary analyses.
	4	Prepare work plan.
II. Assessment	5	Compile and generate source datasets.
	6	Conduct analyses and generate findings.
	7	Prepare final REA report and documents.

Assessment Management Team

The Assessment Management Team (AMT) consists of BLM managers, partner agencies, and technical specialists representing the ecoregion. For the scientists conducting the REA, the AMT provides guidance during AMT workshops and webinars and it provides feedback on interim reports, the work plan, and the final report. The AMT is also responsible for ensuring that management priorities are identified and incorporated into the REA.

Rapid Ecoregional Assessment Products

The purpose of the work plan is to document the selection process for, and final list of, MQs, CEs, and CAs developed during Phase I (although the lists may be updated based on analysis conducted during Phase II). The work plan also presents the overall assessment framework that will be used to determine the status of CEs and answer MQs. The assessment framework describes the overall approach and includes templates for conceptual models and formats for organizing and documenting the data sources and methods, which will be refined and applied in Phase II. To demonstrate how the assessment framework will be applied, the work plan also provides examples of methods, preliminary results, and potential products.

At the end of Phase II, a final REA report is published. The final REA report expands upon the work plan to document specific methods, results, and conclusions relating to MQs, CEs, and CAs. All source and derived datasets are to be provided to the BLM following the guidelines established in the REA Statement of Work.

Components of the Rapid Ecoregional Assessment

The major components of an REA include MQs, CEs, and CAs (table 2). These components are described in detail in the sections that follow. Also crucial to the REA process is the development of conceptual models, which guide the selection of key ecological attributes to be evaluated in the REA.

Table 2. Major Components of the Rapid Ecoregional Assessment[1].

Term	Definition or description
Management Questions	Priority information needs regarding ecological resources and change agents. Management Questions address land-management responsibilities and will guide the assessment process and ensure that the most relevant datasets are compiled, analyzed, and summarized.
Change Agents	Primary factors currently affecting or likely to affect the status of Conservation Elements.
Conservation Elements	A limited number of species, species assemblages, and ecological communities or ecosystems that represent critical components of ecosystems.
Coarse-filter Conservation Elements	Aquatic and terrestrial communities or ecosystems that comprise the ecoregion and are presumed to represent the habitat requirements of most plant and animal species of the ecoregion.
Fine-filter Conservation Elements	Regionally significant species or species assemblages, including sensitive or specialized species, that are not represented adequately by coarse-filter Conservation Elements.
Key ecological attributes	Characteristics of Conservation Elements that are especially crucial and affect long-term persistence or viability of the Conservation Element or associated species.
Indicators or metrics	Measurable variables used to assess the status and condition of key ecological attributes.
Index of Ecological Integrity	A complementary, integrated suite of Conservation Elements that collectively represent important ecological components of an ecosystem.

[1]Adapted from the Rapid Ecoregional Assessment Statement of Work, and from Parrish and others (2003).

Management Questions

Management Questions, developed by the AMT for the ecoregion, identify the information needed for addressing land-management responsibilities, including land-use planning, developing best-management practices, authorizing uses, and establishing priorities for conservation and restoration. MQs help to focus the REA process and ensure that the most relevant datasets are compiled, analyzed, and summarized. The MQs may pertain to ecological resources and CAs. Ecological resources include native terrestrial and aquatic species and communities of regional significance. CAs are ecological processes or human activities that influence the current status of resources and may pose future risks to those resources.

Conservation Elements

Conservation Elements (table 2) represent regionally significant aquatic and terrestrial species and communities that are of management concern. The initial proposed set of CEs (appendix table 1-1) was reduced to a limited suite of CEs for which current status and potential for change will be assessed (table 2). There are two CE categories.

Coarse-filter Conservation Elements

Coarse-filter CEs include terrestrial and aquatic ecological communities (table 2). The emphasis on conserving coarse-filter CEs is based on the premise that intact and functioning systems are more resistant and resilient to stressors (Noss, 1987; Poiani and others, 2000). Because it is not feasible to manage or monitor all species individually, the coarse-filter approach assumes that the protection of intact and functioning systems will serve as a safety net for most species.

Fine-filter Conservation Elements

Fine-filter CEs are plants, animals, and other organisms to be evaluated, and they may be single species, assemblages of taxonomically similar species (for example, five-needle pine assemblage), or species that use similar resources (for example, cold-water fishes). Fine-filter CEs highlight rare or specialized species that likely would not be assessed adequately by the coarse filters (Poiani and others, 2000), either because these species require localized habitats or are already at risk and require active, targeted management to prevent further declines in their populations. Typically, fine-filter CEs are species with special status, including declining, endemic, rare, sensitive, or area-sensitive species [for example, pygmy rabbit (*Brachylagus idahoensis*); table 2].

Key Ecological Attributes

For each CE, we will identify key ecological attributes (such as landscape structure) to be evaluated as part of the REA. The process of selecting the key ecological attributes will be informed by conceptual models, data availability, and relevance to the MQs. Indicator variables and metrics will be developed to quantify the key ecological attributes for use in evaluating CE status.

Change Agents

The REA will identify and assess primary factors (Change Agents) that currently affect or are likely to affect the status of CEs for two future points in time (2025 and 2060). Additional time frames may be included in the assessment, as appropriate. Criteria for including CAs in the REA are as follows.

- The CAs are major drivers of ecosystem change. For each CE, a limited suite of the most pertinent drivers of change are identified and evaluated. The CAs can be either anthropogenic in origin (for example, energy development or invasive species) or natural drivers, which can be altered directly or indirectly by human activities (for example, climate, fire, or insect outbreaks).
- Existing or derived data are sufficient to quantify CAs for the entire REA.
- The CAs to be evaluated for the entire ecoregion minimally will include
    1. development (for example, urban, energy, roads, or dams),
    2. wildland fire,
    3. invasive species, and
    4. climate change.

Conceptual Models

Conceptual models are useful for describing and visualizing ecosystem components and their interactions based on the current understanding of cause and effect relationships (Manley and others, 2000). The conceptual models will be used to highlight the key ecological attributes and CAs addressed by the REA, as well as the pathways of CA influence. Although generally hypothetical, conceptual models can help to organize thinking about ecosystem integrity and to develop approaches for studying, monitoring, and managing ecosystem functions. Another important purpose of conceptual models is to make transparent the assumptions that are made when assessing potential effects of CAs on CEs.

Wyoming Basin Ecoregional Assessment

Background on the Wyoming Basin Ecoregion

The Wyoming Basin Ecoregion (hereafter, “the Wyoming Basin”) encompasses 133,656 km^2, most of which is in Wyoming, with small extensions into northwestern Colorado, northeastern Utah, southeastern Idaho, and south-central Montana (fig. 1). The Wyoming Basin REA project area, however, extends beyond the Wyoming Basin because it includes the entire area of all 5th-level Hydrologic Unit Class (HUC) watersheds that intersect the Wyoming Basin perimeter (appendix fig. 1-1). The Wyoming Basin project area overlaps the jurisdiction of all or parts of 17 BLM Field Offices (9 in Wyoming, 4 in Colorado, 2 in Utah, and 1 each in Idaho and Montana), 2 Fish and Wildlife Service Regions (9 National Fish and Wildlife refuges), 3 U.S. Department of Agriculture Forest Service regions (12 National Forests), 2 National Park Service regions (3 National Parks and Monuments), and tribal lands (2 Indian Reservations), as well as the state agencies that represent and manage wildlife, natural resources, and parks (appendix fig. 1-2, tables 1-2 and 1-3). The adjacent ecoregions are predominantly mountainous to the north, west, and south, and grassland to the east (appendix fig. 1-1).

The Wyoming Basin has some of the highest-quality wildlife habitats remaining in the Intermountain West (Sawyer and others, 2005). The wide variety of vegetation types include intermountain basins dominated by sagebrush (*Artemisia* spp.), greasewood (*Sarcobatus vermiculatus*), and saltbush (*Atriplex* spp.) shrublands; foothill shrublands that flank the adjacent high mountains and are dominated by montane sagebrush steppe interspersed with deciduous and conifer woodlands; montane and subalpine forests dominated by conifer and aspen (*Populus tremuloides*); and flowing and ponded surface waters and their attendant riparian habitats scattered throughout (Knight, 1994). Sagebrush steppe is the dominant ecosystem, covering more than 50 percent of the landscape. In contrast, aspen, limber pine (*Pinus flexilis*) (and other five-needle pine species), mixed desert shrublands, grasslands, mountain shrub, and riparian communities each cover less than 10 percent of the Wyoming Basin; nonetheless, they provide many important ecological functions.

Overall, the Wyoming Basin’s diverse ecological communities support dozens of nongame species of conservation concern, as designated by the states of Wyoming, Montana, Idaho, Utah, and Colorado. The Wyoming Basin also supports some of the largest U.S. populations of game species, including pronghorn (*Antilocarpa americana*), mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), moose (*Alces alces*), and bighorn sheep (*Ovis canadensis*), as well as the greatest densities of greater sage-grouse (*Centrocercus urophasianus*) within the species’ range, and several subspecies of cutthroat trout (*Onchorhynchus clarki* ssp.) and other species of native and sport fish (Wyoming Game and Fish Department, 2010; Rowland and Leu, 2011).

Figure 1. The Wyoming Basin Rapid Ecoregional Assessment project area. Bureau of Land Management Field Office boundaries intersecting the project area are shown.

The Wyoming Basin's vast open spaces also support ranching and agricultural operations that are important to the region's economy and vital for conserving essential seasonal habitats and migration corridors for wildlife. Some of the Nation's most sought-after outdoor recreation opportunities are found in this region, which helps to ensure the long-term economic stability in many local communities. In addition, hunting leases and conservation easements on private lands help promote the conservation of wildlife resources.

The Wyoming Basin also contains abundant energy resources, including some of the largest natural gas reserves in the lower 48 States (U.S. Departments of the Interior, Agriculture, and Energy, 2003). Some of the best wind-energy potential on publicly managed lands in the United States is in the Wyoming Basin (Bureau of Land Management and U.S. Energy Efficiency and Renewable Energy, 2003). Consequently, the region has become a major focus of renewable energy development. Although the Wyoming Basin has long been a provider of the Nation's energy, the recent and projected pace of both renewable and non-renewable energy development is unprecedented in the Basin's history.

Combined with increased residential and industrial development, fast-paced energy development is resulting in notable habitat loss and degradation, including habitat fragmentation due to road construction, increased traffic, drilling rigs and well pads, service units, pipelines, wind turbines, power lines, fencing, water pits, water wells, increased human activity, and dust, among other impacts (Sawyer and others, 2006). Given the large proportion of publicly owned lands (appendix fig. 1-2, table 1-3), decisions regarding current and future land-use management, conservation, restoration, and mitigation efforts on public lands in the Wyoming Basin have the potential to significantly affect regional ecological resources [see Hanser and others (2011) for additional background information on the Wyoming Basin].

Management Questions

A set of MQs was developed by the Wyoming Basin AMT. We organized the MQs into two groups: Core MQs and Integrated MQs (appendix tables 1-4 and 1-5). Core MQs apply to each CE, whereas Integrated MQs address multiple Core MQs or several CEs and CAs.

Core Management Questions

- What and where are the key ecological attributes?
- What and where are the CAs?
- Where do the CAs overlap with the key ecological attributes?
- How do the CAs affect the key ecological attributes?

All Core MQs will be applied to each CE to evaluate its status and the potential threats posed by CAs. Core MQs also may be used to evaluate the individual and cumulative effects of CAs for the entire ecoregion.

Integrated Management Questions

- Where are the priority areas (including rare, unique, and crucial habitats or species)?
- Where are the potential areas for conservation?
- Where are the potential areas for restoration or development?
- Where do the CAs pose the greatest threats?

Conservation Elements

Coarse-Filter Conservation Elements

After considering several alternative vegetation classification systems, we selected eight major biomes to represent coarse-filter CEs (table 3, fig. 2). We define biomes as the dominant plant and aquatic communities and life forms (for example, shrublands, woodlands, and forests). We selected these biomes for the several reasons. First, many of the vegetation types form complex spatial mosaics that result in very heterogeneous distributions, which would make it extremely difficult to assess each of those types separately. Because the coarse-filter approach emphasizes landscape structure and function, it is more meaningful at the ecoregional scale to treat vegetation classes as a part of larger vegetation mosaics rather than defining the classes too narrowly. Second, the use of broader vegetation classes, like biomes, can reduce the misclassification prevalent in finer vegetation classifications [such as Existing Vegetation Types (EVT) in LANDFIRE (Landscape Fire and Resource Management Planning); The National Map LANDFIRE (2006)] and location errors because adjacent, similar vegetation types are pooled. Finally, the biome level is more appropriate for projecting potential shifts in vegetation communities that may result from particular future climate scenarios (Rehfeldt and others, 2012). Although the biome-level analysis does not address finer vegetation classes, these classes can be evaluated as fine-filter CEs if they meet the fine-filter selection criteria (see table 4).

Table 3. Biomes representing coarse-filter Conservation Elements for the Wyoming Basin Rapid Ecoregional Assessment.

System	Biomes	Percent of the Wyoming Basin project area[1]
Aquatic	Lakes and reservoirs	0.6
	Streams, rivers, and riparian	2.3
	Wetlands	1.0
Terrestrial	Sagebrush steppe	52.0
	Mixed desert shrublands	8.7
	Grasslands	7.2
	Foothill shrublands and woodlands	10.4
	Montane and subalpine forests and alpine system	13.4

[1] Developed and agriculture areas not included.

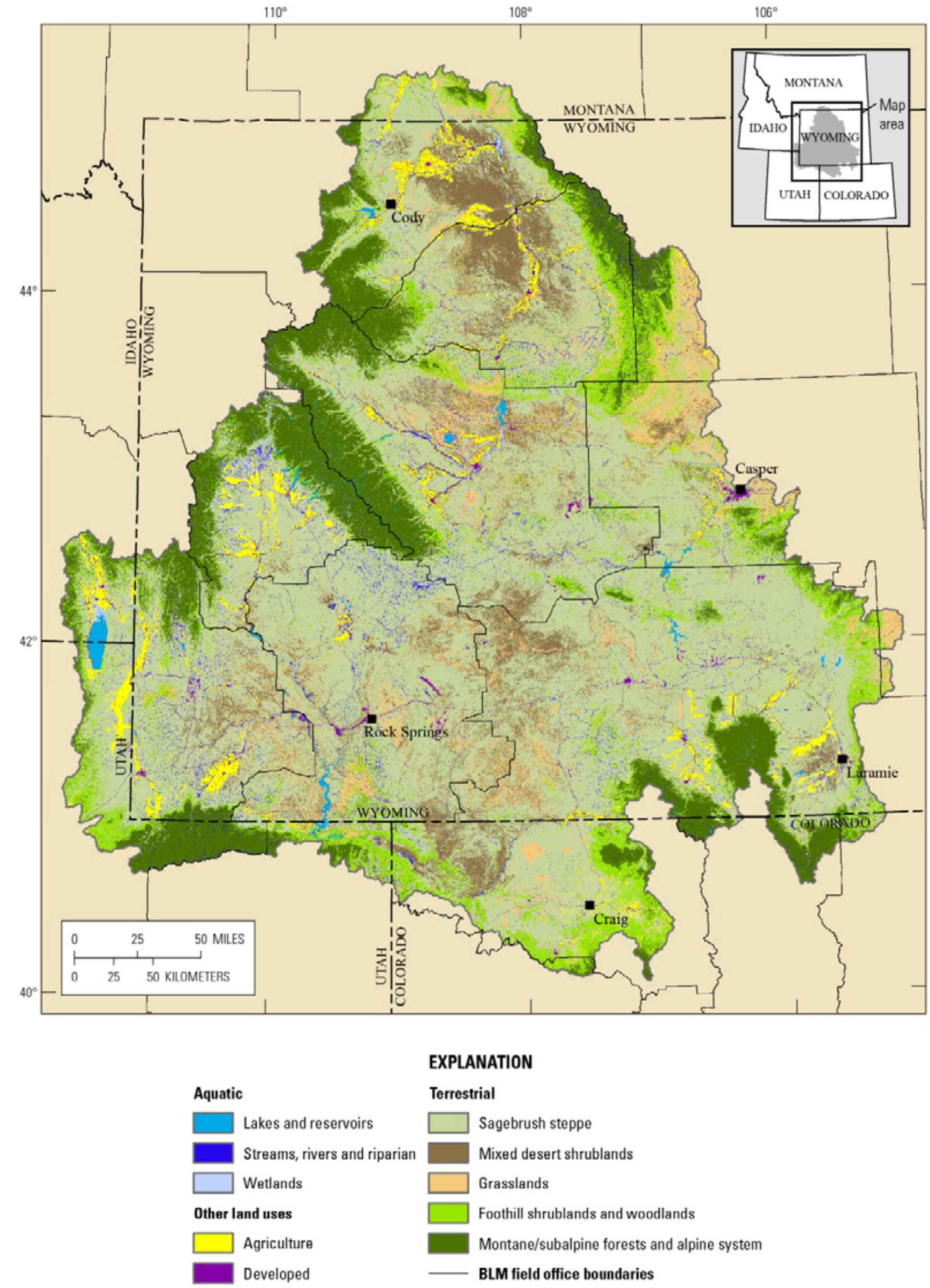

Figure 2. Distribution map for coarse-filter Conservation Elements (Biomes; see table 3) for the Wyoming Basin Rapid Ecoregional Assessment project area (BLM = Bureau of Land Management).

Table 4. Fine-filter Conservation Elements and their status for selection criteria II, IV, and V. Selection criteria I, and III were met by all species and assemblages.

Fine-filter species1	Selection Criteria[2] II	IV	V
	Management priority	BLM state sensitive species lists[3]	Commodity species[4]
Native cutthroat trout	High	All states	Yes
Cool-water fish assemblage (roundtail chub, flannelmouth and bluehead sucker)	High	WY, CO, UT	No
Northern leatherside chub	High	WY, ID, UT	No
Sauger	High	MT	Yes
Boreal toad	High	All states	No
Great Basin & plains spadefoots	Medium, High	WY, CO, MT	No
Greater sage-grouse	High	All states	Yes
Golden eagle	High	MT	No
Bald eagle	High	WY, CO, UT, MT	No
Ferruginous hawk	High	All states	No
Sagebrush-obligate songbirds	High	WY, CO, MT, ID	No
Pygmy rabbit	High	All states	No
Mule deer	High	None	Yes
Pronghorn	High	None	Yes
Elk	Medium	None	Yes
Aspen	High	None	No
5-needle pine assemblage (limber and whitebark pine)	High	WY, ID	No
Pinyon-juniper	High	None	No
Riparian	High	None	No

[1] The scientific names of the species listed are as follows: cutthroat trout (*Oncorhynchus clarkii* ssp.), roundtail chub (*Gila robusta*), flannelmouth and bluehead suckers (*Catostomus latipinnis* and *C. discobolus*, respectively), northern leatherside chub (*Snyderichthys copei*), sauger (*Sander canadensis*), boreal toad (*Anaxyrus boreas boreas*), Great Basin and plains spadefoots (*Spea intermontana* and *S. bombifrons*, respectively), greater sage-grouse (*Centrocercus urophasianus*), golden eagle (*Aquila chrysaetos*), bald eagle (*Haliaeetus leucocephalus*), ferruginous hawk (*Buteo regalis*), pygmy rabbit (*Brachylagus idahoensis*), mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), elk (*Cervus canadensis*), aspen (*Populus tremuloides*), limber and whitebark pines (*Pinus flexilis* and *P. albicaulis*, respectively), pinyon pine (*P. edulis*), and juniper (*Juniperus* spp.).

[2] See Fine-filter Conservation Element section above for descriptions of the Assessment Management Team selection criteria.

