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U.S. Geological Survey Science for the Wyoming Landscape Conservation Initiative—2014 Annual Report

Open-File Report 2015–1091

U.S. Department of the Interior
U.S. Geological Survey

Cover photographs: (Front cover) Doe and fawn mule deer in early winter, along the east side of the Wyoming Range. Photo by Matthew Hayes, Wyoming Cooperative Fish and Wildlife Research Unit. (Back cover) Matt Hayes, Spatial Analyst with the Wyoming Cooperative Fish and Wildlife Research Unit, using telemetry to track collared mule deer as they return to their winter range in the Red Desert, Wyoming, in December 2014. These deer migrate more than 150 miles from their summer range in the Hoback Mountains to their winter range in the Red Desert, Wyoming.

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U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2015

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Conversion Factors

Inch/Pound to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
yard (yd)	0.9144	meter (m)
	Area	
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	2.590	square kilometer (km^2)

International System of Units to Inch/Pound

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
square kilometer (km^2)	247.1	acre
square kilometer (km^2)	0.3861	square mile (mi^2)

Common and Scientific Names of Species in this Report

Common name	Scientific name	Common name	Scientific name
Aspen	*Populus tremuloides*	Mountain sucker	*Catostomus platyrhynchus*
Brewer's sparrow	*Spizella breweri*	Mottled sculpin	*Cottus bairdii*
Cheatgrass	*Bromus tectorum*	Mule deer	*Odocoileus hemionus*
Chipmunk	*Tamias minimus*	Pronghorn	*Antilocapra americana*
Chokecherry	*Prunus virginiana*	Pygmy rabbit	*Brachylagus idahoensis*
Colorado River cutthroat trout	*Oncorhynchus clarki pleuriticus*	Sage thrasher	*Oreoscoptes montanus*
Currant species	*Ribes* spp.	Sagebrush sparrow	*Artemisiospiza nevadensis*
Curl-leaf mountain-mahogany or curl-leaf mahogany	*Cercocarpus ledifolius*	Sagebrush species	*Artemisia* spp.
Deer mouse	*Peromyscus maniculatus*	Serviceberry	*Amelanchier alnifolia*
Elk	*Cervus canadensis*	Snowberry	*Symphoricarpos spp.*
Gooseberry species	*Ribes* spp.	Thirteen-lined ground squirrel	*Ictidomys tridecemlineatus*
Greater sage-grouse	*Centrocercus urophasianus*	Uinta ground squirrel	*Urocitellus armatus*
Mountain mahogany	*Cercocarpus montanus*	Sumac species	*Rhus* spp.

Abbreviations Used in this Report

BLM	U.S. Bureau of Land Management
FY	fiscal year (for example, Federal FY2014 was October 1, 2014 through September 30, 2015)
IA	Integrated Assessment (for the Wyoming Landscape Conservation Initiative)
IAMD	Interagency Monitoring Database
IAMT	Interagency Monitoring Team
LME	Little Mountain Ecosystem
LPDT	Local Project Development Team
MODIS	Moderate Resolution Imaging Spectroradiometer (a moderate-resolution sensor aboard the Terra Satellite)
MT	U.S. Geological Survey Monitoring Team (for the Wyoming Landscape Conservation Initiative)
NDVI	normalized difference vegetation index
QB1	QuickBird site 1 (a high-resolution scene in Southwest Wyoming captured by the QuickBird satellite)
TM	Thematic Mapper (a high-resolution sensor aboard the Landsat 5 satellite)
USGS	U.S. Geological Survey
WGFD	Wyoming Game and Fish Department
WLCI	Wyoming Landscape Conservation Initiative

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Introduction

Assessing and Enhancing Wildlife Habitats While Facilitating Responsible Energy Development

Wildlife, habitat, open spaces, and outdoor recreational opportunities abound in southwestern Wyoming. The region also supports important agricultural economies and is rich in energy resources. Since the late 1800s, Southwest Wyoming has been an important source of coal, oil, gas, and uranium resources that help to meet the Nation's energy demands, but the pace of energy development in the region, including the generation of wind power, began to accelerate in the early 2000s. In turn, urban and exurban development also have accelerated across Southwest Wyoming. As all forms of development increase, so do concerns that broad-scale changes are diminishing wildlife habitat and the quality of human life across the Southwest Wyoming landscape. In 2007, these concerns led to development of the Wyoming Landscape Conservation Initiative (WLCI) (fig. 1).

The WLCI mission is to implement a long-term, science-based program to assess and enhance the quality and quantity of aquatic and terrestrial habitats at a landscape scale in Southwest Wyoming, while facilitating responsible development through local collaboration and partnerships.

Partnerships, Cooperation, and Stakeholder Involvement: Key to WLCI Success

In 2007, WLCI partners entered into a memorandum of understanding that outlined the WLCI's mission, objectives, organization, and partner roles. Partners provide representatives to the WLCI leadership teams and bring their individual strengths and capabilities to the overall WLCI effort. Partners with jurisdiction over public lands and (or) resource-management responsibilities also conduct the planning, decision-making, and implementation of management actions and best management practices across the WLCI region. Since its inception, significant progress has been made in attaining many of the WLCI goals and objectives. This has been made possible, in part, by the Initiative's approaches to partnership, cooperation, and stakeholder involvement. See https://www.wlci.gov/partners for a listing of WLCI partners and specifics about their roles in the WLCI.

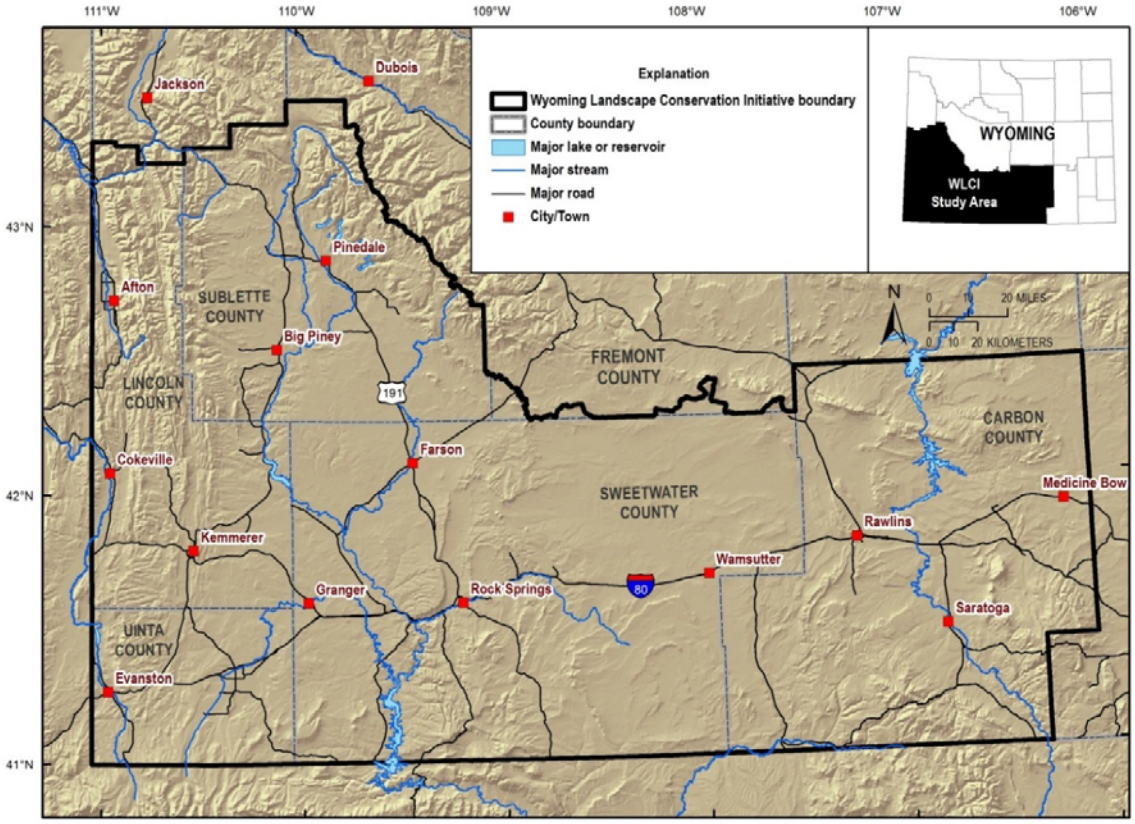


Figure 1. The Wyoming Landscape Conservation Initiative (WLCI) region, which includes all or part of six counties.

The U.S. Geological Survey: Building a Strong Science Foundation to Support the WLCI

The U.S. Geological Survey (USGS) is the WLCI partner responsible for building the scientifically defensible foundation on which WLCI planners, decision-makers, and resource managers may base their WLCI activities. Since 2008, more than 50 USGS scientists, technical experts, and field staff have participated in WLCI science and coordination activities. The Science Team includes wildlife and plant ecologists; geologists (including specialists in energy and minerals); hydrologists; socioeconomic analysts; geographers; experts in remote sensing, geographic information systems, and the analyses of geospatial data; and technologists skilled at building the infrastructure necessary for centralizing, compiling, archiving, standardizing, and displaying (mapping) huge quantities of data, and for developing the Web applications needed by WLCI partners for making the data, tools, and information products accessible and interpretable. The USGS also provides the leadership for the WLCI Interagency Monitoring Team, the mission of which is to standardize and coordinate WLCI monitoring activities and build a centralized Interagency Monitoring Database.

Finally, the USGS also provides a full-time liaison to the WLCI Coordination Team. The liaison helps to facilitate WLCI partner communications and coordinate activities conducted by WLCI partners.

Results of the Science Team's work provide a growing reservoir of knowledge from which the liaison draws to help inform adaptive management strategies, Best Management Practices, and prioritization of on-the-ground habitat projects developed by WLCI partners. The liaison also helps to ensure that new knowledge and technologies are integrated with ongoing and future science and habitat conservation projects and helps to ensure the dissemination, interpretation, and use of USGS products by WLCI partners, collaborators, and stakeholders.

The USGS Science Team: Building a Scientifically Defensible Foundation for the WLCI

- We have provided a multidisciplinary team comprising more than 50 scientists and technological experts.
- We conduct science and develop tools that help to inform and support WLCI partner planning, decision-making, and on-the-ground management actions.
- We provide a liaison to the WLCI Coordination Team to
    - facilitate coordination, communication, and activities among WLCI partners;
    - help partners with integrating new information and technologies in their planning, decision-making, and management actions; and
    - facilitate dissemination, interpretation, and use of U.S. Geological Survey findings, products, and tools.
- We provide leadership to the Interagency Monitoring Team.

Identifying and Prioritizing USGS Science Projects and Tool-Development Activities

Prior to WLCI implementation, a series of workshops was held during which potential WLCI partners and leadership teams identified and refined major management needs and objectives for the WLCI region (table 1) (D'Erchia, 2008). Those needs and objectives fell into four broad themes that were to serve as a foundation for USGS WLCI science.

- Identify and assess the cumulative environmental effects (current and future) associated with energy development and other major drivers of landscape change.
- Develop methods for efficient, effective monitoring of ecosystem conditions across a vast and heterogeneous landscape.
- Evaluate the efficacy of habitat enhancement and restoration projects in meeting objectives.

- Develop the tools for housing, displaying, and disseminating data and other information to support planning and decision-making for conserving ecosystem function and integrity in Southwest Wyoming.

Priority Habitats of the WLCI Region

Sagebrush steppe ★ Aspen ★ Mixed mountain shrubland ★ Riparian ★ Aquatic

The WLCI partners also identified five priority habitats that would be central to all WLCI activities, including science and technological projects conducted by the USGS and on-the-ground conservation activities conducted by WLCI partners. Partners further emphasized that WLCI science and conservation activities target Wyoming's wildlife Species of Greatest Conservation Need (Wyoming Game and Fish Department, 2010). The workshops culminated with a collaborative effort between the USGS and other WLCI partners to develop a list of potential short- and long-term science activities that would help partners to achieve their management objectives.

Subsequently, the USGS developed a Science Strategy (Bowen, Aldridge, Anderson, Chong, and others, 2009) for addressing WLCI partner management needs and objectives. The strategy includes a "conceptual" framework (fig. 2) for organizing and guiding USGS WLCI science and related activities (table 2). The foundational tier of our science strategy is a large-scale, ongoing Baseline Synthesis, which entails synthesizing data for assessing current ecosystem conditions and the cumulative effects of land-use changes, climate change, and other drivers of change across the WLCI landscape. Major aspects of the Baseline Synthesis are to acquire, compile, standardize, and integrate existing and new data for ascertaining baseline conditions (including mapping natural resource distributions and developing indices of resource status), conducting landscape-scale assessments, and projecting potential trajectories of habitat conditions and wildlife populations under future scenarios of energy development and other changes.

The Baseline Synthesis provides a solid science foundation for our Targeted Monitoring and Research and includes projects that focus on (1) inventory and long-term monitoring of WLCI natural resources, (2) effectiveness monitoring of on-the-ground WLCI habitat enhancement and restoration projects, and (3) research studies designed to elucidate the ways in which energy development, climate change, invasive species, and other change agents affect important wildlife and their habitats. All three focal areas of the Targeted Monitoring and Research work also include developing and testing the efficacy of innovative methods for landscape-scale monitoring, particularly fusing data collected from the field and ground-based instruments with various types of satellite imagery and other remotely sensed data. In turn, the data and other information derived from these studies are integrated into the Baseline Synthesis to build the overall science foundation for the WLCI region and other large-scale conservation initiatives.

Table 1. Major management needs and objectives identified by partners of the Wyoming Landscape Conservation Initiative during workshops and meetings prior to initiative implementation.

Management need	Objectives
1. Identify key drivers of change	A. Identify, quantify, and prioritize key drivers of change, including interactive drivers and those measured inadequately in the past, such as energy-development footprints over time (including initial surficial disturbance and associated short- and long-term disturbances, fire, invasive species, and livestock grazing). B. Develop new methods or improve or refine models for predicting potential changes in key drivers over time and projecting likely future responses to them. C. Improve predictive capabilities of future scenario models, update scientific understanding of the origin and occurrence of energy and mineral resources based on most current information for viable deposit types and assessment units. D. Develop methods to assess full costs (exploration, extraction, use) of energy and mineral development.
2. Identify condition and distribution of key wildlife species and habitats and species habitat requirements	A. Identify key aquatic and terrestrial species or assemblages (including indicator, umbrella, socially and economically important, or special status species). B. Assess baseline conditions and determine landscape-level habitat requirements for important aquatic and terrestrial species (special status, keystone, economically and socially important). C. Use Wyoming Game and Fish Department's Strategic Habitat Plan as a foundation to delineate spatiotemporal habitat distribution, map key, and high-quality habitats for key species and assemblages. D. Identify key areas of conservation concern and priority by mapping important, sensitive, and rare habitats, critical habitats (including nesting, rearing, wintering, spawning, and migration) required for long-term persistence of key wildlife species. E. Identify vulnerability and sensitivity of key habitats and areas to key drivers of change. F. Relate habitat characteristics to animal distribution and population dynamics (an index of habitat quality) to assess effects of key drivers of change on aquatic and terrestrial wildlife and habitats.
3. Evaluate wildlife and livestock responses to development	A. Evaluate direct effects of energy development and other major drivers on physiology and demographic performance of wildlife (individual species and species groups) and livestock. B. Evaluate indirect effects of habitat alteration on wildlife and livestock from invasive non-native plants, altered disturbance regimes, increased susceptibility to disease, altered social dynamics, or other changes. C. Assess different patch-size needs and edge effects that influence wildlife behavior and population structure and growth. D. Develop methods to assess influence of energy development on livestock-management systems.
4. Evaluate the effectiveness of restoration, reclamation, and mitigation activities	A. Evaluate effectiveness of specific habitat improvement and restoration practices in different habitat types and precipitation zones. B. Evaluate and guide refinement of best management practices. C. Evaluate relations between observed resource responses and management activities (restoration, reclamation, and habitat-improvement projects). D. Design a framework for objectively developing the most effective restoration and enhancement projects on a landscape scale.
5. Develop an integrated inventory and monitoring strategy	A. Develop inventory and monitoring approach designed to evaluate overall effectiveness of WLCI (on-the-ground habitat projects) and support assessment of cumulative effects. B. Coordinate with WLCI partners to establish landscape-scale monitoring strategies and protocols. C. Integrate WLCI inventory and monitoring programs with other local, State, and Federal efforts. D. Make inventory and monitoring information accessible to WLCI partners and resource managers through data-management framework and data clearinghouse. E. Integrate inventory and monitoring efforts into an adaptive management framework.
6. Develop a data clearinghouse and information management framework	A. Develop a Web-based WLCI information clearinghouse that can protect confidential, sensitive, and (or) proprietary information. B. Develop and implement a project tracking and database system to provide summaries of habitat projects and associated spatial data. C. Provide data-management, visualization (mapping), and decision-support tools for WLCI. D. Provide public information and outreach on WLCI habitat improvement and science activities.

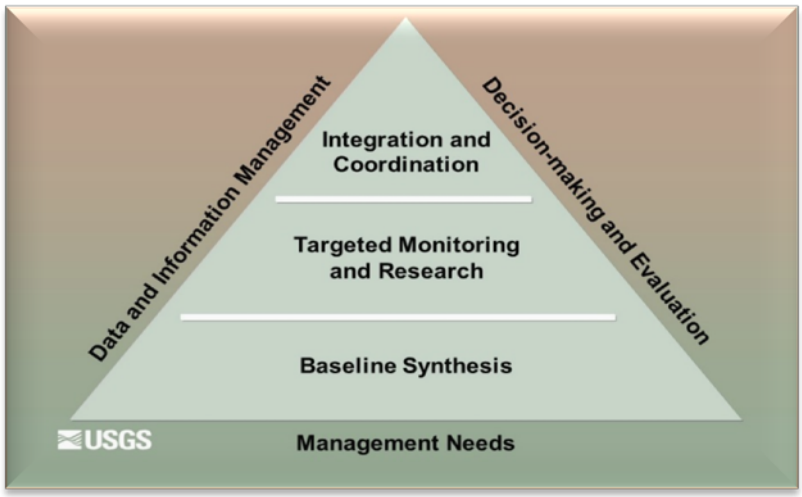


Figure 2. The U.S. Geological Survey's framework for guiding assessment, monitoring, and research of ecosystem components. The Management Needs identified by the Wyoming Landscape Conservation Initiative (WLCI) partners form the foundation of the major U.S. Geological Survey science activities for the WLCI: (1) Baseline Synthesis, (2) Targeted Monitoring and Research, (3) Integration and Coordination, and (4) Data and Information Management, which inform and support (5) WLCI Decision-making and Evaluation. The first three of these activities represent successive stages that build on information gained from earlier stages, and at all stages Data and Information Management ensures access to information and data for use in Decision-making and Evaluation. This approach is iterative and allows for stages to overlap.

A primary means of identifying and prioritizing USGS WLCI science and associated technological support activities is the list of short- and long-term research activities originally developed by WLCI partners in collaboration with the USGS and outlined in the USGS Science Strategy. The USGS Science Team has made substantial progress on (or completed) a majority of the proposed activities. As new information is gained and new technologies are developed, some of the ongoing activities have benefited from retooling or a shift in emphasis, and new activities have been implemented to reflect emerging needs or priorities. New science directions are identified through meetings with the WLCI leadership committees and teams responsible for overseeing and guiding the WLCI effort, including the WLCI Executive Committee, Coordination Team, Science and Technical Advisory Committee, Steering Committee, Local Project Development Teams (LPDTs), and the Interagency Monitoring Team (IAMT). Also, each year, the Steering Committee and the LPDTs meet to identify habitat enhancement and restoration priorities for the following year. In turn, these priorities help to guide USGS WLCI science activities. This iterative process of review and refinement helps to ensure that USGS science remains highly relevant to WLCI partner needs, new information, and changing conditions.

Table 2. Summary of U.S. Geological Survey science and technical development projects conducted in Fiscal Year (FY) 2014 for the Wyoming Landscape Conservation Initiative (WLCI). For each project, the WLCI management needs and objectives addressed (directly or indirectly) by the project are listed by alphanumeric codes that correspond to management needs and associated objectives listed in table 1 (for example, 1A is Management Need 1, objective A). The summary also includes project status as of September 30, 2014, focal species and (or) habitats addressed by the project, and intended or potential applications of project outcomes (such as products, databases, models, or Web tools). Activity titles and page numbers (no.) are hotlinked so that users may go directly to the individual project reports for activities of particular interest.

[N/A, not applicable]

Management needs and objectives addressed	Project title	Status at end of FY2014	Focal species and (or) habitat	Intended and potential applications of project outcomes	Page no.
Baseline Synthesis activities					
1A–C; 2A–F; 3A; 5D	*Application of comprehensive assessment to support decision-making and conservation actions; integrated assessment*	Ongoing	Any species and focal habitat in WLCI study area	Status and trends, science foundation, policy and outreach	*26*
1A–C; 2A–B, F; 3A; 5A	*Modeling land use and cover change*	Ongoing	Greater sage-grouse, pygmy rabbit, mule deer; all focal habitats	Status and trends, policy and outreach, energy development	*27*
1A–C; 2B, F	*Assessing energy resources*	Ongoing	N/A	Science foundation, policy and outreach, energy development	*28*
1A–C; 2B, F	*Assessing mineral resources*	Ongoing	N/A	Science foundation, policy and outreach, energy development	*29*
1A, D; 2B; 3A–B,C; 4B; 5A, C–D	*Important agricultural lands in southwestern Wyoming*	Ongoing	N/A	Science foundation, policy and outreach	*31*
Long-Term Monitoring activities					
2A–F; 2A–B; 3A–C; 4A, C; 5A–E	*Framework and indicators for long-term monitoring* (including leadership and support for the Interagency Monitoring Team)	Ongoing	All focal habitats	Status and trends, science foundation, policy and outreach	*32*
1A–B; 3B–D; 4C; 5B,C	*Remote sensing and vegetation inventory and monitoring*	Ongoing	Sagebrush species, sagebrush steppe	Status and trends, science foundation	*33*
1A–B; 4C; 5B–D	*Long-term monitoring of surface water, groundwater, and water quality*	Ongoing	Riparian, aquatic	Status and trends, science foundation	*34*
1A–B; 3B; 4C; 5B–D	*Wyoming groundwater-quality monitoring network*	Ongoing	N/A	Status and trends, science foundation	*36*
1A–B; 4C; 5B	*Analysis of existing water wells in the Normally Pressured Lance Formation study area*	Ongoing	Aquatic	Status and trends, science foundation, energy development	*37*

Table 2. Summary of U.S. Geological Survey science and technical development projects conducted in Fiscal Year (FY) 2014 for the Wyoming Landscape Conservation Initiative (WLCI). For each project, the WLCI management needs and objectives addressed (directly or indirectly) by the project are listed by alphanumeric codes that correspond to management needs and associated objectives listed in table 1 (for example, 1A is Management Need 1, objective A). The summary also includes project status as of September 30, 2014, focal species and (or) habitats addressed by the project, and intended or potential applications of project outcomes (such as products, databases, models, or Web tools). Activity titles and page numbers (no.) are hotlinked so that users may go directly to the individual project reports for activities of particular interest.—Continued

[N/A, not applicable]

Management needs and objectives addressed	Project title	Status at end of FY2014	Focal species and (or) habitat	Intended and potential applications of project outcomes	Page no.
Effectiveness monitoring activities					
1A; 2A–C,E–F; 3A–C; 4A–D; 5A–E	*Applying greenness indices to evaluate sagebrush in the WLCI region*	Ongoing	Sagebrush species, sagebrush steppe	Status and trends, science foundation, policy and outreach	*39*
1A; 2A–D,F; 3A–C; 4A–D; 5A–E	*Mapping mixed mountain shrub communities to support WLCI conservation planning and effectiveness monitoring of habitat treatments*	Ongoing	Mountain and curl-leaf mahogany, serviceberry, chokecherry, antelope bitterbrush, mixed mountain shrubland	Status and trends, science foundation, policy and outreach	*41*
1A; 2A–C,E–F; 3A–C; 4A–D; 5A–E	*Greater sage-grouse use of vegetation treatments*	Ongoing	Greater sage-grouse, sagebrush steppe (grouse brood-rearing and nesting habitat)	Status and trends, science foundation, policy and outreach	*42*
1A; 2A–B; 3A–C; 4A–D; 5A–E	Occurrence of cheatgrass associated with habitat projects	Suspended[1]	Cheatgrass, sagebrush steppe	Status and trends, science foundation, policy and outreach	
1A; 2A–F; 3A–C; 4A–D; 5A–E	*Landscape assessment and monitoring of semiarid woodlands in the Little Mountain Ecosystem*	Ongoing	Aspen	Status and trends, science foundation, policy and outreach	*43*
1A; 2A–F; 3A–C; 4A–D; 5A–E	Aspen regeneration associated with mechanical removal of subalpine fir	Ongoing[2]	Aspen, conifer species	Status and trends, science foundation, policy and outreach	
1A; 2A–F; 3A–D; 4A–D; 5A–E	Herbivory, stand condition, and regeneration rates of aspen on burned and unburned plots	Ongoing[2]	Aspen	Status and trends, science foundation, policy and outreach	
2B,D,F; 3C; 4C; 5B, C; 6D	*Using science to help the National Park Service interpret a wildlife resource*	New, completed	Elk	Policy and outreach	*44*
2B,C,F; 3B; 4A,B,C; 5A	*Development and evaluation of synthetic high-resolution imagery for effectiveness monitoring*	Completed	Sagebrush steppe, elk	Status and trends, policy and outreach	*46*

Table 2. Summary of U.S. Geological Survey science and technical development projects conducted in Fiscal Year (FY) 2014 for the Wyoming Landscape Conservation Initiative (WLCI). For each project, the WLCI management needs and objectives addressed (directly or indirectly) by the project are listed by alphanumeric codes that correspond to management needs and associated objectives listed in table 1 (for example, 1A is Management Need 1, objective A). The summary also includes project status as of September 30, 2014, focal species and (or) habitats addressed by the project, and intended or potential applications of project outcomes (such as products, databases, models, or Web tools). Activity titles and page numbers (no.) are hotlinked so that users may go directly to the individual project reports for activities of particular interest.—Continued

[N/A, not applicable]

Management needs and objectives addressed	Project title	Status at end of FY2014	Focal species and (or) habitat	Intended and potential applications of project outcomes	Page no.
Mechanistic studies of wildlife					
1A–B; 2A–F; 3A–C; 4C; 5A–D	*Pygmy rabbit*	Ongoing	Pygmy rabbit, sagebrush steppe	Status and trends, science foundation, energy development	*48*
1A–B; 2A–F; 3A–C; 4C; 5A–D	*Mechanistic modeling for greater sage-grouse*	Ongoing	Greater sage-grouse, sagebrush steppe, sage-grouse core areas	Status and trends, science foundation, policy and outreach, energy development	*49*
1A–B; 2A–F; 3A–C; 4C; 5A–D	*Mechanistic understanding of energy development effects on songbirds*	Ongoing	Brewer's sparrow, sagebrush sparrow, sage thrasher, sagebrush steppe	Status and trends, policy and outreach, energy development	*50*
1A–B; 2A–F; 3A–C; 4C; 5A–D	*Mule deer: Identifying threshold levels of development that impede Wyoming ungulate migrations*	Ongoing	Mule deer, mixed mountain shrubland (crucial winter habitat)	Status and trends, policy and outreach, energy development	*51*
1A–B; 2A–F; 3A–C; 4C; 5A–D	*Influence of energy development on native fish communities*	Ongoing	Mountain sucker, mottled sculpin, Colorado River cutthroat trout and all other native fish species; aquatic and riparian habitats	Science foundation, policy and outreach, energy development	*53*
Data and information management activities					
5D; 6A–D	*Data management framework and catalog* (including development of a Web-based reference tool for partner monitoring activities and a data access tool to USGS remote sensing and other products)	Ongoing	N/A	Science foundation, policy and outreach	*55*
6B–D	*Web application development for data and information management*	Completed	N/A	Science foundation, policy and outreach	*56*
6A–D	*Outreach and graphic products*	Ongoing	N/A	Science foundation, policy and outreach	*58*

[1]Activities that entail ongoing monitoring and (or) analyses but which do not need annual data collection or other activities are placed on suspended status between years of activity.

[2]Activities that entail ongoing monitoring and (or) analyses but which did not have tangible outcomes or products in FY2014 are not included in this report.

A Summary of Major USGS Accomplishments for Addressing WLCI Management Needs

- We have acquired and synthesized a significant body of baseline data and used these data for developing an integrated, comprehensive assessment of landscape condition across the WLCI region, and we have met with WLCI partners to help them understand how they may use the assessment.

- We continue to assess historical and current and (or) potential future status and trends of priority habitats and species, agricultural interests, and energy and minerals across the WLCI region.

- We have identified many key drivers of landscape change and continue to develop models for projecting potential future changes arising from these drivers.

- We have identified the distribution and condition of all 152 Wyoming Species of Greatest Conservation need.

- We have established a framework, indicators, and an integrated interagency monitoring database for long-term monitoring of ecosystem conditions across the WLCI region.

- We are monitoring the effectiveness of on-the-ground habitat enhancement and restoration projects implemented by WLCI partners to ascertain whether they achieve intended objectives at landscape scales.

- We have elucidated many of the mechanisms underlying changes in the status and trends of WLCI focal habitats and species that result from energy development.

- We have developed and continue to enhance Web-based applications for making accessible the arrays of WLCI data, maps, models, publications, and other products.

- We continue to inform and provide support to WLCI partner conservation planners and decision-makers.