[3] WY = Wyoming, CO = Colorado, UT = Utah, ID = Idaho, MT = Montana.

[4] Game and furbearer species.

Fine-Filter Conservation Elements

A preliminary list of candidate CEs (table 4, appendix table 1–1) was developed by the BLM and the AMT. Subsequently, the preliminary CEs were evaluated by the AMT for inclusion in the REA based on the CE selection criteria that follow.

I. Regionally significant species or communities—occurrence throughout the jurisdiction of at least three BLM Field Offices, with an emphasis on widely distributed species; this criterion was developed to help meet the REA goal of ensuring that the REA is relevant to regional priority management issues (other management issues may be addressed by specific MQs).

II. Species directly tied to management priorities and issues.

III. Species not addressed adequately by coarse-filter CEs or other fine-filter CEs.

IV. Species of conservation concern or assemblages as determined by BLM and other state and federal agencies.

V. Commodity species (game or furbearer species; Knick and others, 2011).

To be included in the final list of CEs, species or assemblages needed to meet criteria I—III and meet either criteria IV or V. Initially, the AMT considered species with Federal Threatened and Endangered (T&E) status as a selection criterion, and considered including black-footed ferret (*Mustela nigripes*), gray wolf (*Canis lupus*), and grizzly bear (*Ursus arctos horribilis*) as CEs. Because status assessments for T&E species have been provided by the Fish and Wildlife Service, the AMT decided to include available data layers as needed for addressing specific MQs relevant to T&E species. T&E plants also were considered, but the AMT indicated that the data were insufficient for a status assessment at the ecoregional scale. Data layers will be compiled for T&E plants.

The final list of species and assemblages includes 19 species and species assemblages (table 4). Species initially recommended by the BLM that did not meet the selection criteria are listed in the Appendix (table 1–1). Additional species were compiled from BLM State lists of sensitive species to make sure that all sensitive species were considered for inclusion in the REA. Several sensitive species are still under consideration as CEs, although most remaining species from the BLM State lists either occur outside the ecoregion or do not meet the regionally significant criterion.

The final list of candidate coarse- and fine-filter CEs (tables 3, 4) will receive additional evaluation based on the criteria as follows.

1. There are sufficient, region-wide data available for the CE.
2. It is possible to measure or derive information from existing geospatial data for the CE.
3. The CE is sensitive to identified CAs.
4. There is a scientifically defensible basis for developing and evaluating a given set of key ecological attributes and indicators for the CE.
5. Selected CEs are complementary and integrative, whereby the full suite of CEs provides measures of diverse ecological resources identified as management priorities for the ecoregion.

Change Agents

We will address the four primary CAs required for the REA (development, fire, invasive species, and climate change). We also considered inclusion of several other CAs proposed by the AMT, including insect pests and disease, grazing, and off-highway vehicle (OHV) use. It is important to note that fire and climate (for example, drought) are inherent drivers of ecosystem dynamics in the Wyoming Basin, but the fire and climate regimes may be influenced by human activities (Rowland and Leu, 2011).

Conceptual Models

General Conceptual Model

We developed a general conceptual model to highlight the primary CAs, ecological systems, and CEs that will be evaluated as a part of the Wyoming Basin REA (fig. 3). The climate and physiography of the ecoregion limit where species and communities occur on the landscape, and influence the dynamics and spatial distribution of communities. Both natural and anthropogenic CAs alter the dynamics and spatial distribution of communities across the ecoregion. Feedback and interactions (such as competition, predation, flows of energy, and species movements) occur within and among terrestrial and aquatic systems, and between CEs and CAs (Miller, 2005).

The CEs selected for the Wyoming Basin REA include a broad array of species and communities and collectively represent many of the pressing ecological and management issues of the ecoregion (fig. 3). Because shrub-steppe (including sagebrush steppe, mixed desert shrublands, and grasslands) is the dominant system in the ecoregion (table 3, fig. 2), and because development activities are prevalent in this biome, there is an inevitable emphasis on species that occur in the shrub-steppe system. Several fine-filter CEs, such as mule deer (*Odocoileus hemionus*) and golden eagle (*Aquila chrysaetos*), have more generalized habitat requirements; some use both terrestrial and aquatic systems, such as the boreal toad (*Anaxyrus boreas boreas*) and bald eagle (*Haliaeetus leucocephalus*); and others, such as sagebrush-obligate bird species, have more specialized habitat requirements.

Conservation Element Conceptual Models

In addition to the general conceptual model, we will create two types of conceptual models for each CE. A simplified model (fig. 4) will provide an overview of the major CAs and key ecological attributes to be evaluated for the REA. More detailed conceptual models, such as state-and-transition models (fig. 5), will be developed to identify a comprehensive set of key ecological attributes and CAs that are important in assessing CE status (Knapp and others, 2011). These more complex models also will identify variables best addressed in local assessments, as well as data gaps.

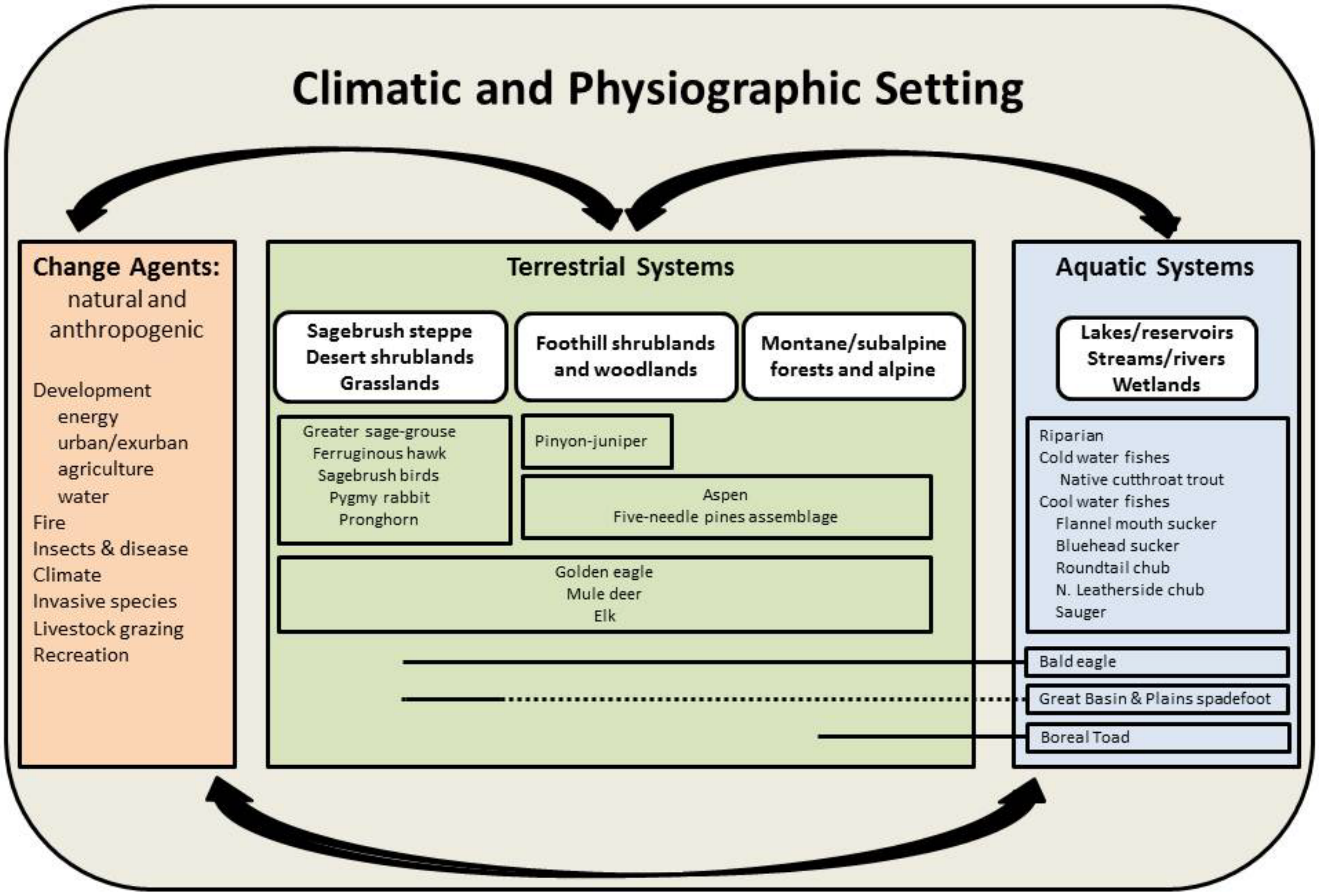

Figure 3. General conceptual model for the Wyoming Basin Ecoregion, representing primary components of the Rapid Ecoregional Assessment (indicated by colored boxes). Coarse-filter Conservation Elements (CE) are shown in the white boxes. Fine-filter CEs are shown in green (terrestrial) and blue (aquatic) boxes. For several wildlife species that are strongly tied to aquatic systems, but which use adjacent terrestrial systems, horizontal lines are placed under the terrestrial systems also used by that species (for the spadefoot species, dashes in the line indicate that the systems above the dashes are excluded). The arrows represent the direction of influence and feedback among the ecosystem components. Livestock grazing and off-highway vehicles lack sufficient data to evaluate regionally for this ecoregion.

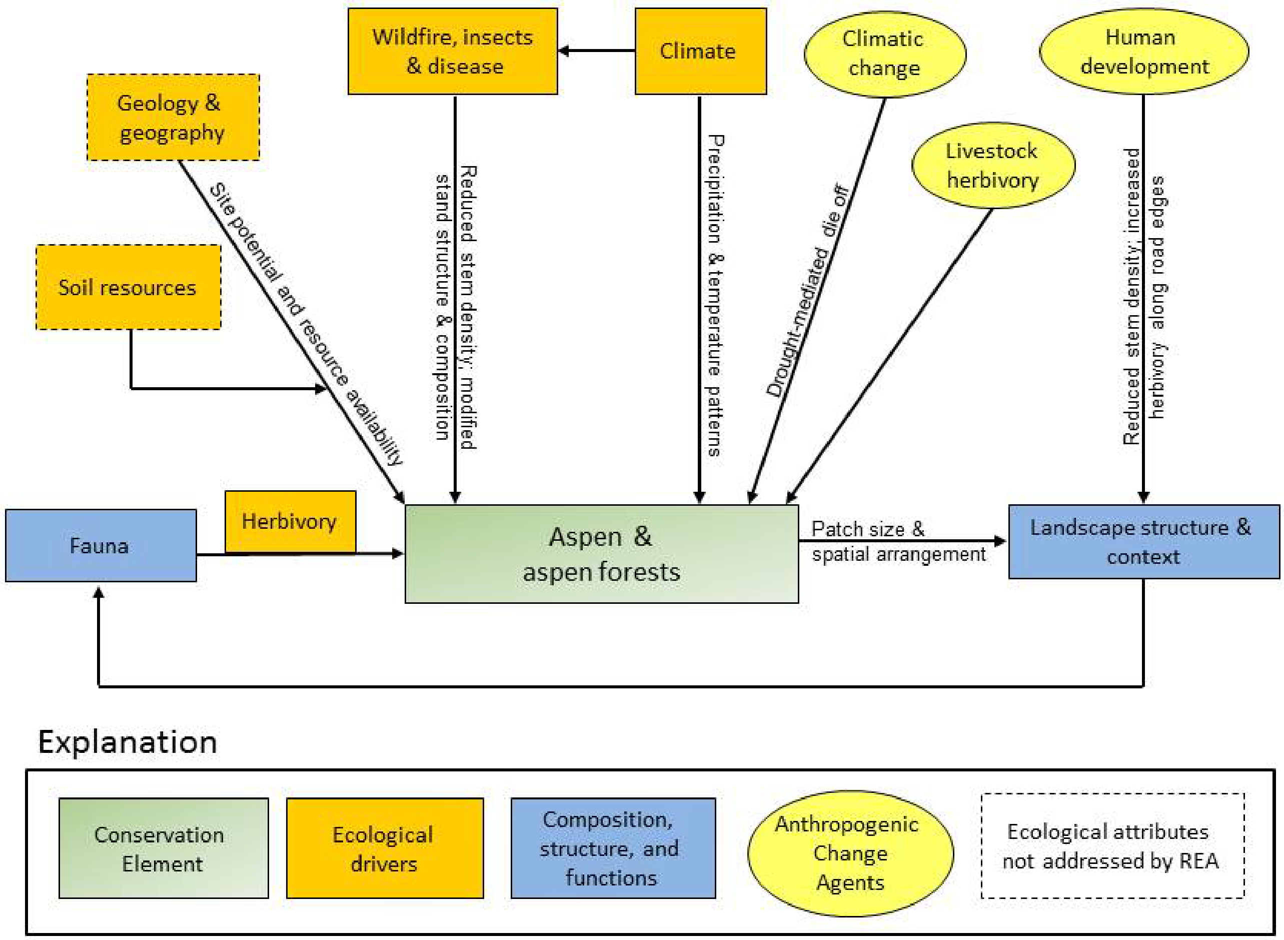

Figure 4. Generalized conceptual model for aspen forests. Key ecological attributes include the biophysical attributes, ecological processes, and landscape composition, structure, and functions. Biophysical attributes and ecological processes that regulate the occurrence and dynamics of aspen are shown in orange boxes, associated fauna and landscape structural components are shown in blue boxes, and anthropogenic Change Agents are shown in yellow ovals. Climate change resulting from anthropogenic effects as projected by climate models (represented by yellow oval) will be evaluated relative to past climate variability.

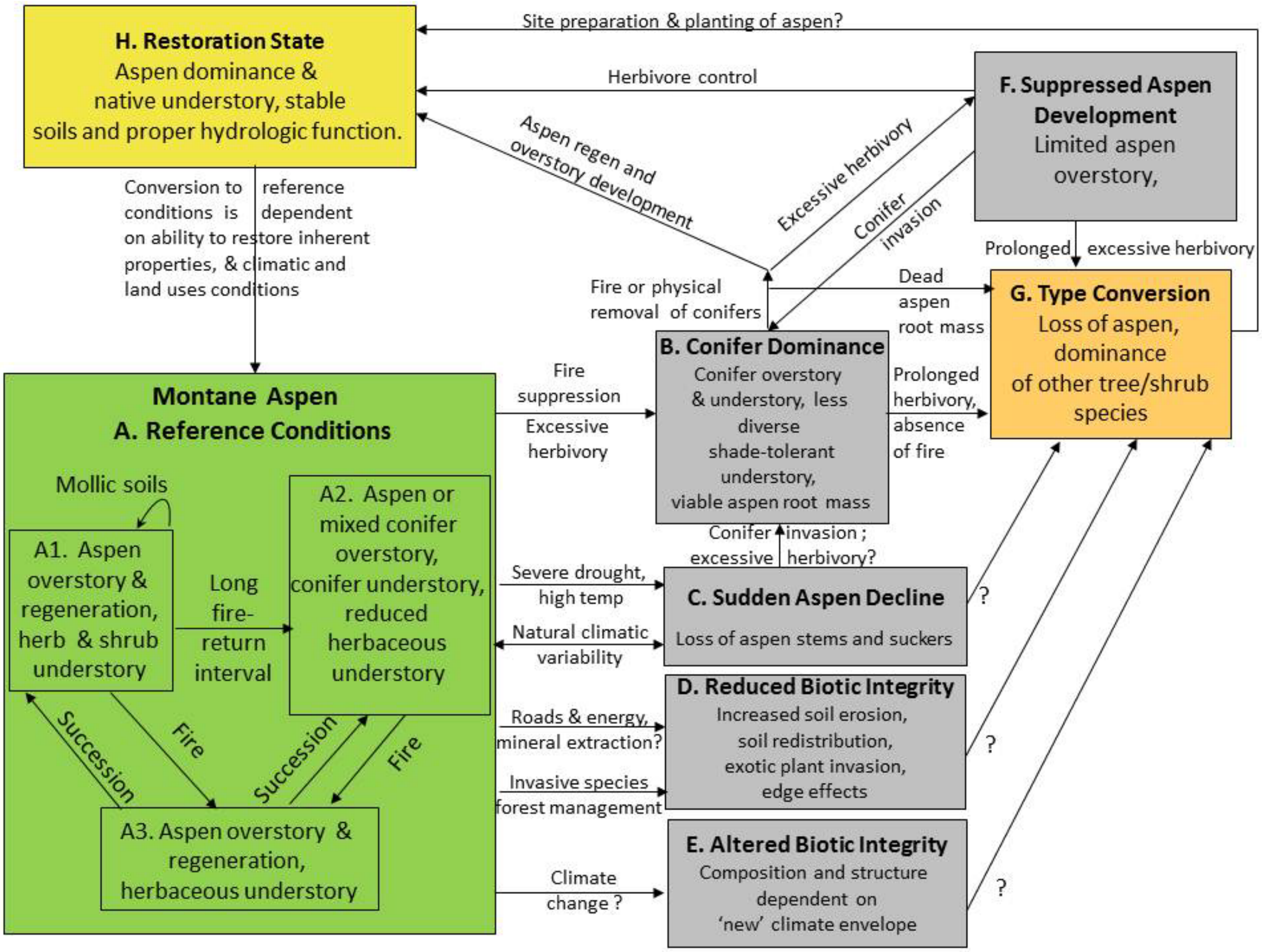

Figure 5. State-and-transition model for montane forest aspen. Colored boxes represent different states that result from various possible pathways and processes, represented by arrows. The green box represents historical or natural dynamics; the grey boxes represent transitional conditions that have some chance of reverting back to historical conditions; the orange box represents highly altered conditions; and the yellow box represents the transition back to historical conditions. Pathways and processes labeled with a "?" are speculative.

Framework for the Wyoming Basin Rapid Ecoregional Assessment

Overview of Assessment Framework

We have developed a generalized approach (fig. 6) for addressing Core MQs and for assessing CAs and the status of CEs identified by the Wyoming Basin AMT. The assessment framework is organized by Core and Integrated MQs. Here we provide an overview of the assessment framework and associated methods.

Initial Data Compilation and Processing

In 2012, we began compiling available datasets for the project area and assessing the quality of the data and metadata. To manage the geographic information system (GIS) data obtained for the REA, we developed an Access database, which allows users to track and search the data by themes, including CEs, CAs, and the data source. This database includes user-friendly forms for viewing, entering, and accessing data and ensures that data-processing protocols and standards are achieved and will facilitate access to datasets by end users. Datasets will be finalized during Phase II.

Core Management Questions and Associated Reporting Maps

For each CE, all Core MQs will be evaluated as outlined in the sections that follow.

What and Where are the Key Ecological Attributes?

A standardized key ecological attribute table (table 5) will be used to summarize the attributes, indicators or predictor variables, metrics or models, and data sources that will be used to evaluate the status of each CE. We organized the ecological attributes into three classes: amount and distribution of habitat or biogeophysical variables, landscape structure, and landscape dynamics. For all biomes and plant CEs, we will evaluate all three classes of ecological attributes. For vertebrate fine-filter CEs, biome-level information on landscape dynamics will be incorporated into our assessment of habitat dynamics as appropriate. The resolution of source and derived data, as well as the scale of analysis and reporting units, will be documented for each indicator or predictor variable.