Long-term monitoring of natural resources is further guided by the WLCI IAMT. This team of WLCI partner representatives was developed at the request of the Executive Committee and the Science and Technical Advisory Committee to gather information, provide summaries, and consult and coordinate with stakeholders on matters related to resource monitoring for the WLCI region. The IAMT is co-chaired by two USGS scientists who provide scientific expertise on monitoring issues, designs, methods, and emerging technologies. The primary focus of the IAMT has been to identify, mine and acquire, and organize data in a centralized Interagency Monitoring Database (IAMD); analyze data and other information from past and current monitoring activities conducted throughout the WLCI region; and communicate with WLCI leadership teams to share and incorporate analysis results and adapt the database framework as needed. Information on IAMT activity is accessible through the monitoring page of the WLCI Web site at https://www.wlci.gov/monitoring. The IAMT continuously gathers additional information and updates the IAMD through ongoing and new monitoring activities. Members of the IAMT are expected to be familiar with monitoring efforts within their agencies and provide updates of those activities, participate in conference calls and meetings that afford opportunities for guiding the format and content of the IAMD, and contribute to the IAMT's utility and success.

A Guide to Using This Report

The USGS has produced a comprehensive annual report to highlight its WLCI science accomplishments for each Federal fiscal year (FY; October 1 through September 30) since inception of the WLCI (Bowen, Aldridge, Anderson, Assal, and others, 2009, 2010, 2011, 2013, 2014a,b). Past reports may be accessed at the URLs listed below. This is the seventh annual report and details USGS science and technical assistance activities conducted in FY2014. The FY2014 activities, as they relate to the WLCI management needs (table 1) and other WLCI activities, are summarized in table 2. This year we added a new column to table 2 to indicate both intended and potential applications of each project's outcomes.

Previous WLCI Annual Reports

2008 Annual Report: http://pubs.usgs.gov/of/2009/1201/

2009 Annual Report: http://pubs.usgs.gov/of/2010/1231/

2010 Annual Report: http://pubs.usgs.gov/of/2011/1219/

2011 Annual Report: http://pubs.usgs.gov/of/2013/1033/

2012 Annual Report: http://pubs.usgs.gov/of/2014/1093/

2013 Annual Report: http://pubs.usgs.gov/of/2014/1213/

To help WLCI partners focus on accomplishments, products, take-home messages, and applications of USGS work, this report provides two major components: (1) FY2014 Highlights, including cumulative lists of primary activities conducted since inception of the WLCI, and (2) individual one- to two-page reports for each activity. Readers seeking just an overview of USGS activities and major accomplishments will benefit from reading the *Highlights of USGS FY2008−2014 Accomplishments* section below. Readers seeking more detailed information on individual projects will benefit from reading the individual reports of interest that follow the highlights section. The individual reports are snapshots of project need and objectives, general approaches, take-home messages of findings, and major products. The individual reports also indicate organizations that are using or may use project products. A new feature this year is the placement of one or more quick reference icons (see definitions below) to the left of each project report title to indicate intended and potential applications of project outcomes. Readers seeking more comprehensive project information, background and methods, detailed results, and a cumulative list of products and outcomes may visit the WLCI Web site at http://www.wlci.gov/ and search on activities of interest. Finally, where applicable, we have included in the individual reports URLs for directly accessing USGS and outside products published in FY2014. At the end of the report is a list of references cited in this document.

Descriptions of the work planned for FY2015 are also available on the WLCI Web site under each ongoing project. In addition to published products, significant USGS Science Team accomplishments continue to be presented at WLCI meetings and science workshops, which are generally posted on the WLCI Web site. The contacts for USGS WLCI activity, including Coordination and Integration and Evaluations of USGS science continue to be Patrick Anderson (970-226-9488; andersonpj@usgs.gov) and Zachary Bowen (970-226-9218; bowenz@usgs.gov).

Quick Reference Icons Used in the Individual Reports

Project outcome applications include addressing ***Policies*** (such as the National Environmental Policy Act), ***Conservation Planning, Education*** and (or) ***Outreach***.

Project outcome applications include building or contributing to the WLCI ***Science Foundation***.

Project outcome applications include assessing and monitoring ***Status and Trends***

Project outcome applications include evaluating effects of ***Energy Development***.

Highlights of USGS FY2008–2014 Accomplishments

In FY2014, the USGS continued or initiated work on 26 individual but highly integrated WLCI projects in 5 major areas of scientific research and technological development: 5 ***Baseline Synthesis*** projects; 5 ***Long-Term Monitoring*** projects; 8 ***Effectiveness Monitoring*** projects; 5 ***Mechanistic Studies of Wildlife***; and 3 ***Data and Information Management*** projects. In the subsequent sections, for

each major area, we indicate the WLCI management needs they address, provide a synopsis of the primary research and (or) activities undertaken since the inception of the WLCI, describe highlights of our FY2014 work and accomplishments, and indicate some of the current and (or) potential uses of project outcomes.

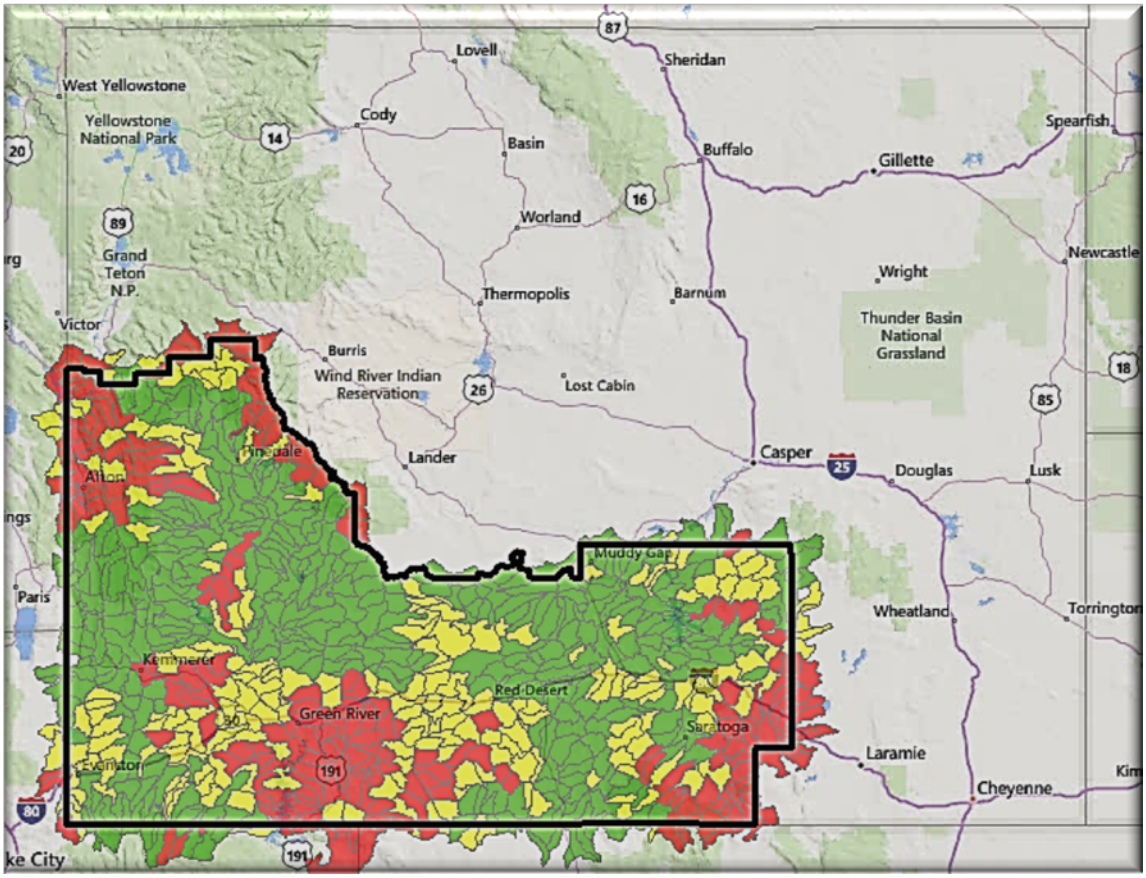
Baseline Synthesis Activities: Supporting WLCI Planning and Decision-Making with Data and New Tools

Our Baseline Synthesis projects directly address WLCI management needs to identify key drivers of change (particularly energy and minerals development, invasive species, and climate change), the condition and distribution of key wildlife species and habitats, and species' habitat requirements. They also support several objectives listed under the management needs to evaluate effectiveness of restoration, reclamation, and mitigation activities and to develop an integrated inventory and monitoring strategy (tables 1 and 2).

Most of our Baseline Synthesis work has been accomplished through direct USGS funding for the WLCI; however, USGS has capitalized on opportunities to leverage other USGS projects to benefit the WLCI mission and add value to the overall science foundation of baseline information, data, and products. Over the 7-year life of the WLCI, our Baseline Synthesis projects[1] have entailed

- acquiring and processing existing and new natural resource data for use in assessing the cumulative effects of land-use and climate changes;*
- developing and enhancing a regional assessment that integrates diverse natural resource data to provide an index of landscape conditions and an interactive map that portrays the distribution of conditions throughout the WLCI region;*
- updating energy and mineral resource databases and mapping* both developed and undeveloped resources;
- mapping land cover (vegetation, surface disturbance) and using what-if scenarios to simulate changes in land cover* associated with climate change and ongoing energy development;
- assessing socioeconomic effects of energy development on important agricultural lands;
- assessing the vulnerability of all Wyoming Species of Greatest Conservation Need to energy development;
- simulating future climate and associated vegetation changes for the WLCI region;
- developing conceptual models and indicators of change for the WLCI region;
- developing methods for characterizing and indexing, mapping, and (or) assessing soil surfaces, soil quality (including elements and organic matter), soil and element availability and mobility, and effects of energy development on soil quality, element mobilization, and biogeochemical characteristics of and cycling in drainages potentially affected by energy development, and mapping invasive species;
- developing estimates of bank-full streamflows for watersheds; and
- developing an online bibliography of publications about energy development in the Western United States.

[1]Ongoing projects are noted with a single asterisk; completed projects are not marked with an asterisk.



Snapshot of the base map developed for the Wyoming Landscape Conservation Initiative (WLCI) Integrated Assessment tool. This interactive map allows users to select from a variety of geospatial data layers to view summary indices, and source data, representing the distribution of terrestrial and aquatic resources and conditions across the landscape. Values are represented by the distribution of wild habitats, as well as social values such as agriculture and protected areas and change agents used to represent influences on habitat conditions, including energy development, mines, roads, and urbanized areas. Influences on future conditions, such as climate (temperature anomalies), invasive species (cheatgrass invasion potential), mineral and energy development potential, and urban development areas, were considered to help anticipate pending changes in environments and habitat conditions. This interactive map and associated data are publically available on the WLCI Web site at https://www.wlci.gov/wlciIA/. Members of the U.S. Geological Survey WLCI Science Team have been providing on-site training workshops for WLCI Local Project Development Teams and others to illustrate this tool's power and potential uses for informing policy, planning, and management decisions.

In FY2014, highlights of our Baseline Synthesis work included publication of two milestone products. One was a journal article outlining a framework for conducting large, collaborative projects that rely on geospatial data; the framework will be a significant resource for conservation planning from local to landscape scales (see O'Donnell and others, 2014, at https://www.fort.usgs.gov/sites/default/files/23686.pdf). We also published Part B of an energy resources map for southwestern Wyoming (see Biewick and Wilson, 2014, at http://pubs.usgs.gov/ds/843/); combined with Part A (see Biewick and Jones, 2012, at

http://pubs.usgs.gov/ds/683/), the two maps depict energy development throughout the WLCI region, including coal, wind, oil, gas, oil shale, uranium, and solar, the associated infrastructure, generation plants, and mines. The energy maps represent a valuable decision-support tool for planners and managers who need to better understand the distributions and locations of energy resources and developments as they plan for protected areas and habitat mitigation and restoration projects.

Other notable baseline assessment accomplishments included using data available through the USGS WLCI Integrated Assessment (IA) to evaluate the relations between energy development and crucial winter habitat for mule deer. In addition to helping WLCI partners understand those relations, this exercise illustrated how the IA may be used for addressing future conservation and management questions. We also began to incorporate feedback about the IA, which we solicited from LPDTs in 2013 to ensure that the IA is user-friendly and relevant to LPDT needs. Important Baseline Synthesis products and publications drafted in FY2014 included maps that portray the importance of agricultural lands and locations of oil and gas well-pad scars, a geodatabase of oil and gas drilling activity, a report on uranium resources in the WLCI region, models for forecasting and evaluating future energy development in the WLCI region, and a fact sheet on the socioeconomic effects of energy development on ranchers and farmers.

Collectively, the data sources, models, and products generated through our Baseline Synthesis work provide WLCI partners and the LPDTs with crucial baseline information about historical and current conditions across the entire WLCI landscape and powerful tools for projecting future conditions. Much of the baseline data are already incorporated in landscape assessments. Compiled, analyzed Baseline Synthesis data are also being used by the LPDTs to guide their development of conservation strategies and prioritization of areas for conservation and (or) restoration at a range of spatial scales.

Wyoming landscape in winter at Camel Rock, south of Rock Springs. Photo by Marie Dematatis, Cherokee Services Group, contracted to the U.S. Geological Survey.

Targeted Monitoring and Research Activities: Assessing Ecosystem and Wildlife Responses to Land-Use Changes

Long-Term Monitoring Activities

Our Long-Term Monitoring projects directly address the WLCI management need to develop an integrated inventory and monitoring strategy. They also indirectly address management needs to identify key drivers of change, the condition and distribution of wildlife and their habitats, and wildlife habitat requirements. Some of these activities entail developing and testing innovative methods for maximizing the efficiency and efficacy of monitoring efforts. Additionally, these activities are integral to addressing the need for developing a data clearinghouse and information management framework (tables 1 and 2).

As with the Baseline Synthesis work, most of the long-term monitoring activity has been accomplished through direct USGS funding for the WLCI, but several (now completed) studies were leveraged through related projects to also benefit the WLCI mission and broaden the scope of baseline information for building the overall WLCI science foundation and baseline data for long-term monitoring. Since inception of the WLCI, important activities and outcomes of our Long-Term Monitoring projects[1] have included

- developing a framework and indicators for long-term monitoring of the WLCI region;*
- assembling and leading an Interagency Monitoring Team for guiding and advancing long-term monitoring efforts and developing an Interagency Monitoring Database for detecting long-term trends;*
- using satellite imagery and field-collected data to map vegetation and monitor trends in vegetation cover of sagebrush steppe of Southwest Wyoming;*
- monitoring streamflow and surface-water quality in regions of energy development;*
- developing a groundwater-monitoring network throughout the WLCI region and beyond;*
- sampling and assessing and mapping soil geochemistry (47 elements and other soil parameters) throughout the WLCI region and providing the data as a baseline for long-term monitoring;
- assessing and mapping the probability of cheatgrass invasion in the WLCI region;
- assessing effects of energy development on soil quality, element mobilization, salinity, and other biogeochemical characteristics of and cycling in drainages, including the New Fork River and Muddy Creek (Carbon County), potentially affected by energy development; and
- assessing stream community composition, bed sediments, and water quality in the New Fork River to identify potential effects of energy development in the Pinedale Anticline Project Area and provide a baseline for future reassessments.

In FY2014, the USGS Monitoring Team cooperated with the WLCI Executive Committee, Science Technical Advisory Committee, and BLM resource managers to renew its data-gathering efforts on habitat and wildlife status and trends for building the Interagency Monitoring Database (IAMD) and conducting analyses of those data. As the IAMD grows, it will become increasingly useful to WLCI partners and scientists not only for ascertaining long-term trends of WLCI ecosystem indicators, but

[1] Ongoing projects are noted with asterisks; completed projects are not marked with an asterisk.

also for conducting future assessments of cumulative effects associated with land-use and climate changes. The USGS Monitoring Team also drafted a fact sheet about its efforts to integrate and analyze IAMD data for application to WLCI assessments and on-the-ground projects; look for this product in early 2016.

To better understand effects of energy development on water resources, USGS hydrologists continued monitoring streamflow and surface-water quality at four sites and groundwater levels at one site. Four additional groundwater-monitoring wells were drilled in the Green and New Fork River basins (two wells at each site on opposite banks of the rivers) along the periphery of the proposed Normally Pressured Lance Formation energy development area. Water quality also was sampled in three wells, expanding the number of wells tested since 2010 in the WLCI region to 19; these data add to the overall network of groundwater monitoring in Wyoming funded by the Wyoming Department of Environmental Quality and the U.S. Environmental Protection Agency. Because the USGS monitoring network targets areas of existing or proposed energy development, the data may serve as a warning system if energy development affects water resources. All water-monitoring results are published for each site at http://waterdata.usgs.gov/wy/nwis/ (specific URLs for each well and stream gage are provided in each WLCI annual report about our water-monitoring projects).

The USGS also processed satellite imagery from 1985−2010 to develop a historical perspective of long-term vegetation changes and a basis for monitoring current and future trends in sagebrush steppe. This work has already been of great use to agencies in Wyoming that are dealing with sage-grouse conservation and energy development, including refinements in and management of sage-grouse core areas.

Effectiveness Monitoring Activities

Our Effectiveness Monitoring projects directly address the WLCI management need to evaluate effectiveness of habitat treatment projects, as well as restoration, reclamation, and mitigation activities. These activities also address the management need to develop an integrated inventory and monitoring strategy, including the objectives to evaluate habitat treatments and Best Management Practices. Because effectiveness monitoring data are being integrated with other monitoring data in the IAMD, these activities also address the objective to make the data available to WLCI partners. Some of these activities entail developing and testing innovative methods for maximizing the efficiency and efficacy of monitoring efforts and ensuring that monitoring results are readily available for use in adaptive management practices. Finally, these activities also indirectly support objectives associated with the management need to identify the condition and distribution of some key habitats and wildlife habitat needs and use.

To date, our Effectiveness Monitoring projects[1] have entailed

- developing efficient methods for tracking vegetation phenology (timing of plant growth and senescence) across large regions and deriving indices of vegetation greenness through the use of

[1] Ongoing projects are noted with a single asterisk (an ongoing project that is active only every few years for ongoing data collection is noted with two asterisks); completed projects are not marked with an asterisk.

Tim Assal (U.S. Geological Survey) collecting field data for an assessment of aspen woodlands in the Little Mountain Ecosystem, Southwest Wyoming. Photo by Marie Dematatis, Cherokee Services Group, contracted to the U.S. Geological Survey.

remotely sensed data collected by satellite and on-the-ground instruments for characterizing sagebrush steppe habitat conditions and treatments and forage quality for sage-grouse and ungulates;*

- assessing sage-grouse use of habitat treatments in sagebrush steppe;*
- mapping mixed mountain shrublands important to migrating and overwintering mule deer;*
- assessing patterns of cheatgrass (and other invasive plant species) occurrence in aspen habitat treatment areas of the Little Mountain Ecosystem area;**
- monitoring aspen responses (such as stand condition and regeneration rates) to prescribed burns, mechanical removals of conifers, and herbivory;*
- developing methods for mapping aspen woodlands at fine scales to enable the detection of aspen responses to habitat treatments, drought, and other factors that may affect the long-term condition and viability of aspen woodlands in the Little Mountain Ecosystem area;*
- use of aspen woodlands by migratory birds in southwestern Wyoming for monitoring effectiveness of treatments as they affect avian diversity; and
- assessing the relations between river basin geology and geochemistry, stream-water quality, and stream biota as they relate to annual run-off cycles and energy development to help identify current conditions and factors affecting water chemistry that will be crucial for future monitoring of potential mitigation or restoration activities.

Highlights of our Effectiveness Monitoring projects in FY2014 included a new project to develop and publish a fact sheet (see http://pubs.usgs.gov/wlci/fs/6/) that describes the ecology of elk inhabiting Fossil Butte National Monument and the surrounding region. The fact sheet was designed to capitalize on previously collected elk-monitoring data for developing a public outreach piece for visitors that interprets a highly visible wildlife species and explains the importance of the Fossil Butte National Monument's habitats to these animals.

Another exciting highlight was a collaborative effort to enlarge the scope and value of our plant phenology studies for Effectiveness Monitoring and other USGS WLCI science projects. This collaboration entailed working with the National PhenoCam Network, the USA National Phenology Network, our WLCI mule deer study, and the USGS Climate Science program to fund and install a PhenoCam internet camera at a site near the Red Desert-to-Hoback mule deer migration route. This will provide an additional dimension to our plant phenology monitoring studies at WLCI study sites. Results of this work are directly supporting the Wyoming Range Mule Deer Project (see http://migrationinitiative.org/).

In support of the Wyoming Range Mule Deer Habitat Plan, our Effectiveness Monitoring scientists used data collected during 2012−2014 to complete and deliver to WLCI partners their maps of mixed mountain shrublands important for migrating and wintering mule deer. In addition, the USGS

published a paper (see http://www.sciencedirect.com/science/article/pii/S0303243414000105) on the efficacy of fusing satellite data collected at various resolutions for monitoring and assessing range conditions.

Our team also continued monitoring and testing methods for evaluating WLCI habitat treatments designed to promote aspen regeneration and enhance sage-grouse habitat and for assessing whether habitat treatments influence cheatgrass occurrence or interact with ungulate herbivory. Significant 2014 accomplishments included completing the data-collection phase (2009−2014) of our sage-grouse habitat-use study and initiating data analyses that will relate the extent of sage-grouse habitat use to the proximity of energy infrastructure. Finally, our study to develop methods for tracking the dynamics of aspen woodlands in the Little Mountain region incorporated digital hemispheric (fisheye) cameras for more precisely measuring trends in canopy cover and a radiation sensor to measure the light available for photosynthesis and how it affects aspen productivity.

Fossil Butte National Monument. Photo courtesy of the National Park Service, Fossil Butte National Monument.

Mechanistic Studies of Wildlife

Our Mechanistic Studies of Wildlife directly address the WLCI management needs to evaluate the responses of wildlife to development and to identify the condition and distribution of key wildlife species and habitats and species' habitat requirements. They also help to address the management need to identify key drivers of change and some of the objectives associated with developing an integrated inventory and monitoring strategy (tables 1 and 2).

Our five Mechanistic Studies of Wildlife[1] target the pygmy rabbit, sage-grouse, sagebrush-obligate songbirds, mule deer, and native fish, all of which are listed as Wyoming Species of Greatest Conservation Need, and the sage-grouse is a candidate for listing under the Endangered Species Act. For all of these species, Wyoming (especially the WLCI region) encompasses some (if not almost all) of the species' most important remaining habitats. Much of this work focuses on seasonal habitat requirements, how these animals move across the landscape, factors that alter or impair their habitats and (or) movements, and how energy development alters other factors that may influence their populations and long-term persistence. Animal movements across landscapes are crucial for accessing seasonal habitats (such as winter range, nesting, and brood-rearing habitats), finding mates, dispersing, and maintaining genetic diversity. Disruptions of those movements due to habitat loss and fragmentation, as well as changes in natural predator-prey dynamics and climate, put populations at risk of extirpation. By conducting successive phases of work that build on knowledge gained through prior phases, our Mechanistic Studies of Wildlife are evolving from ascertaining *how* wildlife species respond to energy development to revealing *why* they respond as they do.

Lines of research inquiry for the pygmy rabbit study have included

- addressing knowledge gaps regarding basic pygmy rabbit ecology, including their habitat requirements, habitat occupancy patterns, dispersal movements across the landscape, and establishing a Wyoming pygmy rabbit working group;
- conducting surveys and initiating long-term monitoring of pygmy rabbit populations across the WLCI region, including existing energy development sites and sites slated for future energy development;
- using the survey data to validate an existing model for predicting pygmy rabbit habitat occupancy and generating a new model and associated pygmy rabbit distribution map that incorporates a greater suite of variables, including vegetation characteristics, habitat patch size, soils, topography, energy development, and climate to predict both occupied and unoccupied habitat; and
- relating pygmy rabbit habitat occupancy to remotely sensed data (light detection and ranging [lidar]) of sagebrush structure.

Pygmy rabbit hiding under the cover of a sagebrush shrub. Photo by Steve Germaine, U.S. Geological Survey.

Highlights of 2014 included completing the pygmy rabbit habitat model and the Wyoming pygmy rabbit distribution map, which indicate factors associated with pygmy rabbit habitat occupancy. In addition, the final year of pygmy rabbit surveys conducted in the BLM Kemmerer region was completed for developing a pygmy rabbit habitat map specific to an area of interest to WLCI partners in that region. Finally, the natural gas

[1] All five Mechanistic Studies of Wildlife have been ongoing since 2008, with the exception of the fish study, which was initiated in 2013.

infrastructure on four major Wyoming gas fields where the USGS conducted 3-year pygmy rabbit surveys was digitized and will be analyzed in relation to the pygmy rabbit survey data. The outcomes and products of our pygmy rabbit work already greatly enlarge the body of knowledge about this species, including areas of potential overlap between potentially occupied pygmy rabbit habitat and proposed energy development, and will provide planners and managers with powerful tools for identifying and conserving suitable pygmy rabbit habitat.

For addressing crucial questions about conserving sage-grouse habitats and population viability, activities for our sage-grouse study have included

- evaluating Wyoming sage-grouse lek-count data to address concerns about using long-term time-series databases for detecting and modeling population trends;
- processing archived satellite imagery to identify changes in vegetation cover in sagebrush steppe and then using these data to model relations between grouse population trends and vegetation cover;
- using movement data collected from radio-marked sage-grouse to develop models for predicting sage-grouse selection of seasonal habitats; and
- publishing a comprehensive Wildlife Monograph that synthesized our sage-grouse work to date.

In FY2014, highlights of the sage-grouse study included expanding on previous work to better understand resources and factors (such as spatial patterns in oil and gas development, the timing and type of grazing, climate change, and fire) that drive long-term viability of sage-grouse populations, particularly factors contributing to population stability, decline, or increase, and predicting future trends. This work also entailed developing a tool that helps to identify key factors limiting sage-grouse persistence in Wyoming and a modeling framework that will allow users to evaluate risk of local extirpation and the adequacy of core areas and other protected areas for ensuring persistence of sage-grouse populations. Two more milestone works were published in FY2014, including a Wildlife Monograph, "Habitat prioritization across large landscapes, multiple seasons, and novel areas: An example using greater sage-grouse in Wyoming," and a USGS data series report, "Wyoming greater sage-grouse habitat prioritization—A collection of multi-scale seasonal models and geographic information systems land management tools" (see http://dx.doi.org/10.3133/ds891). The many products and other outcomes of our sage-grouse studies have greatly fine-tuned our knowledge of sage-grouse habitat requirements in Wyoming, which allows planners to identify important sage-grouse habitats and fine-tune the necessary spatial attributes of core sage-grouse management areas.

Successive phases of research for the sagebrush-obligate songbird study have included

- ascertaining the influences of energy development, specifically the density of natural gas well pads in the Pinedale Anticline and Jonah gas fields, on the diversity, abundance, and nesting success of sagebrush-obligate songbird communities;
- building a baseline database of songbird diversity and abundance for long-term monitoring;
- monitoring hundreds of songbird nests to identify nest predators and patterns of predation as they relate to habitat characteristics and gradients in the densities of gas wells; and
- initiating work to elucidate why increasing well density alters rodent nest predator communities and activities such that they impose greater predation rates on songbird nests.

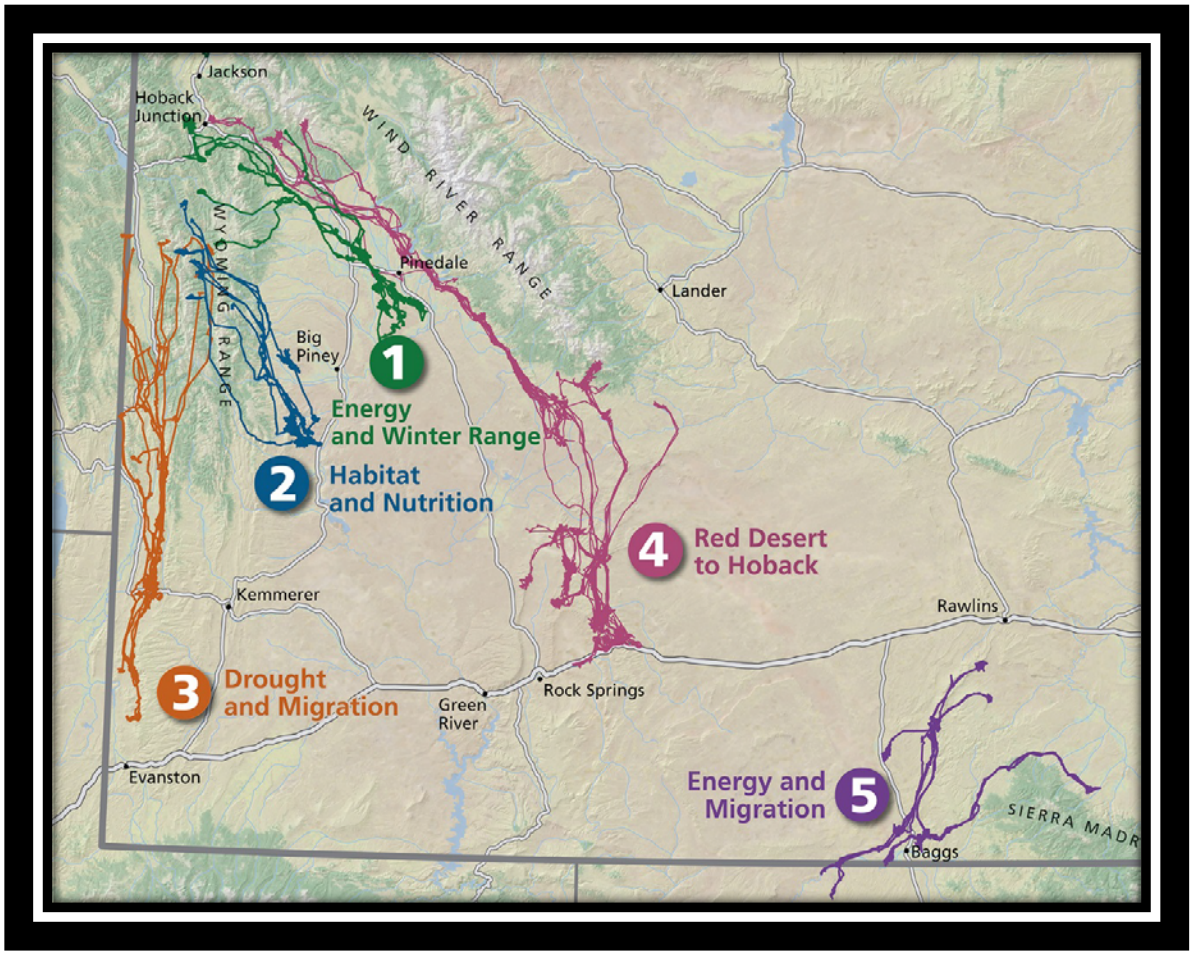
Sage thrasher nest and eggs. Photo by Michelle Gilbert, University of Wyoming.