We will create distribution maps for each biome and plant CE based on existing regional vegetation maps [such as LANDFIRE, ReGAP, and Rehfeldt and others (2009, 2012)]. To create distribution maps for each vertebrate CE, we will use or modify existing habitat models [for example, Wyoming Natural Diversity Database (WYNDD) species occurrence maps] or develop new species occurrence models if there are sufficient data and if existing models are not adequate for the REA. All of the distribution maps represent current distributions and will be used as a baseline for evaluating the effects of CAs. However, “baseline” will include some effects of CAs that preceded the imagery used for creating the dataset. We will use the distribution maps to quantify the amount and spatial distribution of each CE under baseline conditions. To accomplish this, we will use metrics relating to landscape pattern [for example, patch size, connectivity; Noss (1990)]. In addition to the distribution maps, we will generate maps and graphs that summarize metrics used to quantify relevant spatial patterns for each CE. For some CEs, specific components of habitat may also be mapped such as crucial wintering areas for mule deer or brood-rearing areas for greater sage-grouse.

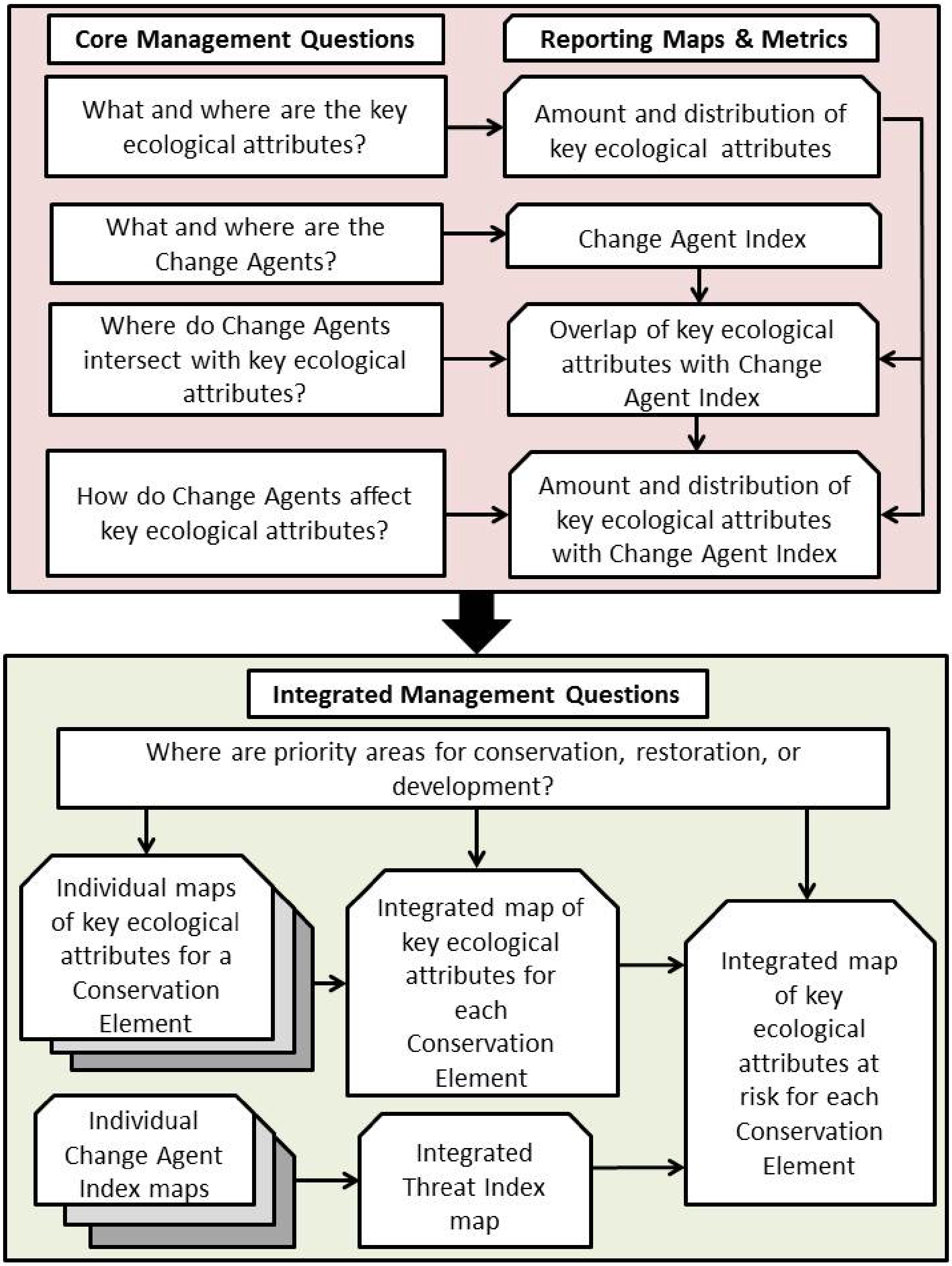

Figure 6. Generalized framework and approach for assessing the status of Conservation Elements and addressing Core and Integrated Management Questions (MQs). Rectangles represent MQs and trapezoids represent examples of map products. Reporting maps will include source data at their native resolution (for example, 90 m^2), and key ecological attributes and Change Agents will be summarized at the appropriate analysis scales (for example, 16 km^2). Overall status assessment maps will be summarized at the required reporting scale [5th-level Hydrologic Unit Code (HUC); see appendix fig. 1-1]. Additional reporting scales may be provided.

Table 5. Key ecological attribute table that summarizes the attributes, indicators, metrics, and data sources for assessing the status of each Conservation Element. The attribute column reflects the three classes of key ecological attributes to be evaluated for each coarse-filter and fine-filter Conservation Element. Examples of possible indicator variables, metrics or models, and data sources are provided.

Attribute	Indicator or predictor variables	Metrics and models	Data source[2]
Amount & distribution	Habitat or biogeophysical variables: soils, topography, climate, water availability, vegetation structure and composition	MAXENT[1], logistic regression, area per analysis unit	LANDFIRE or ReGAP, NWI, NHD, WYNDD, occurrence data
Landscape structure	Patch size, connectivity, edge effects	Spatial statistics	Conservation Element distribution map
Landscape dynamics	Climate regime, disturbance regime, hydroperiod, flow regime	Current temperature and precipitation, recent fire and bark beetle occurrence maps, mean stream flow and variability	Conservation Element distribution map, PRISM climate data

[1] MAXENT, Maximum Entropy.
[2] LANDFIRE = Landscape Fire and Resource Management Planning, ReGAP = Regional Gap Analysis Program, NWI = National Wetlands Inventory, NHD = National Hydrography Dataset, WYNDD = Wyoming Natural Diversity Database, and PRISM = Parameter-Elevation Regression on Independent Slopes Model.

What and Where Are the Change Agents?

For each CE, we will identify relevant CAs to be evaluated based on conceptual models, availability of data, and relevance to the MQs. Species sensitivity to CAs will be based on available information in the literature. A standardized CA table (table 6) will be used to summarize the relevant variables and metrics for quantifying each variable, and the data sources for quantifying the potential effects of the CA on the CE. The resolution of source and derived datasets, as well as the scale of analysis and reporting units, will be documented for each metric. Variables will be quantified using metrics or models and subsequently compiled into an overall CA index. Similar CA variables (such as roads and railroads) may be organized into classes (such as transportation) to address MQs. This flexible organization will allow us to map and summarize various components of each CA.

We will develop an overall index or model for each CA. These indices will be used to evaluate the relative magnitude of influence or risk for each CA across the entire project area. Core MQs and the region-wide assessment of CAs can be used to address several of the Integrated MQs (such as, “Where are the relatively undeveloped areas?”).

Where Do the Change Agents Intersect with the Key Ecological Attributes?

We will evaluate this Core MQ in two ways. First, each CE distribution map will be overlaid by the overall CA index or risk model described in the paragraph above. The overall index/model for each CA provides a standardized approach for comparing the influence of CAs on each CE. Second, because the sensitivity to CAs varies among species, we will adapt the overall CA models for each fine-filter CE (because biomes address assemblages of species, only the overall CA index will be used to evaluate biomes). To adapt the CA models for each CE, we will address the MQ: “What is the relative influence of CA variables (such as oil and gas wells or secondary roads) for each CE?” The results of this evaluation will be used to focus subsequent analyses on the most relevant CAs and associated variables for each CE. Published information on the specific effects of CAs on a given CE will be used to modify the overall CA model for that CE (hereafter "species-specific CA index'). For example, information on avoidance of roads by a particular species could be used to develop metrics for evaluating the disturbance effects from vehicle traffic and the surface-disturbance effects included in the overall development index. The modifications to the overall CA index/models will be summarized in the CA table for each CE.

Table 6. Format of Change Agent table that summarizes information for use in quantifying the relevant Change Agents for each Conservation Element. Variable classes summarize sets of variables that will be compiled into the overall index for each Change Agent. Examples of potential variables, metrics, and data sources are provided.

Change Agent	Variable class	Variable	Metric	Data sources
Development	Transportation	Roads, railroads	Total surface area	U.S. Geological Survey roads for Wyoming Basin
	Energy & minerals	Oil & gas wells, wind turbines, mines, solar facilities	Total surface disturbance	Oil & Gas Commission, U.S. Geological Survey Wind Data Series
	Other land uses	Urban, agriculture	Total surface disturbance	LANDFIRE[1]
Natural disturbances	Insects & disease	Bark beetles	Distance to outbreak weighted by outbreak area	Forest Service surveys of bark beetles
Exotic invasives	Insects & disease	White pine blister rust	Distance to occurrence of white pine blister rust	Forest Service surveys of white pine blister rust

[1]Landscape Fire and Resource Management Planning.

For the overall CA index/models and the species-specific CA index, a visual representation of where the CAs overlap with CEs will be provided by simple overlays of the CA indices on the CE distribution maps. The map overlays (hereafter referred to as "CE-CA overlays") will be provided as map products that will be used to evaluate the status of each CE (see How Do Change Agents Affect the key ecological attributes section below). Individual CA variables or variable classes can be mapped and displayed for each CE; such overlays are useful for determining where on the landscape a particular CA variable poses the least and greatest risks to each CE.

How Do Change Agents Affect the Key Ecological Attributes?

One of the major potential effects of CAs is the alteration of landscape structure. Changes in the spatial distribution of CEs that result from CAs can serve as a means of assessing CE status. We will use the CE-CA overlays to quantify the extent to which a landscape structure, such as patch size and connectivity, has changed from baseline due to a particular CA (for example, development) or CA variables (for example, transportation, oil and gas development).

Because our understanding of how most species respond to landscape structure is limited, the CE-CA overlays provide an index of relative risk from a given CA that can be compared to the baseline state. We assume that differences between the baseline landscape structure and the structure observed when overlaid with the CA indices represent ecological consequences for the CEs. Therefore, the relative magnitude of landscape changes can be used as a relative index of CE status. In some cases (for example, greater sage-grouse, pygmy rabbit, mule deer, and sagebrush-obligate passerines) there may be sufficient published information or available datasets to evaluate the status of CEs (Holloran and others, 2010; Sawyer and others, 2006; Doherty and others, 2008).

Integrated Management Questions

To identify potential areas for conservation and restoration, the metrics for the key ecological attributes will be compiled into an integrated map for each CE. Likewise, the threats posed by individual CAs will be compiled into an integrated risk map for each CE. Finally, an overall integrated map of key ecological attributes at risk will be created for each CE (fig. 6).

Reporting Maps and Metrics

Reporting maps will include source data at its native resolution, whereas derived key ecological attributes and CAs will be summarized at the appropriate analysis scales. Overall status assessment maps will be summarized at the required reporting scale (5th-level HUC; see appendix fig. 1-1). Additional reporting scales may be provided. For each of the Core MQs listed in Figure 6, we will create a series of maps and associated summaries of the reporting metrics.

Quantifying Change Agents

Development Overview

Development, for the purposes of the REA, includes residential, agricultural, and industrial. Several of the major types of development identified as priorities for the REA are highlighted in the sections that follow.

Energy, Minerals, and Associated Infrastructure

Development of energy and minerals, and the associated infrastructure, has been accelerating throughout many areas of the Wyoming Basin (Rowland and Leu, 2011). This ecoregion is underlain by some of the largest onshore oil and gas reserves in the conterminous United States, and it has some of the greatest potential for wind energy development in the intermountain West. The potential consequences of energy development include direct and indirect habitat loss due to surface disturbance during construction, the fragmenting effects of roads and energy infrastructure, direct mortality (such as collisions with wind turbines or vehicles), indirect effects (such as invasive plant species introduced along roads and other infrastructure), and alteration of aquifers and hydrological regimes (such as from coal bed methane operations; Rowland and Leu, 2011).

Dams and Water Diversions

Water use for human consumption, irrigation, and energy development are threatening aquatic ecosystems across the western United States (Sabo and others, 2010; McDonald and others, 2012). Dams and water diversion alter the natural flow regime to which freshwater organisms are adapted (Poff and others, 1997). For fish, hydrologic alteration can lead to declines in abundance (Poff and Zimmerman, 2010) and shifts in community composition (Freeman and Marcinek, 2006).

Grazing

Historically, grazing and browsing (hereafter, "grazing") by wildlife, livestock, and wild horses (*Equus caballus*) and burros (*E. asinus*) have undoubtedly influenced ecosystems in the Wyoming Basin. The effects of grazing and grazing management (for example, sagebrush removal to enhance forage production) on plant and animal communities can be both direct and indirect. Effects include trampled riparian vegetation, removal of vegetative cover, and dispersal of seeds from invasive plants species (Rowland and Leu, 2011). Loss of cover and forage for nesting birds are of particular concern for sagebrush-dependent species, such as sage-grouse (Veblen and others, 2011).

Rowland and Leu (2011) and Veblen and others (2011) evaluated the use of grazing data for regional assessments of the sagebrush ecosystem of the Wyoming Basin. These studies determined that, although the data can be used to assess range conditions on individual allotments, the data are insufficient for assessing grazing effects at the ecoregional scale. In particular, Veblen and others (2011) conducted a rigorous evaluation of the quality and types of livestock grazing data collected by BLM in sagebrush systems and concluded that the availability of standardized, quantitative data is not currently sufficient to quantify grazing intensity and effects for large-scale assessments. In addition, the authors found that, when grazing allotments did not meet the BLM Land Health Standards (LHS) (for example, had more bare ground and less vegetation cover), the localized reduction in cover due to grazing was relatively small compared to the reduction in cover caused by other CAs being evaluated as a part of the REA (for example, fire, climate, and energy development; Veblen and others, 2011). Although in general the local reduction in cover due to grazing may be less than that resulting from development (Veblen and others 2011), the cumulative effects of grazing may be substantial, particularly in riparian areas where grazing activities may be concentrated.

Based on data summarized by Veblen and others (2011), we concluded that an ecoregion-wide assessment of grazing is precluded for the Wyoming Basin REA because the complete coverage of grazing intensity and effects across the entire project area (fig. 7) is not available. There is insufficient information on grazing use for sizeable parts of the project area (as represented by "billed use" reported to the BLM by allotment lease holders), and LHS monitoring data, which can be used as an index of grazing, are not available for all allotments (fig. 7; Veblen and others, 2011; Rowland and Leu, 2011). Thus, there are extensive data gaps for grazing use and grazing effects across the project area.

Where there are adequate data, grazing may be evaluated at smaller spatial extents. To facilitate such "step-down" evaluations, we will include data layers representing BLM grazing allotment boundaries and associated information (for example, LHS or billed use) in the REA, as well as Wild Horse Management Area boundaries. These datasets will facilitate local-scale assessments of grazing on BLM lands, which is subject to the BLM's standards and assessments, per the Federal Lands Policy Management Act. The datasets also delineate the locations of data gaps in grazing information (fig. 7). Additionally, we are compiling BLM monitoring data on proper functioning condition collected in riparian areas.

Veblen and others (2011) suggested that improved data consistency would facilitate broad-scale analyses of the effects of livestock grazing. Indeed, new standardized rangeland-monitoring protocols are being developed as a part of BLM's Assessment, Inventory, and Monitoring (AIM) Strategy, in collaboration with the Natural Resources Conservation Service (MacKinnon and others, 2011; Toevs and others, 2011). The AIM Strategy, once fully implemented, will enable analyses of grazing for subsequent large-scale assessments (Toevs and others, 2011).

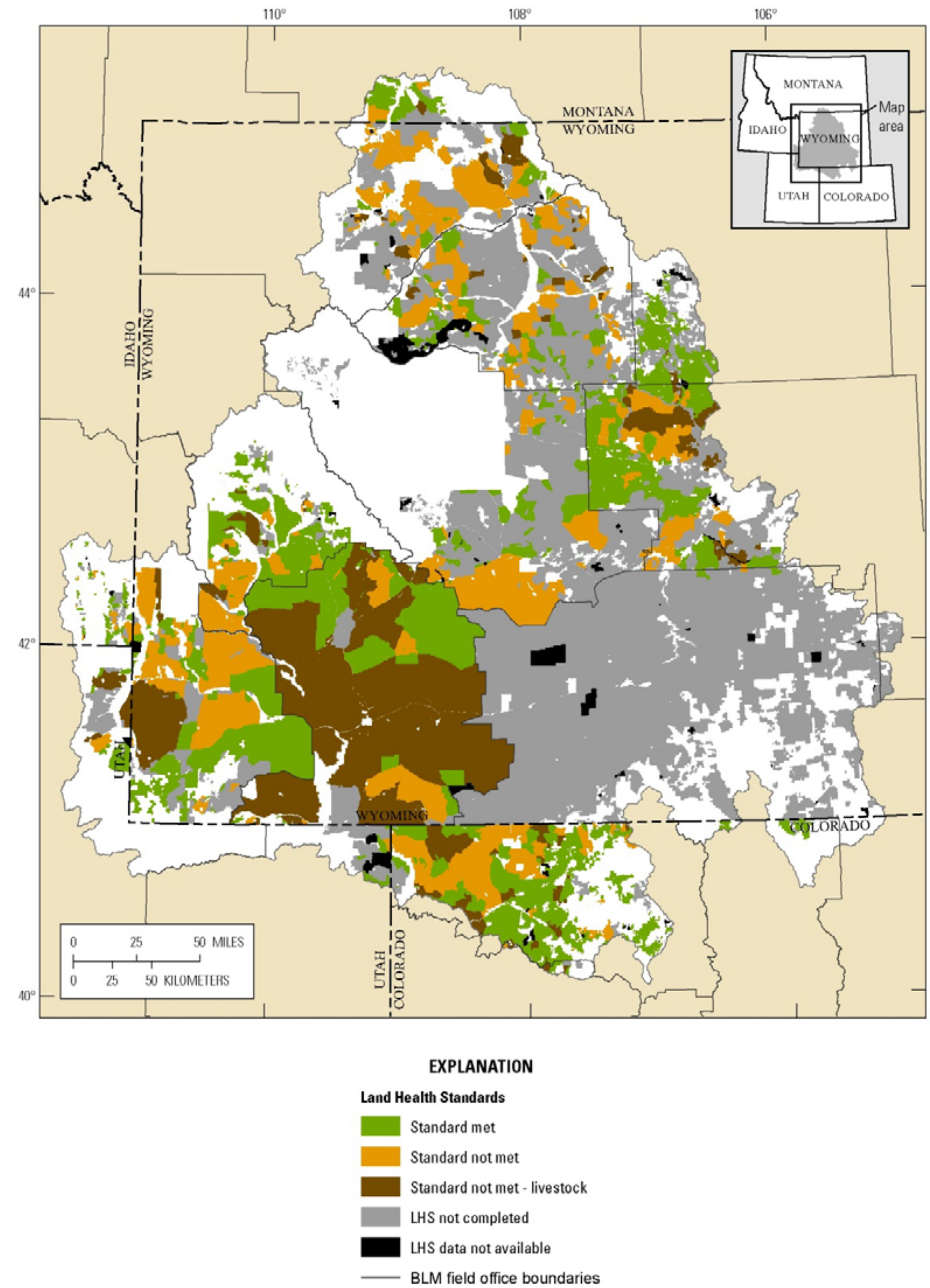

Figure 7. Distribution of grazing allotments under Bureau of Land Management (BLM) jurisdiction. Spatial representation of allotments meeting Land Health Standards (LHS), allotments not meeting standards, allotments in which livestock contributed to unmet standards, and where LHS were not evaluated (after Veblen and others, 2011). White areas within the Wyoming Basin Rapid Ecoregional Assessment project area correspond to other land ownership status.