Work on the songbird study in FY2014 included continued monitoring of nests, identifying nest predator species, and assessing predator abundance across a gradient of energy development to ascertain the spatial and temporal consistency of previous results. Data analyses were initiated to complete this second phase of the project, with preliminary results indicating that increasing densities of gas wells result in altered predator communities and increasing rates of nest predation by rodent predators. Phase III was initiated to ascertain why the activity and (or) abundance of key rodent nest predators changes with increasing gas well density. Milestone FY2014 accomplishments included development of two journal articles detailing outcomes of this work. Much of the songbird research has been leveraged with support from the Wyoming Game and Fish Department, which plans to use the new knowledge gained for updating the Wyoming State Wildlife Action plan and developing mitigation strategies that help to conserve songbird breeding habitat.

As with the songbird study, the mule deer study has entailed successive phases of research, which have included

- ongoing collection and application of movement data from Wyoming's large ungulate species to estimate and map their migration routes, identify route sections used for resting, foraging, and traveling, and which routes are used by the greatest proportions of animals;
- tracking and documenting behaviors of migrating mule deer, particularly time spent at stopover sites, assessing forage quality (timing of spring green-up and extent of vegetation greenness) at stopover sites, and modeling the relation between time spent at stopovers and forage quality; and
- quantifying thresholds of energy development, above which mule deer migration is impeded and (or) the benefits of migration are compromised, by relating migration route attributes to mule deer behaviors (such as rates of movement, time spent along route sections, fidelity to routes, and route avoidance) along gradients of energy development.

Highlights of the mule deer research in FY2014 included analyzing mule deer movements (including their use of the Red Desert-to-Hoback migration corridor; see http://migrationinitiative.org/content/red-desert-hoback-migration-assessment) and use of migration stopover sites, the results of which indicate that the animals tolerate moderate levels of development along short portions of their migration routes without behavioral effects, but they increase their rates of movement if they encounter more intense development along longer portions of their routes. Outcomes of this work are providing managers with refined maps of crucial migration routes and invaluable information that will help planners determine how to balance development with protecting the crucial functions of ungulate migratory corridors in southwestern Wyoming. The BLM, WGFD, and some non-governmental organizations are already using results of this study to guide fencing modifications and habitat enhancements, and for revising their resource conservation planning efforts.



U.S. Geological Survey scientists with the Wyoming Cooperative Fish and Wildlife Research Unit are collaborating with the University of Wyoming, Western EcoSystems Technology, Inc., and Wyoming Game and Fish Department to study mule deer migrations throughout Wyoming. The primary goals of this work are to evaluate how migratory mule deer are responding to development on their winter ranges and migratory routes, as well as the effects of ecological drought. Partial funding is provided by the U.S. Geological Survey National Climate Change and Wildlife Science Center. For more information about ungulate migrations in Wyoming, visit the Wyoming Migration Initiative web site at http://migrationinitiative.org.

Initiated in FY2013, our study of native fish communities is still in its initial phase. To date, the lines of research inquiry for this study have included

- comparing fish community composition, macroinvertebrate community composition (as an indicator of habitat degradation), and habitat availability and quality, including riparian vegetation cover, streamflow, water temperature, levels of suspended sediments and dissolved salts, and hydrocarbon contamination in subwatersheds of the Upper Green River influenced by different levels of energy development; and

- assessing the sensitivity of different fish species to habitat and water-quality factors associated with greater levels of energy development.

Accomplishments during FY2014 for the native fish study included initial data analyses of the community-composition and habitat-quality data. The preliminary results indicate that surface-water quality is reduced in subwatersheds with higher levels of development, as indicated by elevated concentrations of hydrocarbons and dissolved salts, elevated sediment loads, higher temperatures, and missing representatives of sensitive macroinvertebrate families. An important compilation of this work will be a Master's thesis drafted in 2014 to detail the approaches, results, and take-home messages.

Data and Information Management Activities: Providing a Web-based Infrastructure for Managing and Accessing WLCI Data and Products

The Data and Information Management activities directly address the management need to develop a data clearinghouse (data catalog) and information management framework; they also directly and indirectly support and provide access to outcomes of most USGS WLCI projects for addressing primary WLCI management needs, particularly the need to develop an integrated inventory and monitoring system (a major component of the data catalog) (tables 1 and 2).

A multipartner, landscape-scale, long-term undertaking like the WLCI requires a comprehensive data catalog and online services for data and information sharing, tools for displaying geospatial data, outcomes and products of WLCI partner activities, and more. Our Data and Information Management activities not only address this need, they also address the implicit needs for ensuring efficient communications among many partners and cooperators and the ability to organize people and events. Each year, we take advantage of new technologies and software applications for enhancing the capabilities of ScienceBase—the USGS system for cataloguing and managing data—and our associated Web services and tools. Over the 7-year life of the WLCI, our Data and Information Management[1] work has entailed

- developing a framework for a WLCI data clearinghouse (catalog) for all data and other resources assembled on behalf of the WLCI effort and establishing protocols for assembling data into the USGS ScienceBase catalog;
- building and maintaining the WLCI data catalog by identifying, acquiring, and characterizing existing natural resource data available from WLCI partners and collaborators (including ownership, level of propriety or privacy limits, specific content, scale, and issues with regard to the accompanying metadata), and advancing the capabilities and tools associated with the catalog for continuous data mining and harvesting, staying abreast of technological advances and maximizing functionality, developing the WLCI Interagency Monitoring Database, and meeting emerging WLCI needs;
- developing, maintaining, and advancing the capabilities of a WLCI Web site for providing partner and public access to the USGS ScienceBase catalog and a comprehensive WLCI project tracking system (includes projects conducted by all WLCI partners) that provides project location maps,

[1] Ongoing activities are noted with a single asterisk; completed work is not noted with an asterisk.

status, background and objectives, accomplishments, results, and cumulative lists of outcomes and products;*

- developing online applications (accessible through the WLCI Web site) for assessing WLCI landscape conditions and visualizing (mapping) spatial data;*
- developing online applications made available through the myUSGS "wiki" (a password-protected online application for collaborative efforts, including ongoing discussions, document sharing and editing, planning and managing conferences and other events, and so on) for WLCI partners and leadership committees to use on behalf of the WLCI effort.

A stormy sky and a rainbow serve as the backdrop for aspen fall foliage in the Wyoming Landscape Conservation Initiative region. Photo by Tim Assal, U.S. Geological Survey.

In FY2014, the USGS continued advancing the capabilities of WLCI Web site and the ScienceBase infrastructure for cataloguing, archiving, displaying, and making accessible WLCI data, products, assessment tools, and outreach materials. Exciting highlights of FY2014 included the development of three online, interactive map-viewing applications, now available on the WLCI Web site, to display geospatial data pertinent to the WLCI region (all three viewers are accessible at https://www.wlci.gov/wlciMapviewer/). One application displays a time-sequenced map that illustrates progressive oil and gas well development from 1900–2008 within the original WLCI boundaries. Another displays a map produced by the USGS GAP Analysis Program that illustrates predicted distributions of selected Wyoming Species of Greatest Conservation Need. The third displays a map that integrates selected data, including energy developments, power generation facilities, and mines, from the Part A energy map (coal and wind) of southwestern Wyoming with sage-grouse distribution and core management areas, as well as Wyoming's alternative routes for electrical transmission-line corridors to protect sage-grouse core management areas. Collectively, these new tools provide WLCI planners and managers with powerful tools for weighing the pros and cons of different land-use and energy-development scenarios.

Application of Comprehensive Assessment to Support Decision-Making and Conservation Actions

This is a collaborative, two-part project to compile and analyze resource data to support WLCI efforts. Part 1 entails directing data synthesis and assessment activities to ensure that they will inform and support the WLCI LPDTs and Coordination Team in their conservation planning efforts, such as developing conservation priorities and strategies, identifying priority areas for conservation actions, evaluating and ranking conservation projects, and evaluating spatial and ecological relations between proposed habitat projects and WLCI priorities. In FY2014, we helped the Coordination Team complete the WLCI Conservation Action Plan and BLM's annual report, and we provided maps and other materials to assist with ranking FY2015 WLCI conservation priorities. We published a paper outlining a geospatial framework for collaborative, landscape-scale projects and lessons learned from Part 1. This scalable framework should be applicable to any conservation project that relies on geospatial data, and it will benefit natural resource managers, scientists, and geospatial professionals.

Part 2, designed to support decision-making at the WLCI programmatic level and conservation planning at landscape scales, is a multidisciplinary Integrated Assessment (IA) of factors affecting conservation and management across the WLCI region. The IA may be used to identify areas of high conservation and restoration value and those with high development potential on the basis of the current landscape. It also may be used to consider scenarios of potential future development, which, in turn, may be used for evaluating the conservation and restoration potential of a given area. Finally, the IA provides WLCI partners or other entities with a framework for conducting future reassessments and evaluations of change. It addresses priority resources in the WLCI region and their conditions, agents of change, and potential future conditions associated with development and climate change. The IA framework is transparent and hierarchical in that it allows users to decompose the summary scores and evaluate individual resources. A variety of logical assumptions based on current knowledge and data availability are inherent to the initial assessments. Users may incorporate local knowledge into finer scale assessments to inform local management projects for land-uses and resource values not considered in this initial IA effort. In FY2014, we used IA data to evaluate the relations between energy development and crucial winter habitat for mule deer. This effort will help WLCI partners understand these relations and how to use the IA for addressing future conservation and management questions.

Products Completed in FY2014

- O'Donnell, M., Assal, T.J., Anderson, P.J., and Bowen, Z.H., 2014, Geospatial considerations for a multi-organization landscape-scale program: Journal of Map and Geography Libraries, v. 10, p. 62−99, at http://www.tandfonline.com/doi/pdf/10.1080/15420353.2014.885925.
- Continued development of the WLCI IA Web application, at http://www.wlci.gov/integrated-assessment.

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Modeling Land Use and Cover Change

The goal of this project is to develop and use a simulation approach to portray patterns of future oil and gas development and assess its potential effects on wildlife habitat in Southwest Wyoming. This entails using existing energy build-out specifications to locate new oil and gas well pads, wells, and roads on the landscape at annual time steps. Based on results of published species' responses to well pad, well, and road densities, we map simulated infrastructure to assess potential effects on wildlife species. To evaluate the potential for reducing surface disturbance and minimizing the effects of future development on wildlife, we simulate alternative build-out designs, such as increased use of directional drilling, and compare them to proposed designs. Assessments of simulated forecasts can illustrate trade-offs in the conservation potential of alternative designs and help to inform design selection for future developments given specified conservation and energy-production goals. This effort addresses the WLCI management needs to refine approaches and models for predicting future scenarios of potential changes in key drivers of land-use change and likely wildlife responses to these changes.

In FY2014, I simulated three alternative drilling designs for 2,000 new wells in the Atlantic Rim Project Area (based on 2012 conditions): 1 vertical well drilled per pad (2,000 pads), and 2 and 4 directional wells drilled per pad (1,000 and 500 pads, respectively). Then I assessed differences in surface area disturbed from building the pads and associated roads. To compare the ecological implications, I developed analytical procedures to assess design effects on sagebrush-obligate songbird habitat, greater sage-grouse lek attendance, travel rates of mule deer along migration corridors, and elk use of habitat. Initial application results illustrate that surface area disturbed and negative effects on wildlife decrease with fewer pads (fig. 3). Overall, quantitative measures of effects on wildlife provide a basis for cost/benefit assessments among designs. A USGS fact sheet and a journal article were developed to describe this initial application and results. The results and future simulation applications will help WLCI LPDTs to prioritize habitat projects and provide a tool to the BLM and other land management agencies for exploring the conservation potential of alternative energy build-out designs.

Products Completed in FY2014

- Garman, S.L., and McBeth, J.L., 2015, Digital representation of oil and natural gas well pad scars in Southwest Wyoming—2012 update: U.S. Geological Survey Data Series 934, at http://pubs.usgs.gov/ds/0934/pdf/DS934_abstract.pdf.
- Garman, S.L., in press, Forecasting and evaluating future energy development in Southwest Wyoming: WLCI Fact Sheet 7, 2 p., at http://pubs.usgs.gov/wlci/fs/7/.
- Garman, S.L., Forecasting and evaluating alternative energy development in Southwest Wyoming (draft).

Contact: Steven L. Garman, 303-236-1353, slgarman@usgs.gov

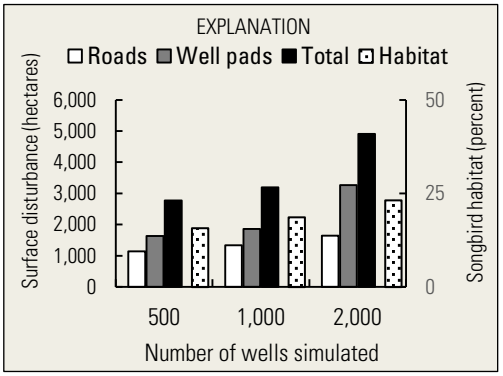

Figure 3. Three alternative well-pad densities were simulated for the Atlantic Rim Project Area, Wyoming, to illustrate mean surface area disturbed by simulating roads, well pads, and their combined totals. Ingelfinger and Anderson (2004) reported 38–60 percent fewer songbirds within 100 meters of oil and gas roads; thus we also quantified mean percent of sagebrush-obligate songbird habitat disturbed with increasing well number.

Assessing Energy Resources

The USGS Energy Resources Program assesses coal, oil and gas, and uranium resources, as well as environmental effects of energy resource occurrence and use. To identify the regions where energy resources are most likely to be developed, we apply a geologic understanding to emerging patterns of extraction for each energy commodity and assess the potential for undiscovered resources. Our studies include (1) maintaining a compilation of public and proprietary information on subsurface petroleum (wells installed) for the Greater Green River Basin, (2) developing new geographic information system products that portray geologic studies of energy resources, (3) automating updates of the database on oil and gas development in the WLCI area, and (4) studying future coal availability in the Washakie Basin (Atlantic Rim).

Pinedale, Sublette County, Wyoming, Wind River Range in the distance. Photo by Laura R.H. Biewick, U.S. Geological Survey.

In FY2014, we continued assembling a comprehensive, publicly available, online inventory of energy resources data. We also completed the energy map of southwestern Wyoming with the publication of Part B, which focuses on oil and gas, oil shale, uranium, and solar energy resources, and includes data layers that portray infrastructure and protected lands and sensitive areas (Part A focused on coal and wind [Biewick and Jones, 2012]). Finally, the Central Energy Resources Science Center Team continued to provide technical input and expertise, as needed, regarding potential development of oil and gas, coal, coalbed methane, uranium, and oil shale resources in the WLCI area to address Integrated Assessment needs and questions pertaining to energy resources. Published energy resource maps, geodatabases, documentation, and spatial-data-processing capabilities are available at http://energy.usgs.gov/RegionalStudies/SouthwesternWyomingHomepage.aspx. For the National Assessment of Geologic Carbon Dioxide Storage Resources, there is a published chapter on the Geologic Framework for the National Assessment of Carbon Dioxide Storage Resources—Greater Green River Basin, Wyoming, Colorado, and Utah, and Wyoming-Idaho-Utah Thrust Belt at http://pubs.usgs.gov/of/2012/1024/e/. This report offers a perspective of CO_2 storage in this area.

Products Completed in FY2014

- Biewick, L.R.H., and Wilson, A.B., 2014, Energy map of southwestern Wyoming, Part B—Oil and gas, oil shale, uranium, and solar: U.S. Geological Survey Data Series 843, 20 p., 4 pls., http://dx.doi.org/10.3133/ds843 or http://pubs.usgs.gov/ds/843/.
- Biewick, L.R.H., and Miller, A.R., Geodatabase of Wyoming Statewide oil and gas drilling activity to 2015, including Python scripts: U.S. Geological Survey Data Series (draft).

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Many mineral deposits (excluding coal and other energy minerals, with the exception of uranium) are located within the WLCI area, mostly within 19 mineralized areas (fig. 4). The mineral-extraction industry is yet another factor to be considered in the development of southwestern Wyoming. Although Wyoming has had a rich mining history, with a few notable exceptions, currently the industry is mostly dormant in the WLCI study area and has been for the study's duration. Despite hundreds of open claims and leases, there are only a few exploration projects and even fewer active mining operations; a major exception, however, is the increased demand for uranium by in situ recovery, which is imposing new demands on the landscape. Understanding the extent of mineralization and historic mining activity allows us to predict the likelihood of continued or future mining development and its associated effects.

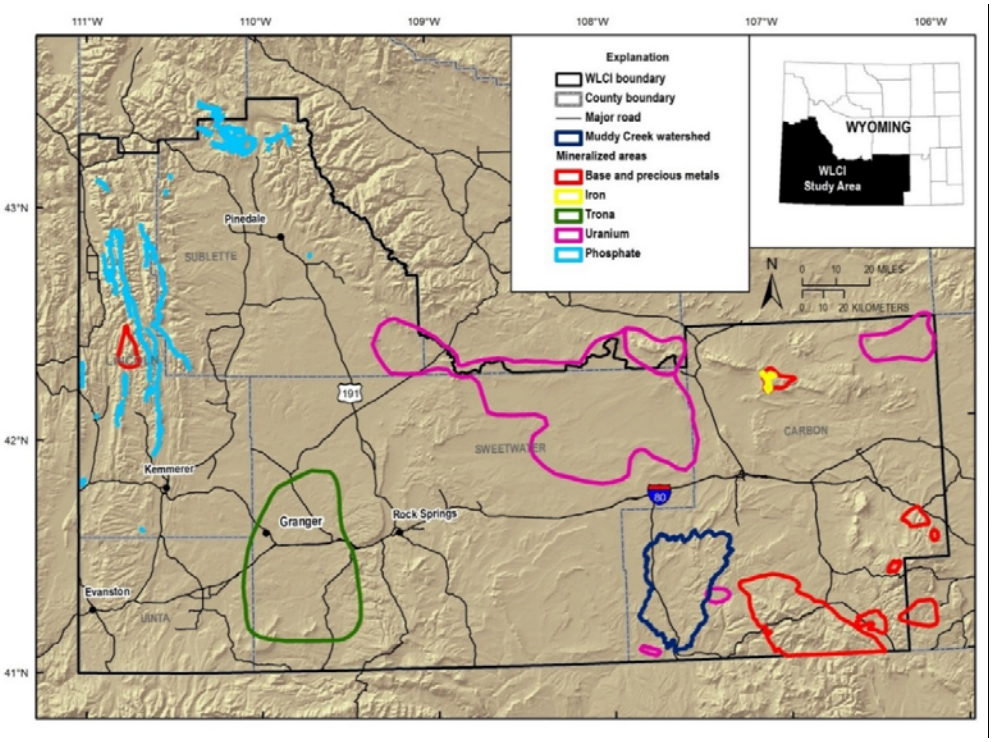
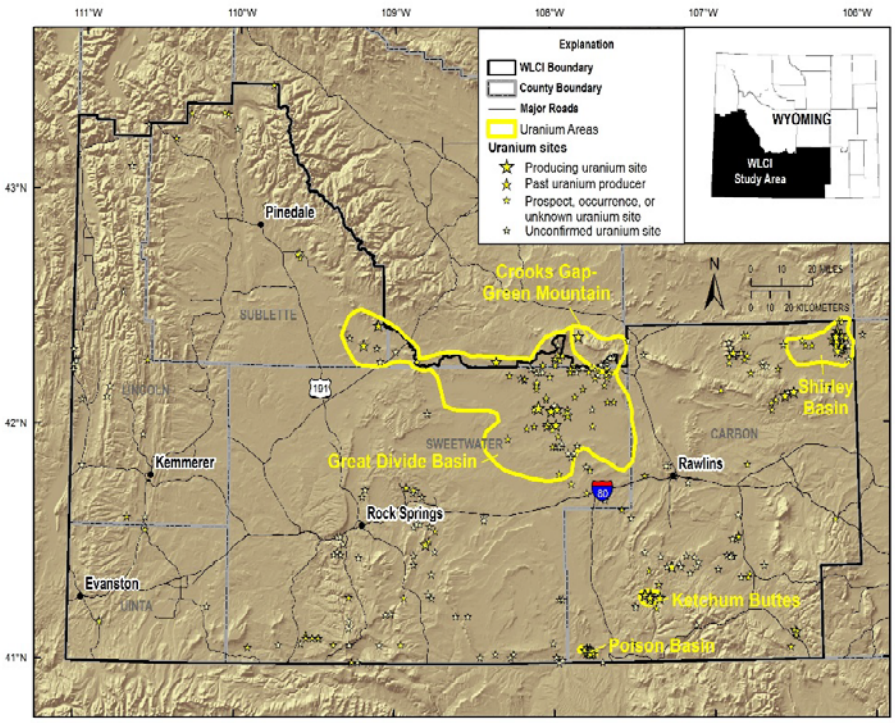


Figure 4. Locations of U.S. Geological Survey's study areas, including mineralized areas, associated with Baseline Synthesis activities in the Wyoming Landscape Conservation Initiative region.

More specifically, metals mining (base and precious metals, both underground and placer) in the WLCI area appears to be non-existent unless there are small-scale operations on private lands. No phosphate mines are currently in operation, although just to the west in Idaho there is some activity. (The largest former phosphate mines in southwestern Wyoming, at Leefe and South Mountain, have been reclaimed.) Uranium companies are exploring and developing some areas in the WLCI region, especially south of the Crooks Gap and Green Mountain area in the Great Divide Basin where traditional surface (open-pit) uranium mining operations have given way to in situ recovery projects. In

the Great Divide Basin area, production began in 2013 at the Lost Creek in situ recovery (Ur-Energy, Inc.). The only current significant production is occurring west of Green River, where several large companies are mining trona underground and processing it on site to make soda ash. The trona occurs in beds in the Wilkins Peak Member of the Eocene-age Green River Formation. Demand for sand and gravel and aggregates is increasing as infrastructure development associated with natural gas extraction continues in the northwestern WLCI area.

In FY2014, the uranium minerals data (fig. 5) were published in a USGS data series, and a USGS open-file report detailing the uranium aspect of our project was approved for publication. An additional report describing the sand and gravel resources (including sand for hydraulic fracturing) has been drafted and will be submitted for review in FY2015. Because mining is a key driver of change, our mineral assessments will help conservation planners and land managers understand and take into account the areas most likely to be affected by future mining development or reclamation from past extraction activities.



Products Completed in FY2014

- Biewick, L.R.H., and Wilson, A.B., 2014, Energy map of southwestern Wyoming, Part B—Oil and gas, oil shale, uranium, and solar: U.S. Geological Survey Data Series 843, 20 p., 4 pls., at http://pubs.usgs.gov/ds/843/.
- Wilson, A.B., in press, Uranium in the Wyoming Landscape Conservation Initiative study area, southwestern Wyoming: U.S. Geological Survey Open-File Report 2014–1123.

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Figure 5. Locations of uranium mines, prospects, and occurrences in the Wyoming Landscape Conservation Initiative region. Currently producing, previously producing, and nonproducing sites are indicated by large, medium, and small yellow stars, respectively. Pale small stars indicate uranium sites that have not been verified in the literature. (To see this map in detail, visit http://pubs.usgs.gov/ds/843/downloads/Plates/ *and click on* Plate1_WLCI_EnergyMapB.pdf.)

Important Agricultural Lands in Southwestern Wyoming

Agriculture is important to the historical identity of and current economic activity within the WLCI region. Understanding the social and economic values derived from agriculture helps policy planners and decision-makers to better assess the effects of landscape planning and conservation efforts in a broader (societal) context. Our study seeks to add more value to the WLCI IA by providing insights on the productivity and historical, ecological, and socioeconomic importance of agriculture across the WLCI landscape. Overall, this project will add another dimension to the WLCI IA's inventory of integrated data and the WLCI data clearinghouse as a whole.

In FY2014, scientists with the USGS, the Wyoming State Engineer's Office, and the Wyoming Department of Agriculture evaluated the quality and limitations of the datasets compiled in FY2013 for characterizing agricultural lands in the WLCI region. This work resulted in making refinements to the datasets, which then were used to develop digital maps for identifying the distributions of agricultural "importance" attributes across the WLCI landscape. Subsequently, these attributes were used to construct an index that assigned agricultural importance scores to agricultural lands, by subwatershed unit (hydrologic unit code 12, level 6; see p. 16 in Bowen, Anderson, Aldridge, and others, 2013, for more information on how the IA scores resource conditions by subwatershed units). The goal in FY2015 is to incorporate these watershed-level scores with the IA, which will provide users quick, easy access to the best existing information available for assessing multiple resource types and uses, including agriculture. Ultimately, this work lays the foundation for addressing two important lines of inquiry: (1) the roles of economics and other social sciences in landscape-level decision-making beyond agriculture; and (2) the gains that can be made from conducting a larger, yet more complete, assessment of local and societal perceptions regarding ranching and other agricultural practices within the WLCI region. Ultimately, the additional information generated by this project will support the WLCI committees and LPDTs and myriad other stakeholders as they grapple with difficult conservation planning and resource management decisions.

Cattle round-up, Southwest Wyoming. Photo by Theo Stein, U.S. Fish and Wildlife Service.

Products Completed in FY2014

- Draft internal report detailing our methods.
- Using the refined datasets compiled in FY2013, we drafted spatially explicit maps that illustrate the importance of agriculture.
- Allen, Leslie, Montag, Jessica, Lyon, Katie, Soileau, Suzanna, and Schuster, Rudy, 2014, Rancher and farmer quality of life in the midst of energy development in Southwest Wyoming: WLCI Fact Sheet 5, 4 p., http://pubs.usgs.gov/wlci/fs/5/. (Note: This product is an outcome of an earlier phase of this project to assess rancher and farmer perceptions of energy development in the WLCI region.)

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Individual Reports: Long-Term Monitoring

Framework and Indicators for Long-Term Monitoring

Limits on the time and financial resources available for monitoring efforts, coupled with the complexities of natural resources and stakeholders, are challenges in resource monitoring. To help address these and related challenges, the USGS Monitoring Team (12MT) has linked conceptual monitoring specialists with habitat and wildlife biologists to inform and develop creative, scientifically defensible approaches for monitoring the status and trends of populations and habitats across the WLCI region. This collaboration has led to spatially balanced monitoring designs that will make it possible to interpret conditions across the WLCI region and a mechanism for integrating species' distributions and population responses with land-cover and land-use patterns and dynamics (a focal aspect of our Mechanistic Studies for the WLCI). Improvements to field-sampling, data-aggregation, and analysis approaches are ongoing, and the USGS MT leads are working closely with the IAMT to better disseminate resource status and trend information and develop collaborative approaches to data collection and analyses. This work helps to address a primary WLCI objective to develop an integrated inventory and monitoring strategy(ies), as well as several additional WLCI management needs: (1) identify key drivers of change, (2) assess the condition and distribution of key wildlife species and habitats, and (3) evaluate wildlife and livestock responses to development.

The IAMT was developed to support the WLCI Executive Committee and the Science Technical Advisory Committee in their efforts to gather information and consult and coordinate with stakeholders about WLCI resource monitoring. The IAMT is composed of a representative from each WLCI partner organization and is currently co-chaired by two USGS scientists who also co-lead the USGS MT. Two important MT roles are to maintain the IAMT and expand its capabilities and information products; in FY2014, this included cooperating with the Executive Committee, Science Technical Advisory Committee, and BLM resource managers to renew data-gathering and data-analysis efforts. We also drafted a publication documenting our efforts to integrate, analyze, and apply habitat and population status and trend information. Future work will include analyses of remotely sensed and field data gathered and compiled by the USGS to better define and elucidate WLCI-wide habitat conditions.

Products Completed in FY2014

- Manier, D.J., Aldridge, C.L., O'Donnell, Michael, and Schell, Spencer, 2014, Human infrastructure and invasive plant occurrence across rangelands of southwestern Wyoming, U.S.A.: Rangeland Ecology and Management, v. 67, no. 2, p. 160−172.
- Geospatial tools for the WLCI Web site at www.wlci.gov/monitoring: a tool for viewing and downloading monitoring data (currently populated by USGS project Sagebrush Map products), and a tool for accessing monitoring contacts (including WLCI Partners) in tabular form.
- Manier, D.J., Anderson, P.J., and Chong, G., Monitoring habitats and wildlife populations in southwestern Wyoming: U.S. Geological Survey Fact Sheet (draft).

Contacts: Daniel J. Manier, 970-226-9466, manierd@usgs.gov; Steven L. Garman, 303-202-4118, slgarman@usgs.gov

Remote Sensing and Vegetation Inventory and Monitoring

This work centers on using remote-sensing tools and protocols for monitoring long-term changes in vegetation cover across the WLCI region (fig. 6). This information is crucial for understanding patterns of change within sagebrush habitats, including historical changes and potential trajectories of future changes. Our study targets five components of vegetation cover: all shrubs, sagebrush shrubs, herbaceous vegetation, litter, and bare ground, which we quantify by one-percent intervals. Based on samples collected both in the field and from satellite imagery, the USGS can evaluate and quantify the amount and distribution of long-term changes in the target components. This work and its associated products represent the operational vegetation monitoring effort for the WLCI, and they provide input to a broad spectrum of on-going WLCI research and conservation and restoration applications.