Off-Highway Vehicles

Off-highway vehicles were considered as a potential CA for the Wyoming Basin REA. It was determined, however, that for most of the ecoregion, OHV use is widely dispersed, poorly mapped, and is best addressed at the field office level. We will compile and evaluate the available data to determine what level of summarization is appropriate given the potential data limitations for this CA.

Development Index

A primary purpose of the overall terrestrial and aquatic development indices is to quantify the cumulative effects of development on individual species, assemblages of species (as represented by biomes), and the entire project area. We focused on the direct effects (surface disturbance that removes vegetation) for the overall index because indirect effects (such as disturbance from vehicles) are more difficult to quantify and responses to disturbance vary greatly among species. Although species vary in their sensitivity to surface disturbance, the overall index nevertheless provides a useful index for comparing the relative degree of surface disturbance across large landscapes. Thus, the overall development index provides a standardized basis for comparing the effects of development across species. Because land uses can affect terrestrial and aquatic ecosystems differently, we created separate development indices for terrestrial and aquatic systems.

To account for variation among species in their sensitivity to the direct and indirect effects of development, we also will adapt the overall index for each fine-filter CE when there is sufficient information on the species-specific response to the development variables. In cases where published information is not sufficient to confidently modify the index, we will use the overall index without any adaptation.

Terrestrial Development Index

The primary variables associated with terrestrial development (table 7) were compiled into the overall development index. To facilitate compilation of the development variables, we used a common metric, surface disturbance, to quantify each variable. All point and line data (such as well pads, roads) were assigned width or radius values to account for differences in expected surface disturbance associated with each development variable (Leu and others, 2008). The terrestrial development index was derived by taking the maximum surface-disturbance value per pixel across all development variables, which is summed to calculate the proportion surface disturbance within a 16-km^2 neighborhood (2,256-m radius sampling window) of each pixel. Preliminary analyses indicated that this scale was optimal for maximizing variation in the development index score among sampling windows. We used agriculture types from LANDFIRE EVT to represent baseline agricultural lands in the development index.

The overall development index scores range from 0 to 100 percent (fig. 8). To represent a range of development intensities, we divided the index scores into seven classes, which are readily interpreted by examining the surface disturbance footprint contributing to the index score (fig. 9). A development index score between 0 and 1 percent represent areas with few roads and a very low density of oil and gas wells (fig. 9). Development index scores between 1 and 3 percent often include low densities of oil and gas wells and roads (fig. 9); development index scores above 3 percent represent moderate to high levels of development, including relatively large oil and gas fields, surface mines, agricultural fields, centers of urban development, and highway/interstate corridors (fig. 9). Because the development scores are continuous, alternative classes can be used to display the data to address a particular management question.

Table 7. Change Agent table for the terrestrial development index. Classes of development and metrics, data sources, and analysis units are provided. The development classes or variables can be quantified individually for each Conservation Element, and can be compiled into an overall index of development[1].

Change Agent	Variable class	Variable	Metric	Data sources[2]
Development	Transportation	Roads, railroads	Total surface area	U.S. Geological Survey roads for Wyoming; TIGER; FRA data
	Energy & minerals	Oil & gas wells, wind turbines, mines	Total surface area	Wyoming and Colorado Oil & Gas Commission, U.S. Geological Survey data series, FAA data
	Transmission structures	Communication towers, transmission lines	Total surface area	FAA data, SAGEMAP
	Other land uses[3]	Urban, agriculture	Total surface area	LANDFIRE EVT

[1] The overall development index is based on the percent of surface disturbance in a 16-km^2 moving window.
[2] TIGER = Topological Integrated Geographic Encoding and Referencing from U.S. Census data, FRA = Federal Railroad Administration; FAA = Federal Aviation Administration data, SAGEMAP = Sagebrush and Grassland Ecosystem Map Assessment Project, and LANDFIRE EVT = Landscape Fire and Resource Management Planning existing vegetation type.
[3] Regional grazing and off-highway vehicle data will only be compiled as data layers for the REA, but were not included in the index because the data were not sufficient to allow regional analyses.

We summarized each development variable class for the entire project area (table 7). The four maps in Figure 10 show the results for several variable classes. It is clearly evident that surface disturbance resulting from transportation was much greater than any from other variable class. Because roads attributable solely to energy development are not easily identifiable, the transportation variable class includes surface disturbance resulting from energy development. Although transportation is the most pervasive class of development variable in the Wyoming Basin, there are large areas where agriculture, energy and minerals, and urban development also contribute to high development index scores (fig. 10).

Our approach is similar to other recently published methods for quantifying the human footprint (Theobald, 2010; Leu and others, 2008) with several important distinctions. First, Leu and others (2008) included additional variables (such as mortality risk for corvids and domestic cats and dogs, fire-ignition locations), whereas we include only development variables that generate a surface-disturbance footprint. In addition, Leu and others (2008) include fragmentation indices in their human footprint model, but we quantified the spatial patterns resulting from the surface-disturbance footprint in separate analyses so as to not complicate the model. Theobald (2010) compiles the scores at multiple scales, whereas we focused on one scale, although other window sizes may be used in subsequent analyses. Our objectives were to keep the overall index as transparent and understandable as possible by focusing only on direct effects summarized at a single scale. Interpretation of the index is facilitated by allowing users to readily decompose the overall scores into component variable scores to allow examination of the spatially explicit contribution of each variable (fig. 10) and to allow visual examination of how the surface-disturbance footprint influences the overall score (fig. 9).

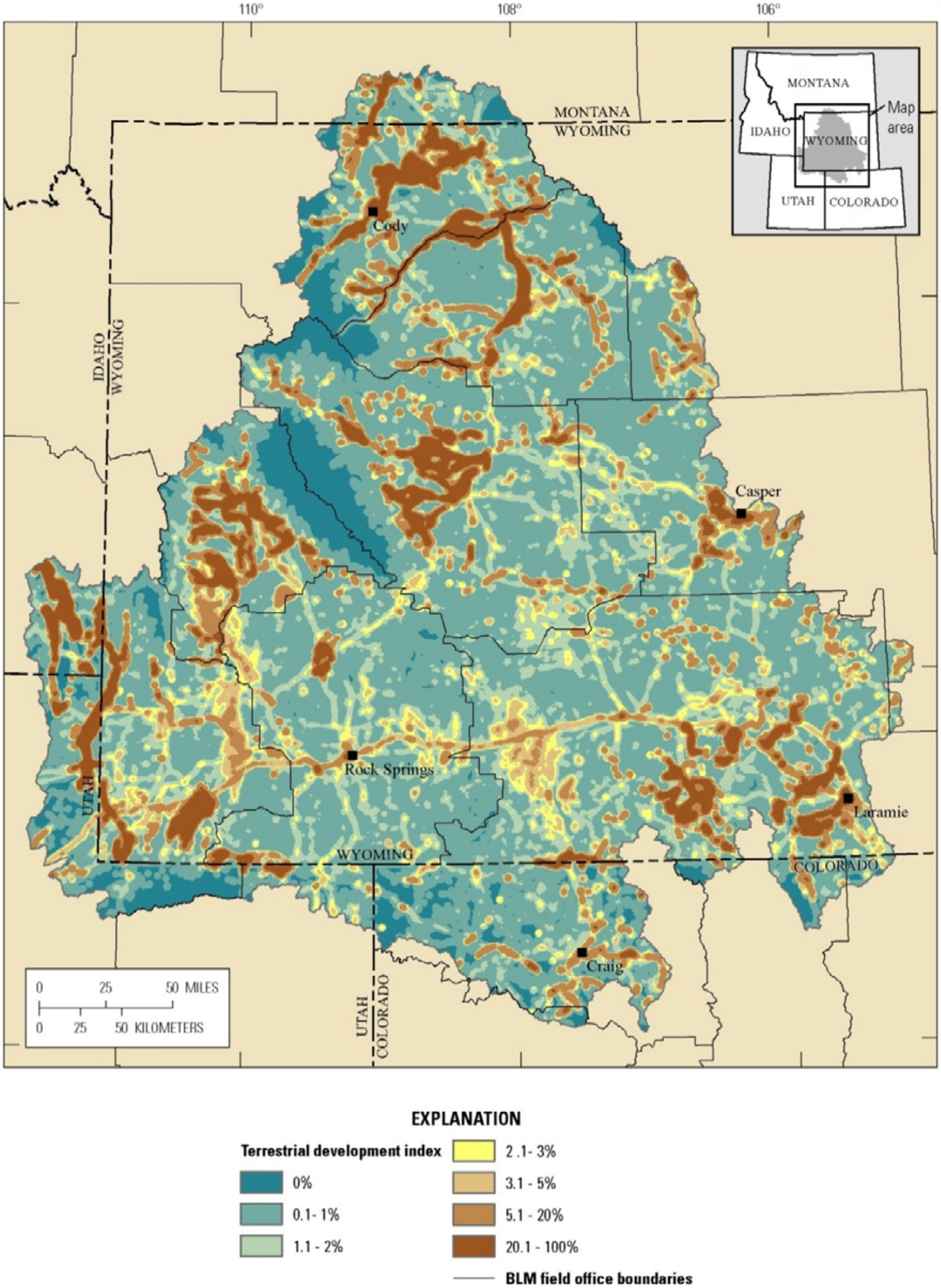

Figure 8. The overall terrestrial development index as applied to the Wyoming Basin Rapid Ecoregional Assessment project area. Table 7 lists the variables used to develop the index. Development index scores are based on the total percent area of surface disturbance in a 16-mk[2] moving window (1600 ha).

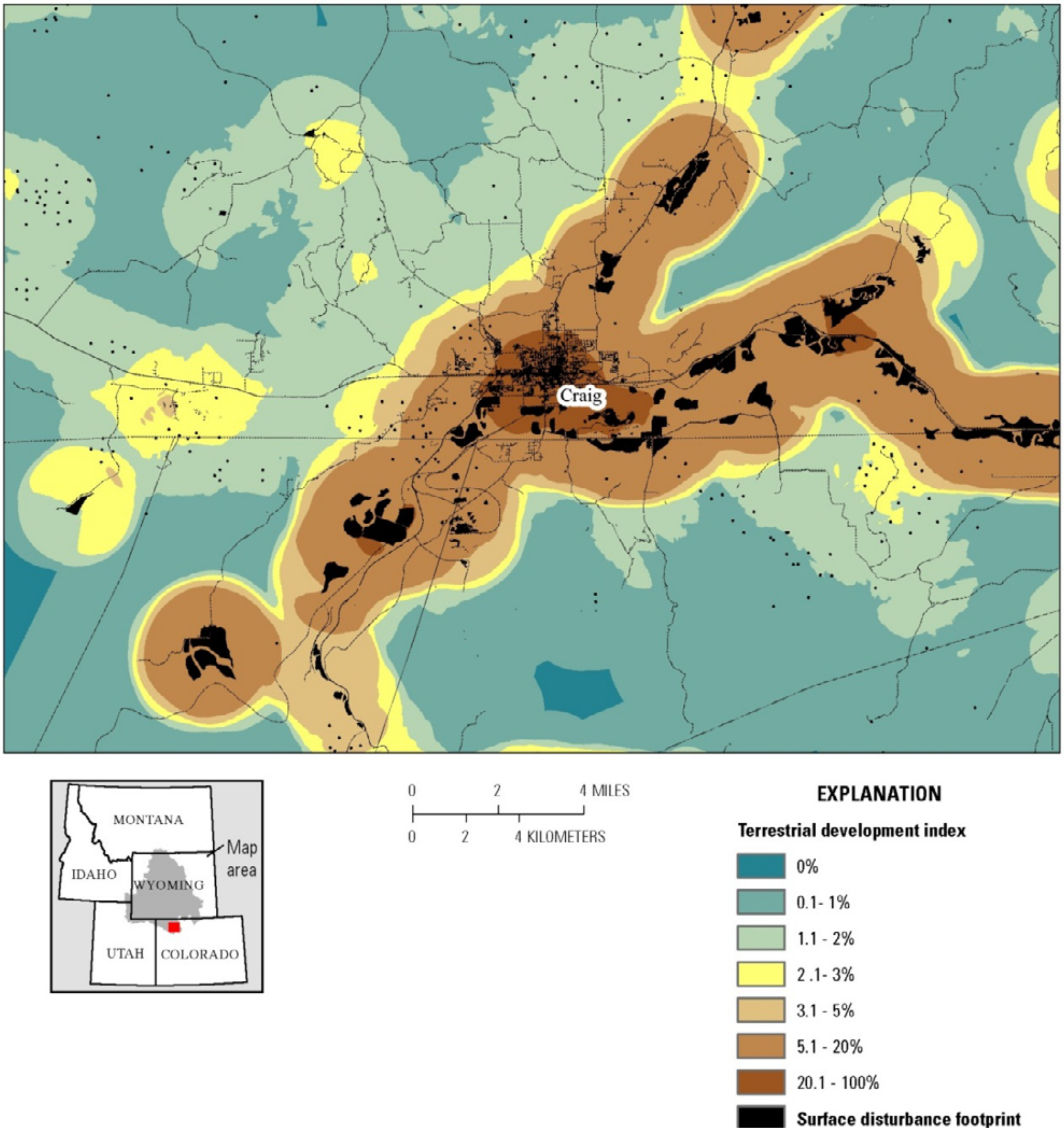

Figure 9. The terrestrial development index scores and associated surface-disturbance footprint for an area near Craig, Colorado. The surface-disturbance footprint from development is shown in black. Development index scores are based on the total percent area of surface disturbance in a 16-km^2 (1600 ha) moving window.

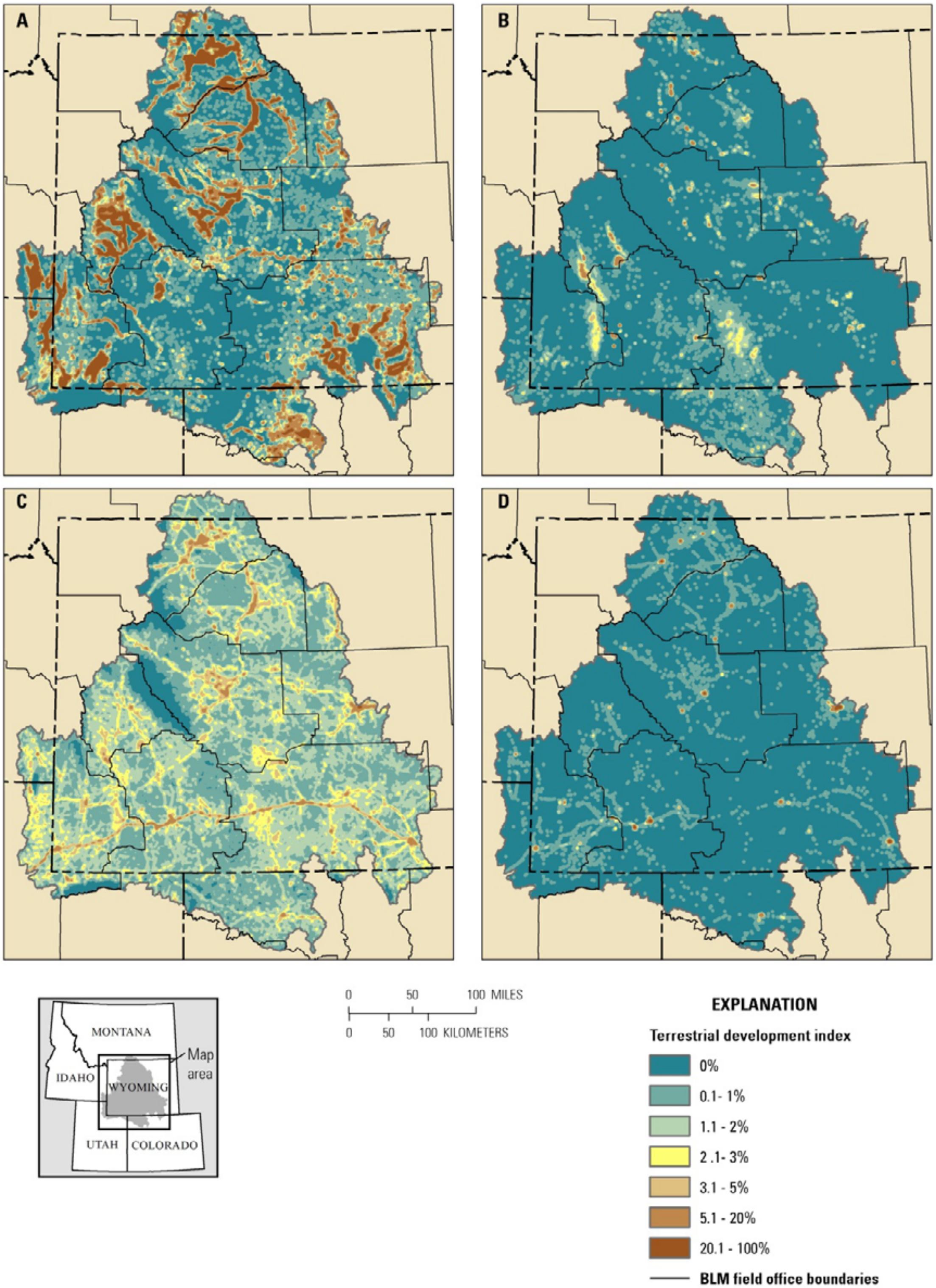

Figure 10. Percent surface area in a 16-km^2 (1600 ha) moving window for four of the variables compiled in the terrestrial development index (fig. 8, table 7). (A) Agriculture; (B) energy and mineral development excluding roads; (C) all transportation; and (D) urban development.

Aquatic Development Index

We calculated an overall aquatic development index using an approach similar to that used for calculating the terrestrial development index (table 8). The overall terrestrial development index was used to represent surface disturbance in the aquatic development index. A major difference between the terrestrial and aquatic indices is that the aquatic development index also includes variables relating to water use and quality (such as dams and diversions), and some of the metrics we used for evaluating the development variables were different (for example, number of stream crossings per mile for the roads variable).

Table 8. Change Agent table for the aquatic development index. Classes of development and metrics, data sources, and analysis units are provided. The development classes or variables can be quantified individually for each Conservation Element, and can be compiled into an overall index of development. Each variable and the overall development index will be summarized by 5th level watershed boundaries (HUC10).

Change Agent	Variable class	Variable	Metric	Data sources[1]
Development	Transportation	Roads, railroads	Total surface area, number of road, crossings per stream km	U.S. Geological Survey roads for Wyoming and Colorado; TIGER; FRA data
	Energy & minerals	Oil & gas wells, wind turbines, mines	Total surface area	Wyoming and Colorado Oil & Gas Commission, U.S. Geological Survey data series, FAA data
	Water	Dams, diversions	Number of dams, number of diversions per stream km, 303D stream length per stream km	State water resource data[2]
	Other land uses[3]	Agriculture	Total surface area	LANDFIRE EVT

[1] U.S. = United States; TIGER = Topological Integrated Geographic Encoding and Referencing from U.S. Census data; FRA = Federal Railroad Administration; FAA = Federal Aviation Administration data; LANDFIRE = Landscape Fire and Resource Management Planning; and EVT = existing vegetation type.
[2] Wyoming State Water Plan, Idaho Water Resources, Colorado Division of Water Resources, Montana National Resource Information System.
[3] Regional grazing (Proper Functioning Condition) and off-highway vehicle data will only be compiled as data layers for the REA, but were not included in the index because the data were not sufficient to allow regional analyses.