During FY2014, our on-the-ground vegetation monitoring continued in plots along 260 marked transects distributed across two QuickBird (18 square kilometers [km^2] each) satellite scenes for assessing long-term changes. The plots have been sampled since 2006 providing nearly a decade-long record of change that we use to understand trends observed in satellite images and extrapolate them to the WLCI landscape. We also use Landsat satellite images that include our study plots to understand how precipitation changes affect sagebrush cover. In FY2014, we began new research to quantify changes in shrub, sagebrush, herbaceous, litter, and bare ground cover across the entire WLCI region from 1985 to 2010, which is made possible by using the Landsat imagery archive. When this effort is completed in FY2015, it will provide a record of vegetation change for every 3 years from 1985 to 2010 within every 30-meter (m) cell of the WLCI region. The procedures and products developed through these efforts will facilitate a broad array of applications for better understanding the historical trajectories of vegetation change.

Products Completed in FY2014

- We acquired and processed Landsat 5 images of the WLCI region for 1985, 1988, 1991, 1993, 1996, 1999, 2003, 2006, 2008, and 2010, and we acquired Landsat 8 images for 2014; the results are being used to backcast predictions of shrub, sagebrush, herbaceous, litter, and bare ground cover across the WLCI area to quantify vegetation change from 1985 to 2010.
- Target vegetation components were measured at 260 plots along marked transect for on-going, ground-based monitoring.
- Homer, C.G., Xian, G., Aldridge, C.L., Meyer, D.K., Loveland, T.L. and O'Donnell, Michael, 2015, Forecasting sagebrush ecosystem components and greater sage-grouse habitat for 2050—Learning from past climate patterns and Landsat imagery to predict the future: Ecological Indicators (in revision).

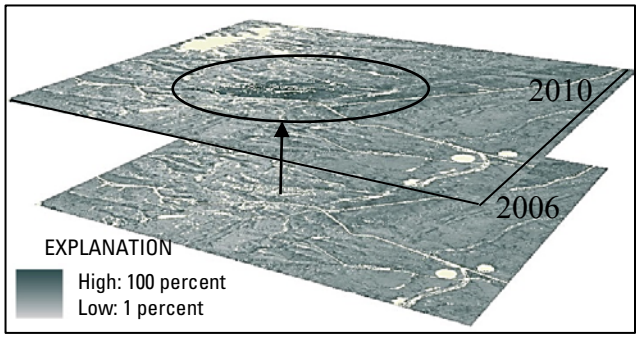

Figure 6. An example of change in bare ground cover from 2006 to 2010 in the Wyoming Landscape Conservation Initiative region (darker shading means greater percent of bare ground); the change was caused by a wildland fire that occurred after 2006.

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Long-Term Monitoring of Surface Water, Groundwater, and Water Quality

Riparian and aquatic ecosystems in semiarid landscapes like Southwest Wyoming contribute significantly to regional biodiversity. Long-term monitoring data that describe streamflow, surface-water quality, and groundwater levels are needed for assessing possible effects of changes in land use, land cover, and climate on those ecosystems. With WLCI funding, surface-water quality has been monitored at four sites, and groundwater levels have been monitored at one site (fig. 7). The monitoring sites were selected to provide baseline characterization of the upper Green River Basin and the Muddy Creek watershed. All data are collected according to USGS methods (Wagner and others, 2006; Kenney, 2010; Sauer and Turnipseed, 2010; Turnipseed and Sauer, 2010; U.S. Geological Survey, variously dated). This project helps to address the WLCI management need to develop an integrated inventory and monitoring strategy designed to evaluate overall effectiveness of WLCI on-the-ground habitat projects and support assessments of cumulative effects of change.

Measuring streamflow in the New Fork River near Big Piney, tributary to the Green River, prior to collecting a water-quality sample. Photo by J. Brooks Stephens, U.S. Geological Survey.

In FY2014, we decommissioned the existing groundwater-monitoring well near Rock Springs (fig. 7) after collecting the 2014 data because the well was suspected of being affected by local irrigation activities, which would confound future interpretations of changes in water levels associated with energy development and (or) climate change. To replace that well, four new monitoring wells were drilled in September 2014 (one on each side of the river in the New Fork River alluvium and one each side of the river in the Green River alluvium) near the northwest and southwest Normally Pressured Lance boundaries (fig. 7), and water-level monitoring in those wells will commence in early 2015. The data collected from these wells will elucidate interactions between surface water and groundwater in the area's shallow aquifers. Although it is known that the area's shallow, near-stream aquifers supply water to nearby surface waters, the quantity of water supplied is unknown. Long-term data from these new wells will be crucial to understanding how groundwater contributes to streamflows in the Green River Basin, and they will be important for managing water resources of the basin as a whole. Any activity that impacts the groundwater has the

Installing shallow alluvial well near the New Fork River near Big Piney. Photo by Cheryl A. Eddy-Miller, U.S. Geological Survey.

potential to impact surface waters as well. Understanding the relation between groundwater and surface water will help managers make informed decisions to mitigate impacts.

In FY2014, surface-water-quality data were collected at the four sites in the upper Green River Basin and Muddy Creek watershed, and groundwater-level data were collected at the now-decommissioned well in the Green River Basin. In cooperation with and funding from the State of Wyoming, BLM, and Bureau of Reclamation, additional surface-water-quality and quantity data were collected. Combined with WLCI monitoring data, these water-resources data support resource management and research in the WLCI study area and beyond.

Products Completed in FY2014

For all monitoring sites, preliminary real-time data were provided in FY2014, and final data were published in FY2015 through the USGS National Water Information System Web site at http://waterdata.usgs.gov/wy/nwis/ (individual reports listed below).

- Real-time data from the two new wells
  at http://wy-mt.water.usgs.gov/projects/GW_streamgaging/index.html
- http://waterdata.usgs.gov/wy/nwis/wys_rpt/?site_no=09205000
- http://waterdata.usgs.gov/wy/nwis/wys_rpt/?site_no=09217000
- http://waterdata.usgs.gov/nwis/wys_rpt/?site_no=09258050
- http://waterdata.usgs.gov/nwis/wys_rpt/?site_no=09258980
- http://waterdata.usgs.gov/wy/nwis/wys_rpt/?site_no=413850109150601

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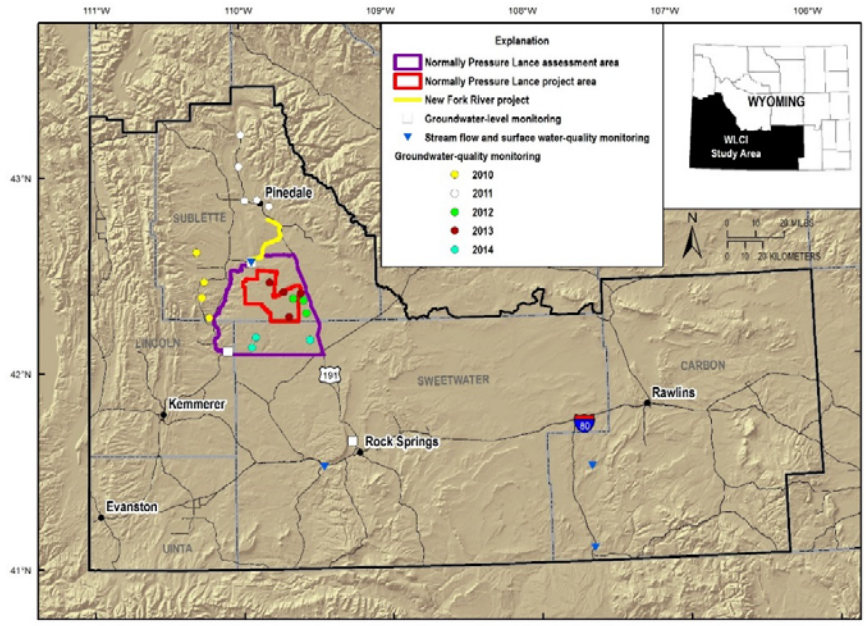

Figure 7. Locations of U.S. Geological Survey's field-based study areas associated with Long-Term Monitoring projects during FY2014 in the Wyoming Landscape Conservation Initiative region.

Wyoming Groundwater-Quality Monitoring Network

Stock well 421051109543001, located in Sweetwater County and sampled on September 10, 2014. Photo by Gregory K. Boughton, U.S. Geological Survey.

A wide variety of human activities has the potential to contaminate groundwater. In addition, naturally occurring constituents in groundwater can limit the suitability of that water for some uses. Baseline groundwater-quality data can be used to facilitate analysis of water-quality trends over time and to understand the effects of human activities. Such information is an important tool for protecting groundwater resources that are crucial for drinking water and other uses.

The USGS is working in cooperation with the Wyoming Department of Environmental Quality on the Wyoming Groundwater Quality Monitoring Network, the goal of which is to collect water-quality samples at 20–30 wells within each of 33 priority areas (Boughton, 2011). The project entails sampling existing shallow (less than or equal to 500 feet deep) wells to evaluate groundwater in priority areas where groundwater has been identified as an important source of drinking water for public and private water supplies, is susceptible to contamination, and is overlain by one or multiple land-use activities that could have negative effects on groundwater resources. Funding from the WLCI allows for additional wells to be sampled in priority areas within the Green River watershed.

Levels of numerous constituents in groundwater samples collected for the Wyoming Groundwater Quality Monitoring Network have exceeded State and Federal water-quality standards. The Wyoming Department of Environmental Quality is using these data to determine whether groundwater quality is being adversely affected by overlying land uses, including oil and gas development. The outcomes of this work are expected to contribute baseline groundwater-quality data in support of the WLCI management need for an integrated inventory and monitoring strategy. Since FY2009, groundwater samples have been collected and analyzed from 26 (1 of which was resampled) wells in the Green River watershed, including 3 wells sampled in FY2014 (fig. 7). All of the data are available on the USGS National Water Information System Web site at http://bit.ly/1ELgNcy.

Products Completed in FY2014

- A map of all well sites sampled for this project and the water-level and water-quality data are available at http://bit.ly/1ELgNcy.
- Boughton, G.K., 2014, Groundwater-quality characteristics for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012 (ver. 1.1, October 2014): U.S. Geological Survey Scientific Investigations Report 2014–5130, 80 p., at http://pubs.usgs.gov/sir/2014/5130/.

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Analysis of Field Reconnaissance of Existing Water Wells in the Normally Pressured Lance Formation Study Area

Water-level measurements taken from existing wells in the northern Green River structural basin were used to construct a potentiometric surface of the lower Tertiary aquifer system. Photos by Chery A. Eddy- Miller, U.S. Geological Survey.

Ongoing energy development in the northern Green River structural basin necessitates information about groundwater resources that supply water to the basin's wells. Many human activities in that area, including pumping water from the aquifers for agricultural, domestic, and industrial use, and penetration of the heterogeneous (that is, complex intertonguing of layers) aquifers (see Bartos and others, 2015) during deeper drilling for natural gas, have the potential to impact the aquifer system that supplies water to most wells in the area. We initiated this study in FY2012 as "A Retrospective Assessment of Groundwater Occurrence in the Normally Pressured Lance Formation and a Field Reconnaissance of Existing Water Wells in the Study Area." The assessment was completed in 2012, but in 2013, ownership of the mineral rights to develop the Normally Pressure Lance Formation (fig. 7) changed. Therefore, to assist agencies such as the BLM with upcoming development, the emphasis of the study was modified and previously collected data were used to develop a potentiometric-surface map (a visual representation of aquifer-water levels) for the lower Tertiary aquifer system that underlies the Green River Basin.

During 2010−2013, groundwater levels (depth to water and shut-in well-head pressure [the above-ground elevation to which groundwater would rise if released from a confined aquifer]) were measured according to USGS methods (Cunningham and Schalk, 2011) in 77 wells throughout the basin (fig. 8), including the proposed Normally Pressured Lance project area (Sweat, 2013). In 2014, depth to water was measured in 12 wells and shut-in water pressure was measured in 4 flowing wells. The 2014 water levels were used to augment the previously collected data for constructing a generalized potentiometric-surface map (a representation of groundwater-level altitudes in multiple hydrologically connected geologic units) of the Green River Basin lower Tertiary aquifer system.

The draft map indicates that groundwater in the study area generally moves from north to south, but this pattern of flow is altered locally by groundwater divides and by groundwater discharge to the Green River, Fontenelle Reservoir, and possibly to a tributary (Big Sandy River) and a reservoir (Big Sandy Reservoir). The final report and potentiometric-surface map will provide decision-makers with updated groundwater information and document groundwater levels for evaluating any future changes in the aquifer system. In combination with other WLCI monitoring activities, the groundwater-level data directly address the WLCI management objective to develop inventory and monitoring approaches for evaluating the overall effectiveness of WLCI habitat projects and supporting assessments of cumulative effects from changing land uses and other changes. These products also will support the BLM and other land and resource managers in their planning and decision-making for resource management in the WLCI region and beyond, and they will support future research.

Products Completed in FY2014

- All water-level inventory data can be found at http://pubs.usgs.gov/ds/770/.
- Bartos, T.T., Hallberg, L.L., and Eddy-Miller, C.A., Hydrogeologic framework, groundwater levels, and generalized potentiometric-surface map of the Green River Basin lower Tertiary aquifer system, 2010−14, in the northern Green River structural basin, Wyoming: U.S. Geological Survey Scientific Investigations Report (draft).