Key ecological attributes for aquatic systems affected by development include:

- flow regime,
- sedimentation regime,
- riparian zone habitat quality,
- connectivity, and
- water quality.

Watershed land use has repeatedly been shown to be a good predictor of stream/riparian degradation (Paukert and others, 2010). Table 9 summarizes the variables and metrics serving as indicators for each of these key ecological attributes. Variables and metrics can address more than one ecological attribute. For example, surface disturbance directly impacts the habitat quality of riparian zones, but the presence of impervious surfaces also can alter flow regimes. Likewise, structures that alter connectivity (roads, dams, and water diversions) can alter flow or sedimentation regimes. We used the terrestrial development index to address multiple ecological attributes (table 9) such as increased sedimentation in areas of higher agriculture use. Water diversions can be used as an indicator of altered flow regime on relatively small streams, whereas dams can be used as an indicator of altered flow regime on relatively large streams and rivers. To control for variation in perennial stream length in each analysis unit, we divided the number of diversions by total stream length per analysis unit. Because there were relatively few dams relative to the length of streams in each analysis unit, we did not control for stream length for this metric.

Table 9. Relationships between component variables and metrics for the overall aquatic development index and key ecological attributes.

Variable	Metric	Key ecological attribute				
		Flow regime	Sedimentation regime	Riparian zone	Connectivity	Water quality
Surface disturbance	Terrestrial development index	X	X	X		X
Road crossings	Number of road crossings per stream km		X		X	
Water use	Number of dams	X			X	
	Number of water diversions per stream km	X			X	
Water quality	303d waterways present per stream kilometer					X

All variables will be quantified for a given catchment area. We will evaluate the appropriate area for defining catchment units (analysis unit), which will be nested within each 5th- or 6th-level HUC (reporting units). Because aquatic condition is a function of local and upstream conditions in the watershed (Allan and others, 1997; Gomi and others, 2002), we will evaluate potential threats based on the development variables (table 8) for a given catchment area, and we will include potential threats from the terrestrial development index for upstream catchments. We will test methods for addressing upstream threats using distance to point locations (roads, wells, mines, dams, and diversions) as weighting factors, based on the Human Threat Index developed by Annis and others (2010). To account for variation in the units among metrics, we normalized each metric score by dividing the score by the maximum score for the project area. Each metric score was added together for a given catchment to create a final score, which was normalized to obtain a final score between 0 and 100. Preliminary aquatic development index scores (not including upstream scores) summarized at the 6th level HUC for the project area are presented in Figure 11. The overall aquatic development index is evaluated for catchments and has the flexibility to be quantified at different scales (for example 5th or 6th level watershed units; see fig. 11).

As with the terrestrial development index, the aquatic index will be adapted for assessing aquatic biomes and species. We will evaluate existing indicators and metrics used to quantify the landscape structure relevant to aquatic systems (for example, landscape permeability, and riparian threat scores; Theobald and others, 2010), and we have reviewed the NHDPlus Catchment feature class to assess how flow and connectivity attributes may be used as indicators of flow regime in aquatic systems. We will evaluate the use of various metrics, such as wetland patch size, distribution, and connectivity, for the REA and are continuing a review of literature on the responses of species to landscape patterns that may be quantified for assessing the aquatic biomes. Managers may use this information to interpret the biological relevance of landscape patterns for species not evaluated as fine-filter CEs.

Fire and Other Disturbances

Fire

Fire is a dominant process affecting landscape structure and dynamics in many ecological systems. The ecological role of fire varies among plant communities and their corresponding fire regimes, which are dictated in large part by the interplay between climate and fuels (Baker, 2009). Because fire is a natural driver of ecological systems, it is challenging to differentiate the relative influence of natural and anthropogenic factors that shape current fire regimes. The degree to which fire regimes have been altered by human activities varies among vegetation communities (Littell and others, 2009). Active fire suppression, grazing (by reducing fine fuels), and other forest management activities can affect vegetation communities by altering the frequency and severity of fire across the landscape (Baker, 2009). Also, increasing frequency of droughts and increasing temperatures under certain future climate scenarios have the potential to promote greater fire size and frequency (Littell and others, 2009).

One of the challenges of evaluating fire as a CA is characterizing fire regimes. Fire regimes are spatially and temporally variable; consequently they are non-equilibrial (McKenzie and others, 2011). Yet, fire regimes are generally evaluated relative to a particular reference period, which assumes equilibrium conditions (Littell and others, 2009). Nevertheless, information on fire regimes can provide a general indication of the dominant processes that helped to shape existing vegetation communities. For example, some communities are relatively dependent on fire to maintain competitive dominance, such as seral (successional) aspen stands, whereas other communities are relatively independent of fire, such as salt desert shrublands, and can persist without the occurrence of fire (Knight, 1994; Shinneman and others, 2013). Determining fire regimes requires site-specific research, and for many landscapes, historical evidence of fire is fleeting and uncertain. Attempts to classify fire regimes at the regional scale (such as LANDFIRE) can lead to overgeneralizations that lack site-specific relevance. Furthermore, planning at regional scales may be too coarse because the local patterns of spatial and temporal variability in fire regimes are not addressed (McKenzie and others, 2011).

Even when fire regimes are well established, considerable data are required to evaluate fire effects, including fire size and severity, and the presence of invasive species (such as cheatgrass) that can alter fire regimes. Regional data on burn perimeters and burn severity are available for the ecoregion, but these datasets represent recent fires (since 1984) and generally are insufficient for evaluating long-term consequences of anthropogenic influences on local fire regimes (Littell and others, 2009).

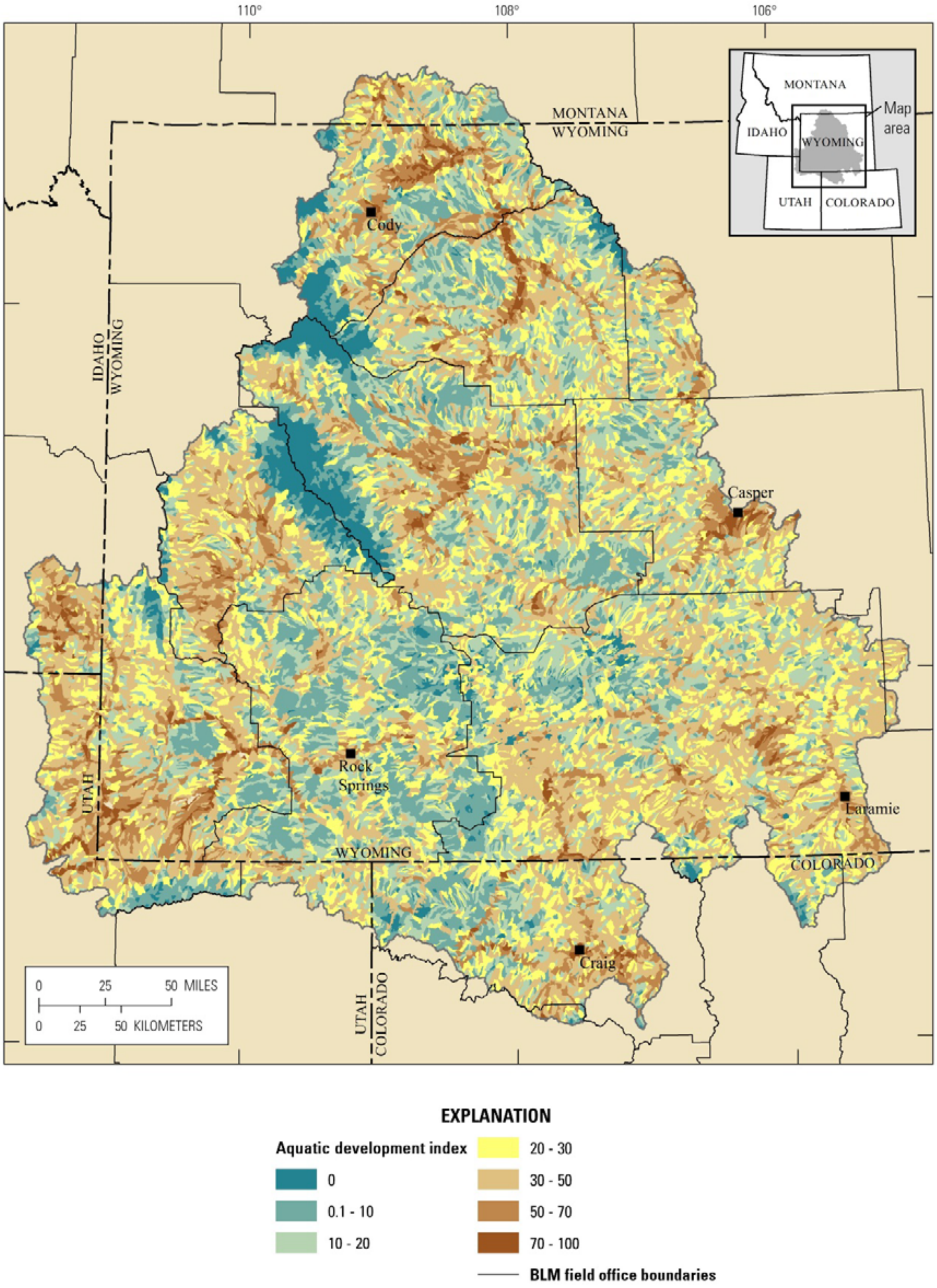

Figure 11. The overall aquatic development index as applied to the Wyoming Basin Rapid Ecoregional Assessment project area. Table 8 lists the variables used in the index (currently grazing and off-highway vehicle use are excluded). Development index scores are summarized by 6th level watershed boundaries [Hydrologic Unit Code (HUC)].

For the REA, we will focus on compiling available fire data layers, but due to the coarse scale and short-duration of many of the datasets, this information is best used in quantifying recent disturbances. We will compile available data layers for wildfire perimeters and severities, and for prescribed burn perimeters for the project area. We also will include LANDFIRE's Fire Regime Group for characterizing fire regimes for each biome prior to Euro-American settlement (U.S. Department of Agriculture Forest Service and U.S. Department of the Interior, 2010). These data layers may be useful in evaluating fire effects in step-down (local) assessments to address specific management objectives. For example, understanding where aspen stands are typically seral (such as upper montane zones), are largely independent of fire (many foothills stands tend to be stable at maturity), or perhaps a mixture of both types (in lower montane areas), can be augmented by local stand and fire history information to help inform resource managers which management approaches (such as prescribed fire, wildland fire, or no action) might be appropriate for a given situation.

Insects and Disease

Insects and disease include both native and introduced organisms. Recently introduced diseases, such as West Nile virus (*Flavivirus* Japanese encephalitis antigenic complex) and white pine blister rust (caused by the *Cronartium ribicola* fungus), can be especially devastating to species that lack any natural immunity. Sage-grouse are particularly vulnerable to West Nile virus (Rowland and Leu, 2011), and white pine blister rust is a major threat to the five-needle pine communities in Wyoming (Keane and others, 2011). In addition, the current widespread and severe outbreak of mountain pine beetle (*Dendroctonus ponderosae*), a native species, in conjunction with the occurrence of blister rust, is of particular concern for five-needle pines [whitebark pine (*Pinus albicaulis*) and limber pine (*P. flexilis*); Keane and others, (2011)]. Insects and disease will be evaluated for specific CEs (for example, white pine blister rust and mountain pine beetles will be evaluated for the five-needle pine community).

Invasive Species

Aquatic and terrestrial invasive species occur in the ecoregion. The negative effects of invasive species include displacement of native communities, degradation of habitat quality and forage, and alteration of fire regimes (Roland and Leu, 2011). There also can be interactions among invasives and CAs. For example, often the spread of invasive plant species is promoted by development activities. Although cheatgrass (*Bromus tectorum*) and tamarisk (*Tamarix* spp.) are not as pervasive in the Wyoming Basin as they are in warmer regions of the United States, they can be locally abundant and both species have the potential to expand in the Wyoming Basin under projected future climate scenarios (Rowland and Leu, 2011). Invasive aquatics include introduced species [such as introduced populations of rainbow trout (*Oncorhynchus mykiss*)], which have the potential to interbreed with genetically pure native fish species (such as, cutthroat trout (*O. clarkii*)].

Data limitations present substantial challenges for assessing invasive species for the entire project area, but we will compile and evaluate available invasive species data. In addition, we will evaluate available regional invasive species risk models that may be used to map risk for cheatgrass, tamarisk, and Russian olive (*Elaeagnus angustifolia*) in the project area (see example in fig. 12; Jarnevich and Reynolds, 2011; Jarnevich and others, 2010, 2011; Morisette and others, 2013). We propose to re-run the available models with ancillary data on invasive species occurrence that we will compile for the Wyoming Basin REA project area.

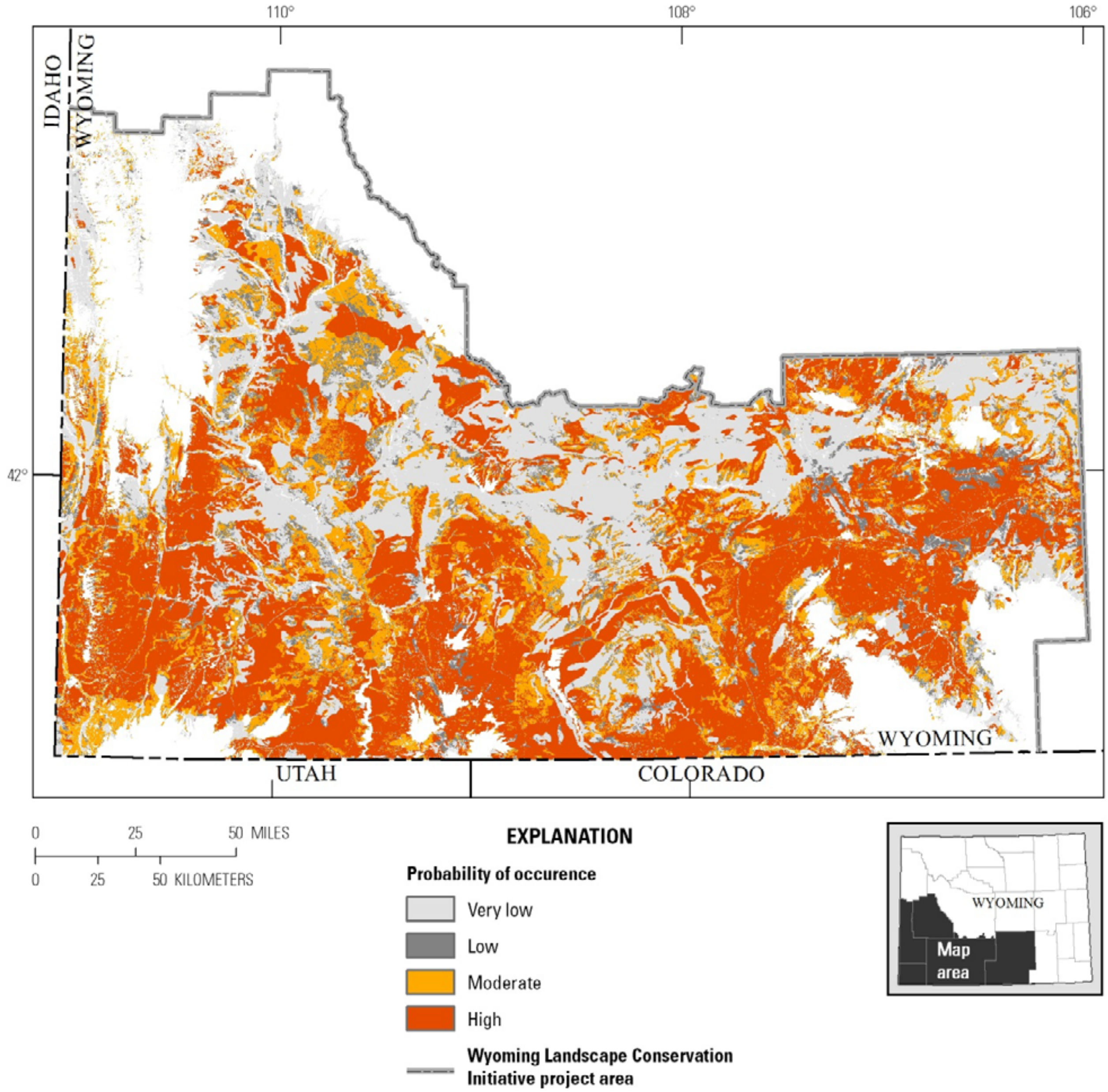

Figure 12. Example of potential risk for occurrence of cheatgrass (*Bromus tectorum*) developed for the Wyoming Landscape Conservation Initiative (adapted from Bowen and others, 2013).

Climate Change

Climate change has the potential to change the landscape in fundamental ways, with potential consequences for natural communities and exacerbating many other CAs. Based on climate projections, the Wyoming Basin could experience changes in snowpack that in turn will change the water availability, including annual runoff and runoff seasonality. For example, warming even without any decrease in precipitation could lead to increased evapotranspiration from the watershed and decreased annual runoff (Bureau of Reclamation, 2011). Climate change influences fire regimes, can promote expansions of invasive plant species, and affects hydrologic regimes. Changes to water temperature and flow regime are of particular concern for fish populations, in particular the cold-water fishes, including cutthroat trout. Furthermore, the timing, or phenology, of critical biological events, such as spring bud burst, emergence from overwintering, and the start of migrations, can shift, with potential consequences for species and habitats (Groffman and Kareiva, 2013).

Wyoming temperatures have warmed by almost 2°F in the past 30 years (Climate Change Science Program SAP 3.3, 2008). Climate models project that by 2025 Wyoming will warm by 2.5°F (+1.5 to +3.5°F), relative to the 1950–1999 baseline, and by 4°F (+2.5 to +5.5°F) by 2050. The baseline likely includes some anthropogenic warming in North America. The models also project that summer temperatures will warm [+5°F (+3 to +7°F)] more than winter temperatures [+3°F (+2 to +5°F)], and they suggest that typical summer temperatures in 2050 could be as warm as or warmer than the hottest 10 percent of summers that occurred from 1950−1999 (data from International Panel on Climate Change, 2007; as shown in Ray and others, 2008; fig. 13).

Reasonably Foreseeable Climate Scenarios and Historical Climate Reconstructions

A primary objective of the climate analysis is to develop Reasonably Foreseeable Climate Scenarios (RFCS), based on analysis and comparison among several climate projection datasets and to compare the RFCS to the historical period for the region (for example, the past 50–100 years) and the paleo period (for example, for the past 1,000–2,000 years; fig. 14). The projection datasets will include the U.S. Geological Survey (USGS) dynamical downscaled climate projection dataset (Hostetler and others, 2011), as required by the REA Statement of Work, and other appropriate downscaled projection datasets. Climate projections will provide a context for the existing ecological modeling results of Rehfeldt (2006) and Rehfeldt and others (2012), which will be used to evaluate the potential for biome shifts under the RFCS (see Application of Climate Analysis to Management Questions section below).

The following are the five objectives and proposed methods for developing and communicating the climate analysis and RFCS.

1. *Assess historical variability in past climate parameters*: We will determine the salient climate features affecting ecological communities and driving natural processes relevant to the MQs. In addition to temperature and precipitation variables, the climate analysis may include snow water equivalent, soil moisture and runoff (surface and sub-surface) determined from land data assimilation, and meteorological processes, such as the position of the springtime storm track.
2. *Analyze climate projections and compare at the Wyoming Basin ecoregional scale*: We will use ecologically relevant climate variables and suitable spatial and temporal scales, and document simplifying assumptions for modeling efforts. Because streamflow is important for fisheries, trout in particular, we will consider snow and runoff projections from the Bureau of Reclamation's statistically downscaled data that have been processed through the Variable Infiltration Capacity hydrological model. We also will consider results available from Shafer (in Bowen and others, 2013) for the Wyoming Landscape Conservation Initiative.

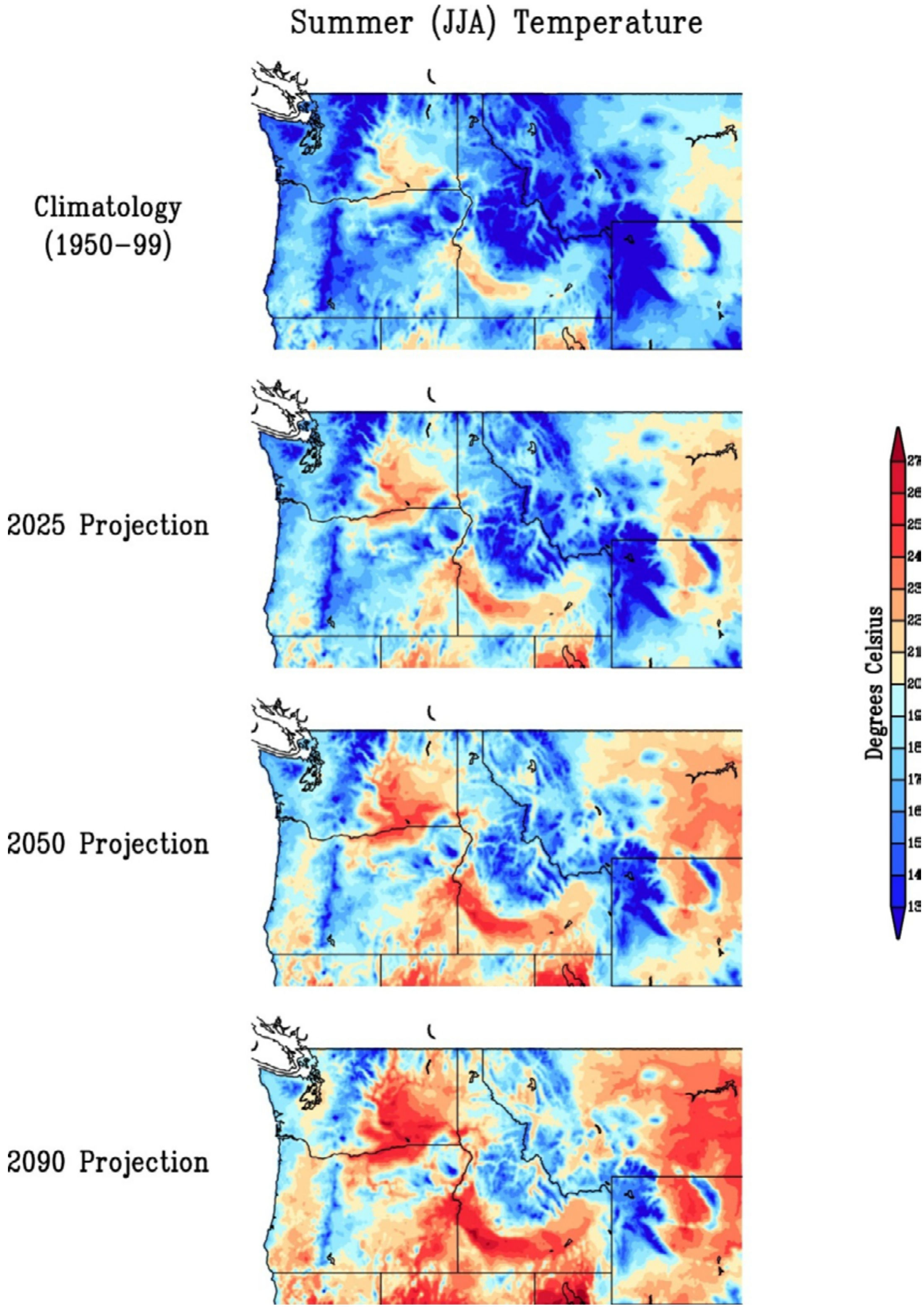

Figure 13. Current and projected summer temperatures (June 20 to August 20) for the western United States. Projections for 2025, 2050, and 2090 are based on an ensemble of 22 climate models used in the Intergovernmental Panel on Climate Change Fourth Assessment Report. Changes are shown relative to the 1950–1999 baseline average (Ray and others, 2008).

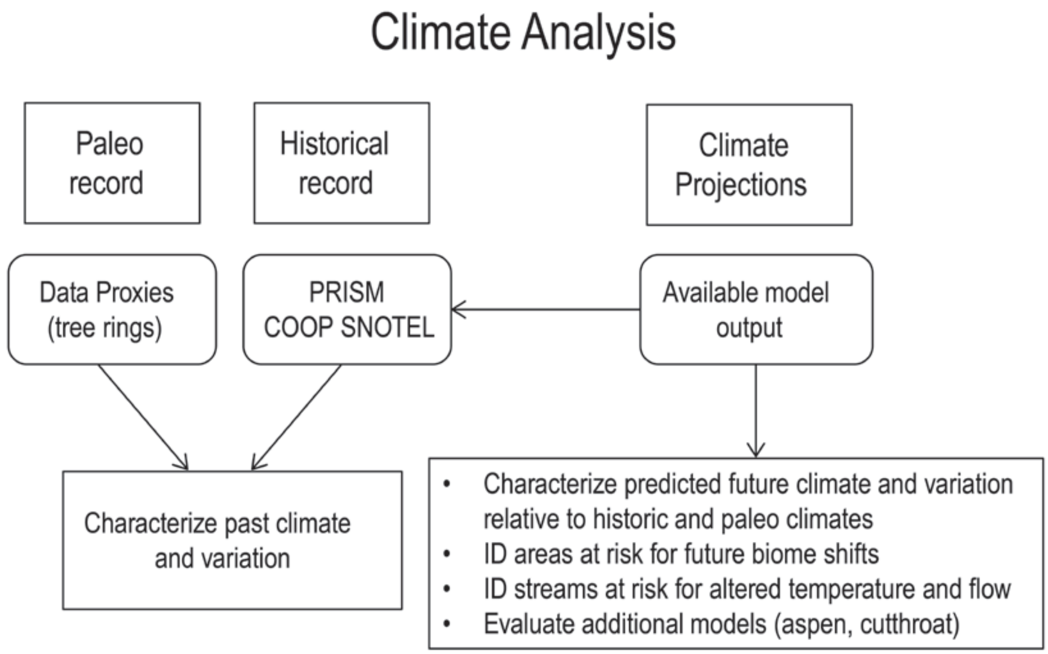

Figure 14. Overview of the major aspects of the climate analysis for the Wyoming Basin Rapid Ecoregional Assessment. The objectives are to develop Reasonably Foreseeable Climate Scenarios based on available climate models, and to compare these scenarios with historical climate conditions. The results of the climate analysis also will be used to evaluate the potential for biome shifts and the risk for selected fine-filter Conservation Elements (PRISM = Parameter-elevation regressions on independent slopes model, COOP = National Oceanic and Atmospheric Administration's National Weather Service Cooperative Observer Program, and SNOTEL = Snowpack Telemetry).

3. *Evaluate the U.S. Geological Survey dynamical downscaling method for the historical period*: We will use PRISM (Parameter-Elevation Regression on Independent Slopes Model) and other empirical datasets to evaluate how well the data dynamically downscaled by Hostetler and others (2011) simulates local features of the current climate. In particular, we will compare the results from different downscaling methods for climate data.
4. *Evaluate confidence in model output*: We will define a process for evaluating confidence in predicted climate variables, which will be based on the range of model projections. We will identify the climate variables and features in which we have the greatest confidence and the variables for which modeled output varies considerably. We also will compare the dynamic modeling climate predictions to statistically downscaled climate data to determine whether the level of detail from statistical models is sufficient for the REA objectives compared to dynamically downscaled models.
5. *Develop Reasonably Foreseeable Climate Scenarios using regional climate data:* Products will include
   - a description and display of projected changes in the context of natural climate variability for the Wyoming Basin REA project area, including a narrative description of temperature and precipitation variability and trends in the past century; and

- a narrative description and display of predicted future climate changes, including concise narrative descriptions of current and potential future climate change relative to historical climate variability.

Application of Climate Analysis to Management Questions

The results of the climate analysis will be used to compare predicted biome changes under climate scenarios to those reconstructed based on past (historical) climate variability (forecasting versus hindcasting). The historical and paleo climate reconstructions will provide the reference conditions for future time periods (for example, 2030, 2060, and 2090, averaged over 10 years) from which to evaluate current and projected climates. We will use the results of an existing ecological model (Rehfeldt and others, 2012) to predict the potential consequences of past and projected climate scenarios for the dynamics of the Wyoming Basin biomes. In particular, it will be important to determine where biomes are particularly at risk of shifting ecologically from one biome type to another under projected changes and how forecasted dynamics compare to historical reconstructions of past vegetation dynamics. We will provide relevant summaries and map products for use with the Climate Change Vulnerability Index (Young and others, 2010) to evaluate fine-filter CE vulnerability. We also will explore other available models for evaluating the potential consequences of projected climate scenarios for riparian areas and greater sage-grouse (fine-filter CEs).

Application of the Assessment Framework

We applied the overall development index to test the methodology outlined in the assessment framework. This section describes the methods we are testing and the preliminary results of this effort for sagebrush steppe and pygmy rabbit CEs.

Development Index for Coarse-Filter Conservation Elements

The overall development index will be used for the status assessments of coarse-filter CEs because these CEs represent diverse communities of species that vary in their sensitivity to the development variables. The overall development index is designed to represent potential effects on species that are sensitive to development.

Development Index for Fine-Filter Conservation Elements

Fine-filter CEs are likely to vary considerably in their sensitivity and magnitude of response to development. For example, for some species roads represent direct effects, such as habitat loss, barriers to movement, and mortality; roads also may lead to indirect effects, for example if species avoid areas adjacent to roads due to traffic-related disturbance. To account for different responses to development among species, we will use several lines of evidence to modify the disturbance index for each fine-filter CE. We will accomplish this by first determining whether there is evidence that a given species is sensitive to a particular development variable and then we will identify the nature of its sensitivity. In addition, we may weight some development variables more than others to account for differences in the strengths of their effects on species. For example, interstate highways would be weighted more heavily than secondary roads because they have greater traffic volumes.

Secondly, we will consider the metric to be used for measuring the magnitude of response of a given species. For example, when we assess effects of roads on the distributions of species particularly sensitive to road disturbance, we may need to develop buffers around the roads that represent the distances at which roads have both direct and indirect effects on the species, or we may need to develop a disturbance decay function that accounts for declining responses along a distance gradient from a given source of disturbance (Kotliar and others, 2008).

Our third approach will be to determine the magnitude of effects and the relative weights for each variable. Empirical evidence can provide a quantitative basis for developing metrics and for creating variable weights in the overall index. Biological or descriptive information can be used to provide a qualitative basis for weighting variables in the overall index. If the available information is not sufficient for developing metrics or variable weights for a particular species, we will use the overall development index without modifications.

Applications of the Overall Development Index for Coarse-Filter and Fine-Filter Conservation Elements

In this section, we provide two examples of how the overall development index can be applied to a coarse-filter (sagebrush steppe biome) and a fine-filter CE (pygmy rabbit). These examples are intended to demonstrate how the general index could be applied without modification.

To delineate the distribution of the sagebrush steppe biome, we used LANDFIRE EVT classes, which in turn was overlaid with the overall development index for the CE-CA overlay (fig. 15). Using disturbance scores of less than or equal to 1 percent to represent relatively undisturbed areas, Figure 16 illustrates the size of relatively undeveloped areas compared to baseline conditions. Areas with moderate to high development scores (development index scores greater than 1 percent) accounted for 54 percent of the total baseline area of sagebrush steppe. One consequence of development is that the larger areas of baseline sagebrush steppe (greater than 2,000 km^2) are effectively fragmented by development, as indicated by the limited patches greater than 2,000 km^2 that are relatively undeveloped (fig.16).

To delineate the pygmy rabbit's baseline distribution, we used the WYNDD map of pygmy rabbit distribution in Wyoming (fig. 17). To evaluate how development can affect the amount and spatial distribution of pygmy rabbit habitat, we applied the overall development index to the baseline distribution map (fig. 18). Potential pygmy rabbit habitat with moderate to high development scores (greater than 1 percent) represents 54 percent of the total baseline habitat (fig. 18). In particular, relatively undeveloped habitat patches in the largest three size categories (greater than 500 km^2) are effectively fragmented into smaller patches by high levels of development (fig. 18). To determine which land uses pose the greatest threats to the amount and spatial distribution of potential pygmy rabbit habitat, we will evaluate the relative degree to which individual development variables overlap with the pygmy rabbit baseline distribution map. We also will adapt the overall development index for pygmy rabbits by using the results of an ongoing study to assess the effects of energy development on pygmy rabbits in southwestern Wyoming (Bowen and others, 2013).

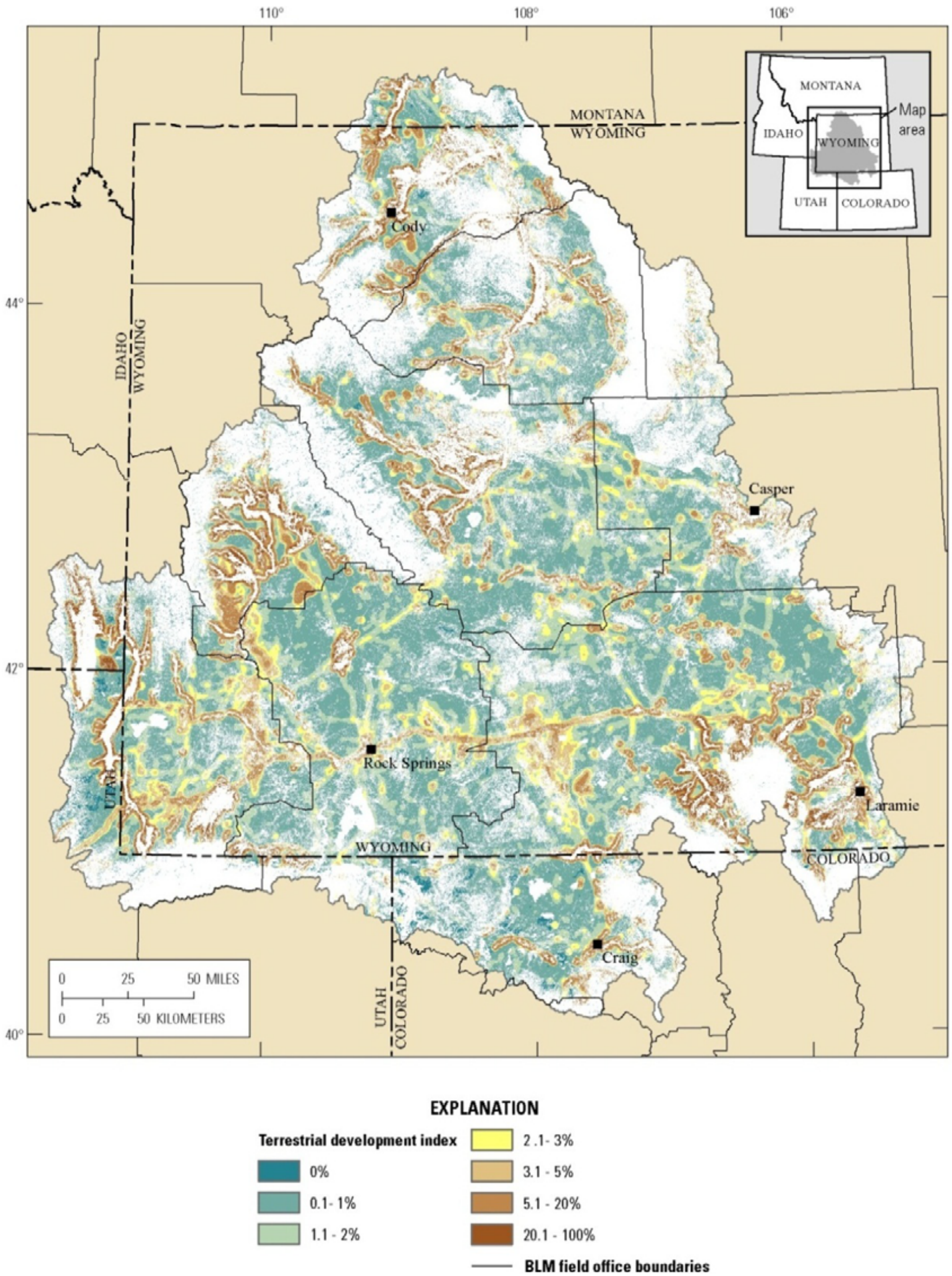

Figure 15. Conservation Element-Change Agent overlays for the sagebrush steppe biome. The development index scores for the distribution map for the sagebrush steppe biome in the Wyoming Basin Rapid Ecoregional Assessment project area, based on Landscape Fire Resource Management Planning (LANDFIRE) are shown.

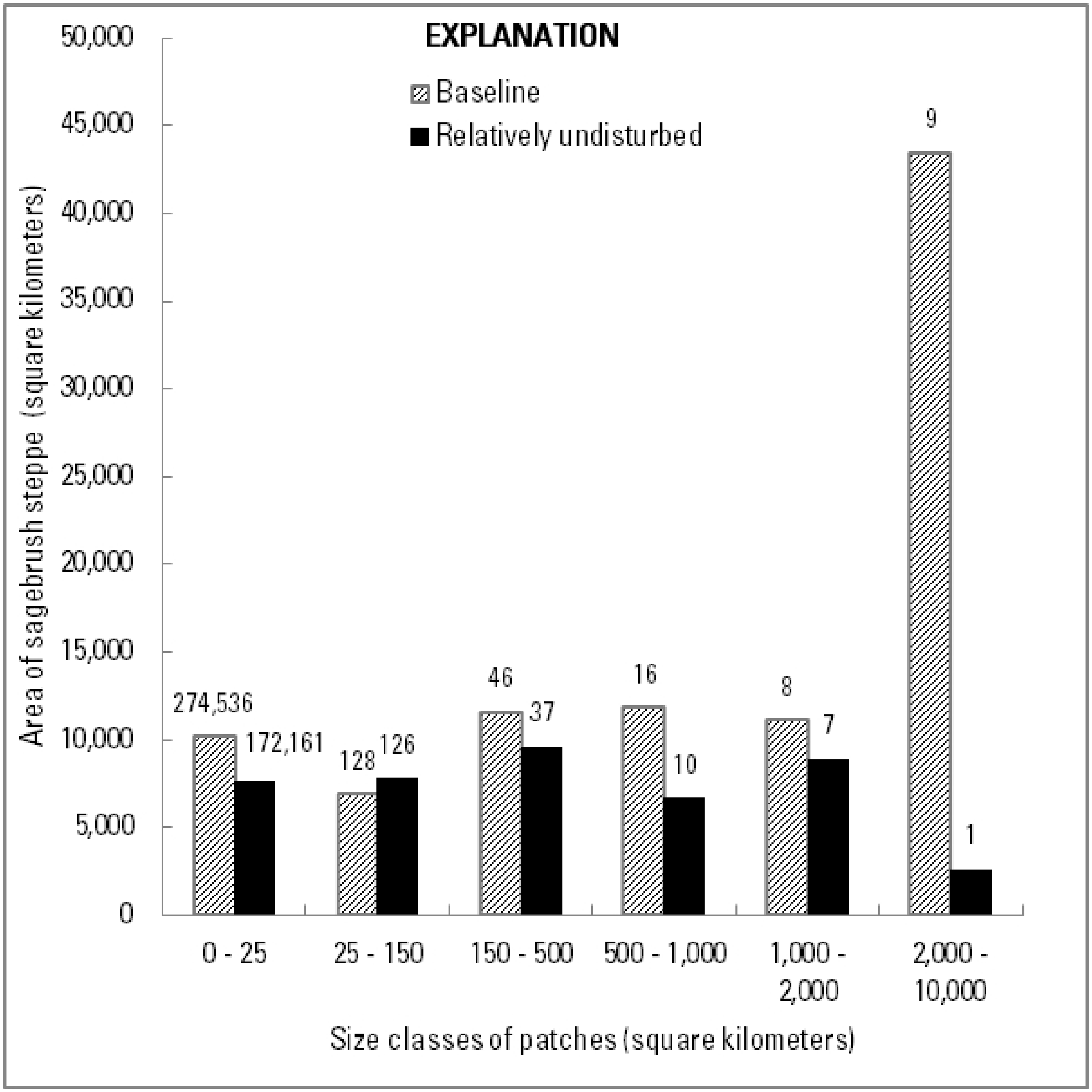

Figure 16. Results of Conservation Element-Change Agent overlays for sagebrush steppe. The size classes of sagebrush steppe patches under "baseline" conditions can be compared to the size classes of relatively undeveloped sagebrush steppe patches (for example, baseline areas with a development index score less than or equal to 1 percent; fig 15). The number above each bar is the number of patches in that size class.

Integrated Management Questions

In addition to the Core MQs for each CE, there are several Integrated MQs, which require compilation of the reporting maps and metrics developed for the Core MQs (appendix table 1–4). One of the primary Integrated MQs for the REA is, “Where are the intact areas?” To answer this, we first need to define intact areas. Intactness is related to ecological integrity (table 2), which is one of the REA components and is defined as a “complementary, integrated suite of CEs that collectively represent important ecological components of an ecosystem.” One of the reasons for identifying large areas that have high ecological integrity is the assumption that these areas will have greater resistance and resilience to CAs, such as fire or drought. The inclusion of this concept in the REA is not without controversy, however, and past attempts to assess ecological integrity have proven to be impractical due to the lack of empirical data at an ecoregional scale that can be used to create and evaluate an index of ecological integrity. Instead, other REAs have developed an index of intactness (Colorado Plateau REA), or landscape condition (Central Basin REA). Other regional assessments have used similar terms, such as an index of naturalness (Theobald, 2010). A common feature of these indices is that they include development as a primary CA. In addition, each of these indices is based on the premise that low-scoring areas represent large, relatively undeveloped areas that are assumed to be more natural or intact relative to areas with higher index scores. This assumption cannot be tested readily, therefore, it would be more accurate and direct to simply define areas with low development scores as “relatively undeveloped” without assuming that they are more intact or natural than other areas. We assume that the higher the development score, the higher the risk to the CE. The development scores also can indicate the potential need for conservation (low scores) or restoration (high scores). Likewise, potential risks from other CAs can compound the potential risks from development; thus, we will explore the potential to combine risk scores from all CAs into an overall threat index for the REA.

Where Are the Large Intact Areas?

The overall development index can be used to identify large, relatively undeveloped areas based on development index scores of less than 1 percent (fig. 19). Areas lacking any surface disturbance within a 16-km^2 area, as defined by the development index, represent about 15 percent of the Wyoming Basin REA project area (fig. 20, upper panel). In general, the lowest development scores occur at high elevations, whereas smaller, undeveloped areas are scattered throughout the ecoregion. Because much of the undeveloped area scored as 0 percent falls within the buffer surrounding the Wyoming Basin ecoregion, we also summarize the development index score for the Wyoming Basin ecoregion without the buffer (fig. 20, lower panel; appendix fig. 1-1). Alternative break points for defining relatively undeveloped areas could be used. Information on the amount and distribution of relatively undeveloped areas can be summarized in various ways (for example, by land ownership). The location of relatively undeveloped areas can be used in conjunction with other, more detailed site-level information to help to set conservation priorities and inform management decisions.

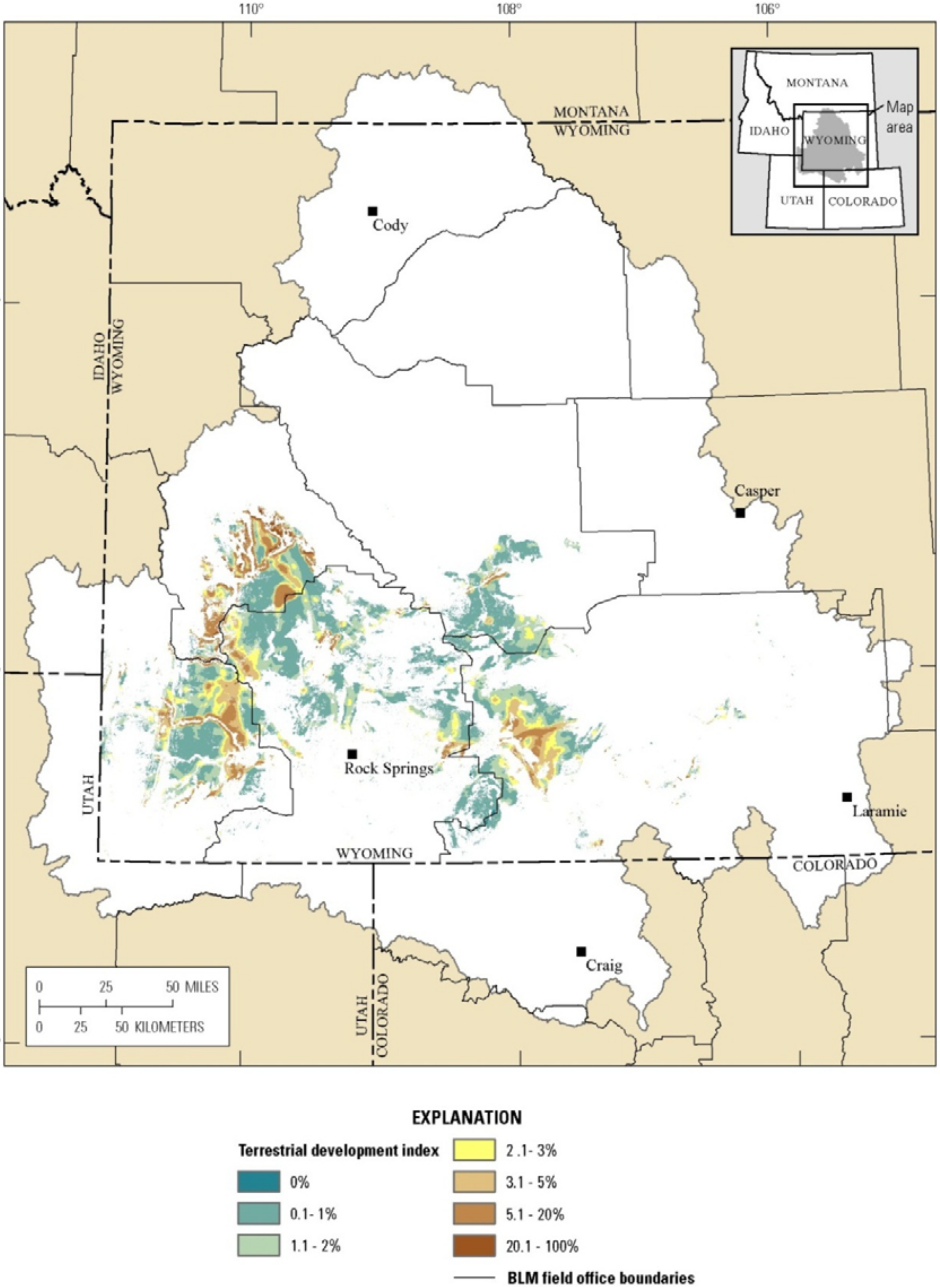

Figure 17. Conservation Element-Change Agent overlays for pygmy rabbit (*Brachylagus idahoensis*). The development index scores for pygmy rabbit habitat derived from the Wyoming Natural Diversity Database distribution map (probability of occurrence greater than 0.4) are shown.

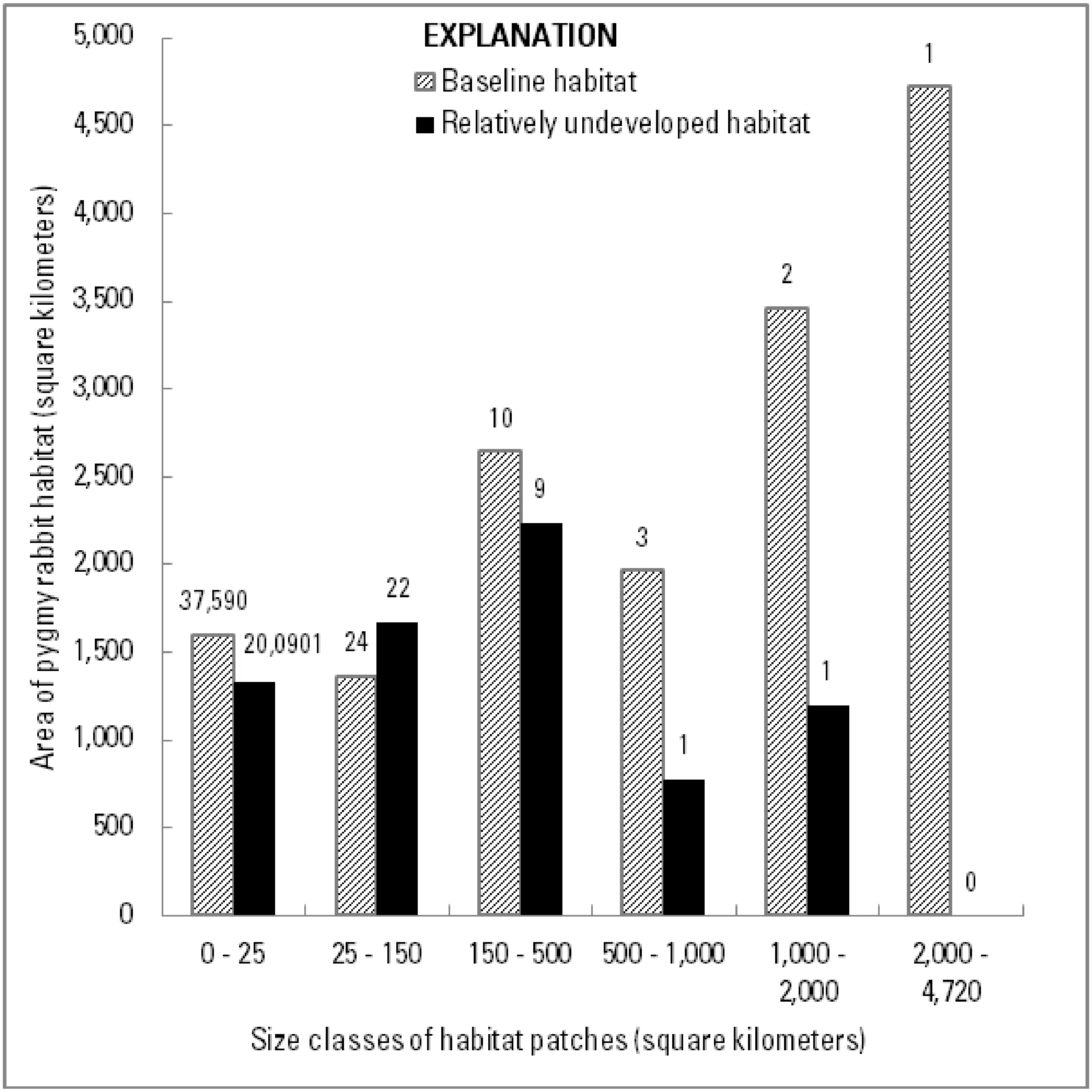

Figure 18. Results of Conservation Element-Change Agent overlays for pygmy rabbit (*Brachylagus idahoensis*) habitat patches. The amount of area in various size classes of habitat patches under "baseline" conditions can be compared to the difference in the size classes of relatively undeveloped habitat patches (baseline habitat with a development index score of less than or equal to 1 percent). The number above each bar is the number of patches in that size class.

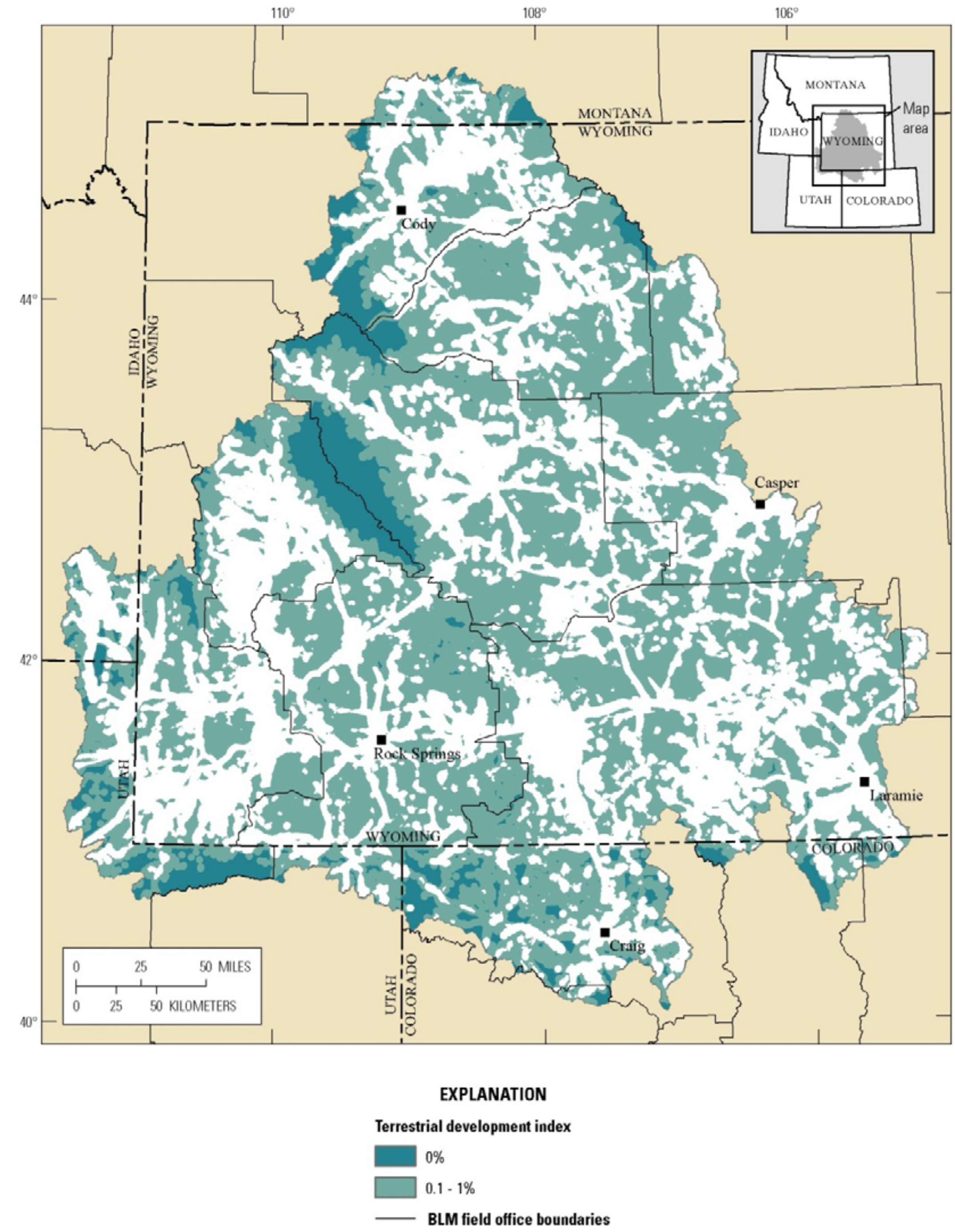

Figure 19. Relatively undeveloped areas in the Wyoming Basin Rapid Ecoregional Assessment project area, based on development of less than or equal to 1 percent surface disturbance from development activities.

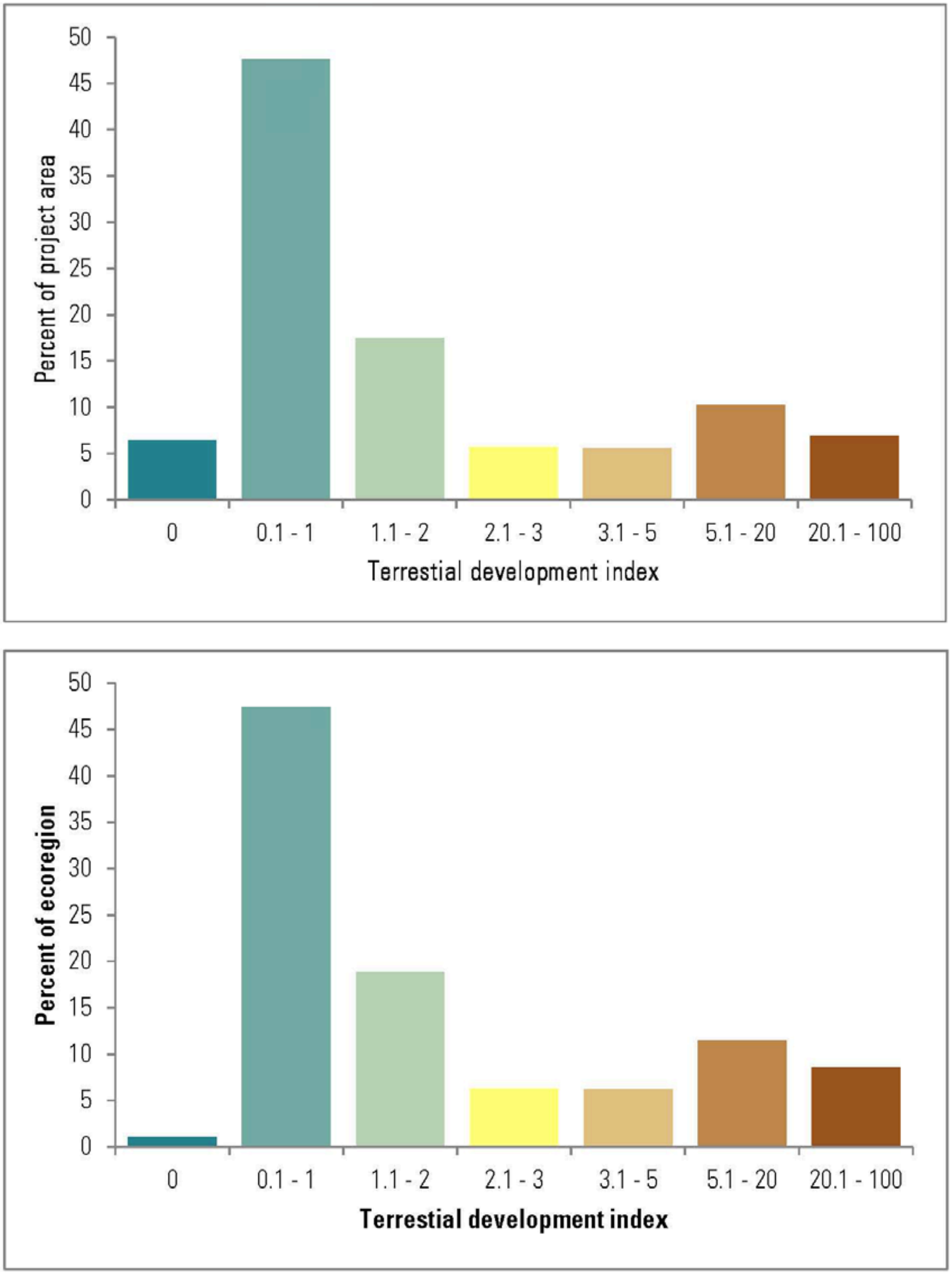

Figure 20. The percent of land in each development index class for the entire Wyoming Basin Rapid Ecoregional Assessment project area (top panel; see fig. 8), and the percent of land in each development index class falling within the ecoregion boundary (bottom panel; see fig. 1–1 in appendix for the ecoregion boundary map). Approximately 5 percent of areas with a development index score of 0 percent fall outside the ecoregion boundary in high-elevation portions of the project area.

Application of the work plan for the Wyoming Basin Rapid Ecoregional Assessment Phase II

This work plan will serve as the road map for conducting the assessment in Phase II. For each CA, we will develop an overall threat or risk index. We will follow the steps outlined in Figure 6 and described in this work plan to assess the status of each CE. To facilitate review of the methods and products developed for each CE, we will provide CE packets to the subject matter experts and the AMT. The CE packet will include a short narrative on the relevant CAs, key ecological attributes, and methods; conceptual models (figs. 4 and 5); a CA table (tables 7 and 8); a key ecological attribute table (table 5); map products; and a brief discussion of the results. The CE packets will be included in the final REA report.

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Appendix. Supporting Materials

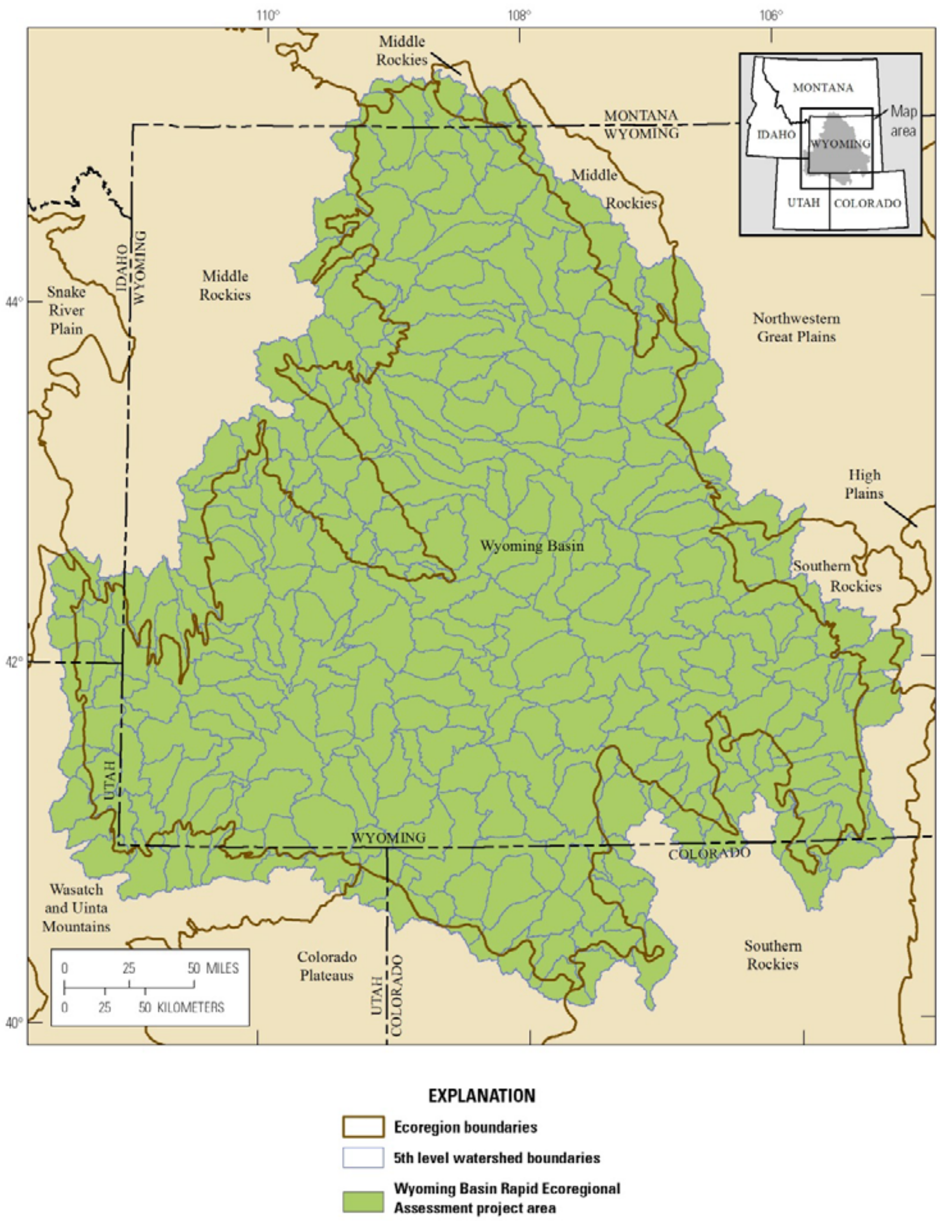

Figure 1–1. Wyoming Basin Ecoregional Assessment Project Area (green), with 5th-level (Hydrologic Unit Code [HUC]) watershed boundaries shown (pale blue lines). The 5th-level HUC is one of the required reporting units for assessing the status of Conservation Elements. The Wyoming Basin Ecoregion corresponds to Level III Ecoregion 18, as defined by the U.S. Environmental Protection Agency *(*http://www.epa.gov/wed/pages/ecoregions.htm), which is based on Omernik (1987).

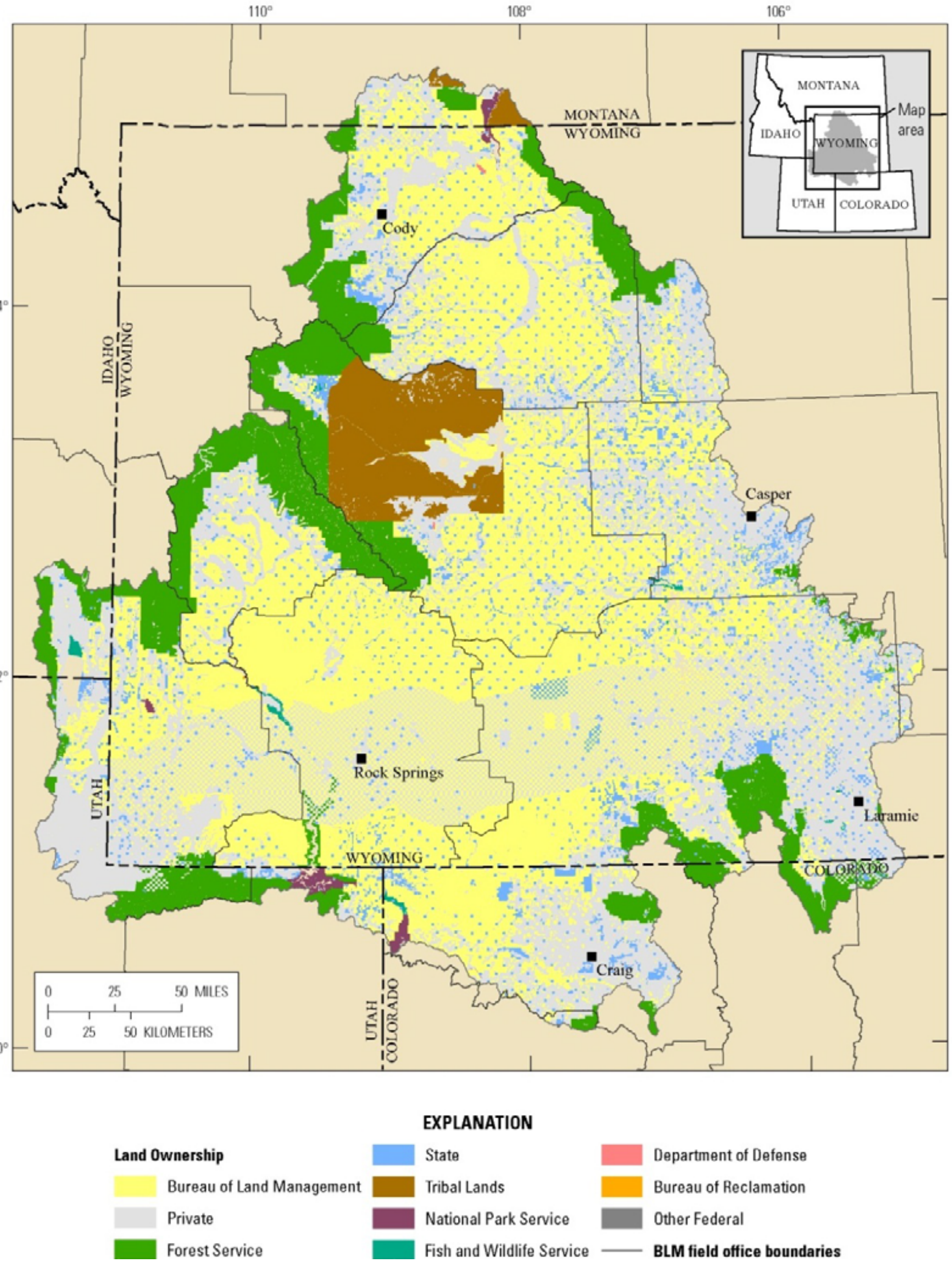

Figure 1–2. Wyoming Basin Rapid Ecoregional Assessment project area and jurisdictions, including Bureau of Land Management (BLM) Field Office boundaries. National Park Service lands include Dinosaur National Park, Fossil Butte National Monument, and Bighorn Canyon National Recreation Area. USDA Forest Service lands include Routt, Roosevelt, and Shoshone National Forests. Fish and Wildlife Service lands include Seedskadee, Cokeville, Mortenson Lake, Brown's Park, Bear Lake, Bamforth, Hutton Lake, and Pathfinder National Wildlife Refuges. Tribal lands include the Wind River and Crow Indian Reservations. Department of Defense lands include Powell Air Force Station. Bureau of Reclamation lands include Bighorn, Big Sandy, Fontenelle, Flaming Gorge, Seminoe, Pathfinder, and Buffalo Bill Reservoirs.

Table 1–1. Species initially considered as Conservation Elements, but which did not meet the Selection Criteria. An explanation of why these species were excluded is provided. Data will be compiled for these species, but the status for these species will not be evaluated for the Wyoming Basin Rapid Ecoregional Assessment.

	Conservation Element (CE) selection criteria					
	I	II	III	IV	V	
Species[1]	Regional significance	Management priority	Coarse filter sufficient	Bureau of Land Management state lists[2]	Commodity species[3]	Why excluded
Fish						
Bear River fish: mountain & Utah suckers, mottled sculpin, speckled & long-nosed dace, redside shiner, mountain whitefish[3]	No	High (Utah only)	No	None	No	Most species do not meet criterion V; possibly include mountain whitefish as an indicator
Amphibians/reptiles						
Northern leopard frog	Yes	High	Yes	WY, CO, MT, ID	No	Addressed by Coarse Filter
Midget faded rattlesnake	No	High	No	WY, CO	No	Did not meet criterion I
Northern tree lizard	No	Medium	No	None	No	Did not meet criterion I
Mammals						
Bats	Yes	High	No	All states	No	Data limitations
Wyoming pocket gopher	No	Medium	No	WY	No	Did not meet criterion I
Idaho pocket gopher	No	Medium	No	WY	No	Did not meet criterion I
Black-tailed prairie dog assemblage (incl. black-footed ferret, mountain plover, burrowing owl)	No/Yes	High	No	WY, CO	No	The prairie dog did not meet criterion I and would be difficult to map
White-tailed prairie dog	Yes	High	No	WY, CO, UT, MT	No	Data limitations
Crucial winter range/ corridors/transition range for mule deer, elk, pronghorn	Yes	High	No	None	Yes	Addressed by individual CE species status assessments
Bighorn sheep	No	High	No	CO, ID (but outside the assessment area)	Yes	Addressed via Step-down process
Plants						

	Conservation Element (CE) selection criteria					
	I	II	III	IV	V	
Species[1]	Regional significance	Management priority	Coarse filter sufficient	Bureau of Land Management state lists[2]	Commodity species[3]	Why excluded
Mountain shrub community	Yes	High	No	None	No	Addressed by mule deer CE
Federally listed plant species that occur in one or more states (Ute ladies' tresses, desert yellowhead, blowout penstemon)	No	High	No	All states	No	Data limitations; may be addressed by soils or species richness
Other priority species, terrestrial/aquatic communities or systems						
Additional Federally listed Animal species that occur in one or more states (black-footed ferret, gray wolf, grizzly bear, Wyoming toad)	Yes	High	No	All states	No	Addressed by existing programs, will include as data layers
Bureau of Land Management sensitive plant species list	No	High	No	All states	No	Data limitations; may be addressed by soils or species richness
Sensitive soils	Yes	High	No	Not applicable	Not applicable	Data limitations; potential for reclamation is a Management Question

[1] Scientific names of species listed above are as follows: mountain sucker (*Catostomus platyrhynchus*), Utah sucker (*Catostomus ardens*), mottled sculpin (*Cottus bairdii*), speckled dace (*Rhinichthys osculus*), long-nosed dace (*Rhinichthys cataractae*), redside shiner (*Richardsonius balteatus*), mountain whitefish (*Prosopium williamsoni*), northern leopard frog (*Lithobates pipiens*), midget faded rattlesnake (*Crotalus oreganus concolor*), northern tree lizard (*Urosaurus ornatus*),Wyoming pocket gopher (*Thomomys clusius*), Idaho pocket gopher (*T. idahoensis*), black-tailed prairie dog (*Cynomys ludovicianus*), black-footed ferret (*Mustela nigripes*), mountain plover (*Charadrius montanus*), burrowing owl (*Athene cunicularia*), white-tailed prairie dog (*C. leucurus*), mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), pronghorn (*Antilocapra americana*), bighorn sheep (*Ovis canadensis*),Ute ladies' tresses (*Spiranthes diluvialis*), desert yellowhead (*Yermo xanthocephalus*), blowout penstemon (*Penstemon haydenii*), gray wolf (*Canis lupus*), grizzly bear (*Ursus arctos horribilis*), Wyoming toad (*Anaxyrus baxteri*).
[2] WY = Wyoming, CO = Colorado, MT = Montana, ID = Idaho, UT = Utah
[3] Game and furbearer species.

Table 1–2. Area and percentage of land managed or owned by different entities in the Wyoming Basin Rapid Ecoregional Assessment project area (based on fig. 1-2).

Jurisdiction	Area (hectares)	Percentage
Bureau of Land Management	7,542,621.15	42
Private	6,032,135.12	34
USDA Forest Service	2,174,365.40	12
States	1,072,238.44	6
Tribal lands	775,899.67	4
Lakes/reservoirs	146,675.40	1
National Park Service	61,500.19	<1
Fish and Wildlife Service	28,978.59	<1
U.S. Department of Defense	2,010.81	<1
Bureau of Reclamation	421.40	<1
Other Federal lands	54.72	<1

Table 1–3. Total area of Bureau of Land Management Field Offices in the Wyoming Basin Rapid Ecoregional Assessment project area.

State	Field Office	Area (aces)
Colorado	Kremmling	397,592
	Little Snake	2,938,376
	Royal Gorge	93,442
	White River	76,038
Idaho	Pocatello	677,670
Montana	Billings	645,828
Utah	Salt Lake	1,629,211
	Vernal	468,809
Wyoming	Buffalo	902,889
	Casper	2,729,429
	Cody	2,956,473
	Kemmerer	3,314,165
	Lander	6,455,151
	Pinedale	2,754,351
	Rawlins	8,920,669
	Rock Springs	5,359,393
	Worland	3,764,212

Table 1–4. Core Management Questions.

Where are the priority Conservation Elements?
What is the spatial distribution of the Conservation Element?
What are the key ecological attributes and ecological functions of the Conservation Element?
What is the distribution of key ecological attributes?
What are the baseline conditions of the key ecological attributes of the Conservation Element (for example, size, connectivity)?
What is the historical (or desired) range of variation in dynamics/spatial patterns of the Conservation Element (alternatively current conditions may be evaluated as baseline conditions due to the difficulty of defining historic or desired range of variation)?
Where has the Conservation Element changed?
Where is the Conservation Element degraded, intact, or high value (for example, large areas, natural flow regime, important functions)?
Where are the Change Agents?
Where is the Change Agent occurring?
Where has the Change Agent changed?
What are the predicted future trends (including potential development areas) of the Change Agent?
What is the magnitude & spatial distribution of the Change Agent?
What are the historical trends & distribution of the Change Agent?
Where do the Conservation Elements and Change Agents intersect and how do Change Agents affect the spatial distributions of Conservation Elements?
What are the key CAs affecting the Conservation Element?
Where will the Conservation Element be affected by projected future changes?
Where will the Conservation Element be most vulnerable to future change?
Where are Change Agents most likely to affect key ecological attributes and ecosystem functions?

Table 1–5. Integrated Management Questions.

Where are the priority areas (rare, unique, and crucial habitat types/species assemblages)?
Where are the Federal, State, and non-governmental designated lands (including Areas of Critical Environmental Concerns, Wilderness Study Areas, National Wildlife Refuges, National Parks, No Surface Occupancy Areas, Withdrawn Areas, Forest Service Wilderness Areas, priority sites in State Wildlife Action & Strategic Habitat Plans, Trout Unlimited's National Fish Action Plan sites, sites in The Nature Conservancy's terrestrial portfolio, NatureServe sites, National Audubon's Important Bird Areas, sites recognized by Partners-in-Flight)?
Where are specially designated areas of high ecological value (designated by various agencies or in other work)?
Where are the potential areas for conservation ?
Where are areas with potential for high conservation priority based on the status assessments developed for the Rapid Ecoregional Assessment?
What/where is the potential for future change to the areas with potential for high conservation priority?
Where are large areas of native vegetation?
Where are the large, intact areas?
What is the distribution of rare/endemic plant species (valuation for pockets of endemism, ecological integrity layer)?
Where are the key habitat types (seasonal refuges, corridors/connectivity, migration routes, and concentrations of regionally significant species)?
Which Conservation Element vegetation types/habitats are suitable for potential migratory corridors?
Where are the big game transition/migration areas?
Where are migration areas for non-game terrestrial species?
Where are areas of greatest carbon sequestration?
Where are the potential areas for restoration or development?
Where are potential connectivity-restoration areas (undesignated areas/potential corridors adjacent to areas specially designated for their high ecological value)?
Where are potential site-restoration areas that would enhance connectivity?
Where are degraded aquatic systems (water quality) and what are the sources of the degradation (saline discharges, petrochemical discharges, leaching of toxic mineral salts, eutrophication due to concentrated nutrient runoff, other)?
Which invasive species have significant effects on ecosystem function and where are they significantly affecting ecosystem function?
Where are invasive species likely to spread?
What is the potential extent of riparian areas when compared with current riparian areas?
Where do important habitats need protection from off-road vehicles?
Where are potential development areas in which there would be minimal conflicts with Conservation Elements ?
Where are reclaimed brownfields and (or) greyfields appropriate for developing renewable energy?

Where do Change Agents pose the greatest threats?
Where do Change Agents pose greatest risks to the most vulnerable sites (compiling Change Agents and Conservation Elements)?
Which factors/Change Agents are driving site vulnerability?
How does site vulnerability to Change Agents relate to resistance and resilience?
Where will current Conservation Element vegetation types be at greatest risk from Change Agents?
Where are riparian/aquatic areas currently at risk of fragmentation due to impoundment/diversion or lowered water tables due to energy development, mineral extraction, and (or) agricultural/residential development?
Where are sensitive soils that are susceptible to disturbance and difficult to reclaim after disturbance?
Which Change Agents are likely to affect soil fertility and erodibility, especially if cover is removed?
Where are areas with potentially leasable subsurface minerals (for example, coal, uranium, trona)?

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