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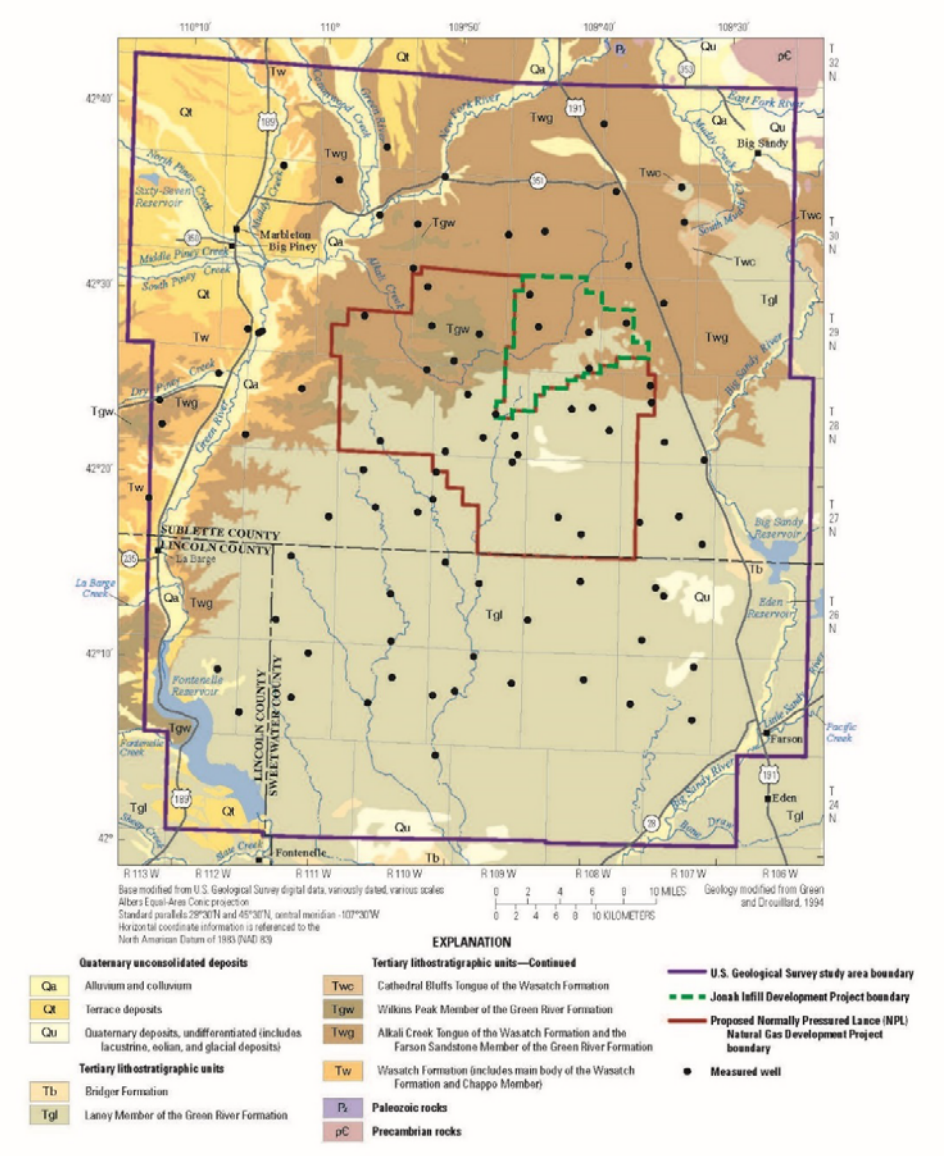

Figure 8. Locations of wells in which water levels and shut-in well-head pressures were measured for developing a generalized potentiometric-surface map for the northern Green River structural basin (from Bartos and others [draft]).

Applying Greenness Indices to Evaluate Sagebrush in the WLCI Region

Weather and climate influence plant productivity, which in turn influences wildlife habitats and behaviors (Monteith and others, 2011). Monitoring plant phenology (such as the timing of green-up, flowering, or senescence) reveals patterns that can serve as indicators of habitat condition and quality. Climate change may alter phenology patterns and plant species composition, which could affect the availability and quality of forage and cover for WLCI species of concern, such as elk, mule deer, pronghorn, greater sage-grouse, and livestock. This project entails monitoring plant phenology to address the WLCI management need for monitoring and evaluating the effectiveness of habitat-management activities. Our work also integrates USGS monitoring efforts with those of WLCI partners responsible for managing species, habitat, and land use.

PhenoCam image of QuickBird site 1 (with a Red Desert elk running through the site) on June 8, 2014. Archived and live photos are available at http://phenocam.sr.unh.edu/webcam/sites/quickbird/.

In 2014, we continued monitoring vegetation greenness, soil moisture, and temperature at QuickBird site 1 (QB1; fig. 9). We also collaborated with the USGS North Central Climate Science Center, the National PhenoCam Network, and (indirectly) the USA National Phenology Network to install a PhenoCam webcam to monitor greenness at a QB1 sampling point. We are collaborating with Ellen Aikens, a Ph.D. candidate working with Matt Kauffman at the University of Wyoming, to provide data and analyses of plant phenology data in support of the Wyoming Range Mule Deer Project, which receives partial funding from the National Climate Change and Wildlife Science Center. We are examining whether drought diminishes the benefit of migration by reducing the period of high-quality forage availability. Once they are linked with mule deer movement and fitness data, the analyses will advance our understanding of how mule deer migrations and use of migration stopover sites may be affected by climate change and drought. Ultimately, the results will give managers crucial habitat-quality information and advance the science of measuring and monitoring vegetation greenness as an indicator of habitat quality and productivity.

Products Completed in FY2014

- Steltzer, Heidi, Chong, Geneva, and Shory, Rick, 2013, Linking near-surface observations, individual plant phenology, and microclimate [abs.]: Invited presentation, NEON Phenocam workshop, October 9−11, 2014, Boulder, Colo., at http://eco.confex.com/eco/2014/webprogram/Paper45596.html.
- Steltzer, Heidi, Chong, Geneva, and Weintraub, M.N., 2013, From spring to fall—Life-cycle responses of plant species and communities to climate change [abs.]: American Geophysical Union fall meeting, December 9−13, 2014, San Francisco, Calif., at http://adsabs.harvard.edu/abs/2013AGUFM.B53F..03S.

- Wyoming Range Mule Deer Project update, summer 2014, at http://migrationinitiative.org/sites/migration.wygisc.org/themes/responsive_blog/images/WRMD_Update_Summer2014.pdf.

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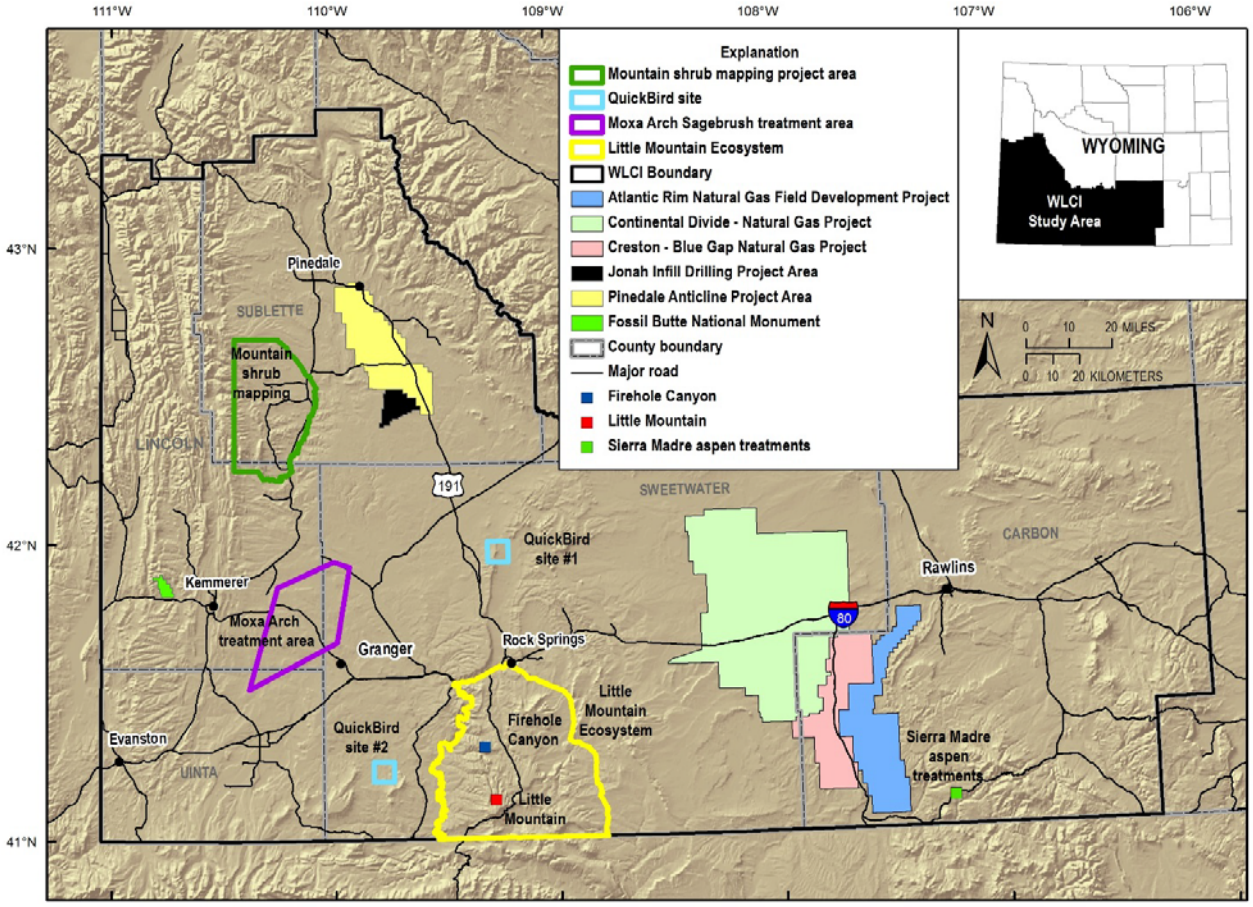

Figure 9. Locations of the U.S. Geological Survey's FY2013 field-based study areas associated with Effectiveness Monitoring activities and Mechanistic Studies of Wildlife in the Wyoming Landscape Conservation Initiative (WLCI) region.

Mapping Mixed Mountain Shrub Communities to Support WLCI Conservation Planning and Effectiveness Monitoring of Habitat Treatments

The mixed mountain shrub community is one of the WLCI priority habitat types and is associated with numerous WLCI conservation priority areas and habitat projects. The current extent and condition of mountain shrub patches is unknown in most of the WLCI region; thus, trends in their condition and mechanisms driving those conditions are also unknown. Ongoing monitoring data from selected stands indicate an overall decline in this community type. Hypotheses as to what is causing the decline range from persistent drought to herbivory and, possibly, factors associated with increased energy development. Our long-term objectives are to measure and map the current conditions and distribution of mixed mountain shrub communities and evaluate the potential effects of habitat treatments (such as those supported by LPDTs to improve mule deer habitat), weather-related trends, increased energy development, and other change agents.

During FY2014, we continued efforts to record the presence of mixed mountain shrub communities within the Big Piney–La Barge area identified in the Wyoming Range Mule Deer Habitat Plan (Damm and Randall, 2012). We selected this area to take advantage of existing assessment and monitoring data acquired by WLCI partners. Mapping efforts, which we began in 2012, were expanded in 2013 to include currant, gooseberry, and sumac species in addition to the original target species ("true" mountain mahogany and curl-leaf mountain mahogany, chokecherry, antelope bitterbrush, and snowberry). Spatial data collected in 2014 will be used to improve existing map products completed in 2013 (Bowen and others, 2013). We also conducted vegetation sampling in FY2014 to assess the condition of mahogany shrub communities in the Big Piney−La Barge area. Thirty-three study locations were randomly selected from previously developed maps (Bowen and others, 2013). Measurements were taken to quantify shrub foliar cover, density, size, mortality, age-class structure and diversity, and the extent of herbivory on shrubs across the Big Piney−La Barge area.

Maps and other information from this work are being used to support WLCI partners with conservation planning and effectiveness monitoring of habitat treatments in mixed mountain shrub communities. The treatments, designed to enhance crucial winter and transition habitat for mule deer, include mowing, aeration, seeding, burning, and herbicide applications. The USGS continues to improve its approaches to modeling (mapping) vegetation to support our ongoing mountain shrub and mule deer research. The associated products and information are shared with WLCI partners during LPDT meetings.

Products Completed in FY2014

- 2014 vegetation sampling database.
- Vegetation maps resulting from 2012−2014 data.

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Measuring the height of a young mountain mahogany shrub. Photo by Marie Dematatis, Cherokee Services Group, contracted to the U.S. Geological Survey.

Greater Sage-Grouse Use of Vegetation Treatments

Members of the WLCI LPDTs have raised questions about sage-grouse use of past vegetation treatments and which treatment types (such as prescribed burns, mowing, or herbicide applications) best support sage-grouse habitat needs. This study is designed to evaluate (1) greater sage-grouse use of past and current vegetation treatments and (2) how treatment type, design, location, and site-based ecological variation may influence seasonal use and foraging behavior by sage-grouse. Information resulting from this study will be used to develop more effective treatment designs and approaches that support habitat needs for sage-grouse during nesting and brood rearing.

Biologists with the BLM and WGFD suggested studying sage-grouse responses to treatments that were conducted as part of the BLM mitigation plan for the Moxa Arch Infill Natural Gas Development Project. Between 1997 and 2002, numerous sagebrush areas were mowed or treated with the herbicide tebuthiuron (Spike®) in the Moxa Arch Infill area. The goal of these treatments was to mitigate the effects of energy development habitat and forage by creating a mosaic of sagebrush stands at different seral stages. Treatments were conducted within upland areas that represented habitats selected by pronghorn and by sage-grouse for nesting and early brood-rearing.

In FY2009, the USGS initiated a study within the Moxa Arch area (fig. 9) to evaluate sage-grouse use of mowed and tebuthiuron-treated habitats and to ascertain whether birds are responding to differences in vegetation composition, the size and shape of treatment patches, distances between treated patches and occupied leks, and influences associated with energy infrastructure. To measure sage-grouse use, pellet counts were conducted along 4-m × 100-m belt transects established within treated and adjacent untreated sites during early brood rearing (late April to early May), late brood rearing (late June to early July), and early fall (September). In FY2010, the spatial extent of this study was expanded to include a total of 123 transects within or adjacent to all vegetation treatments in the Moxa Arch area. In addition to seasonal pellet surveys, in FY2011 vegetation composition and soil texture were measured along all the transects.

Last year, we used the National Agriculture Imagery Program to digitize all energy infrastructure (roads, pipelines, and well pads) within 1 km of our transects. This information helped us determine the proximity of energy infrastructure to each transect. In FY2014, we completed the pellet surveys, and all data from 2014 and previous years were incorporated into a single database. We also initiated data analyses and discussed preliminary findings with WLCI partners and LPDT members.

Product Completed in FY2014

- 2009 to 2014 pellet transect database.

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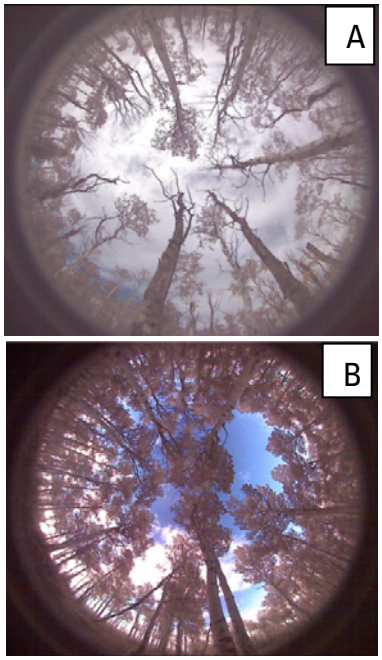
Male greater sage-grouse strutting on a lek in early spring. Sage-grouse require different habitats for breeding, nesting, brood-rearing, and winter survival. Photo by Marie Dematatis, Cherokee Services Group, contracted to the U.S. Geological Survey.

Landscape Assessment and Monitoring of Semiarid Woodlands in the Little Mountain Ecosystem



Digital hemispheric photos of aspen forest canopy collected on (A) Little Mountain and (B) Pine Mountain. Photos by Tim Assal, U.S.Geological Survey.

The Little Mountain Ecosystem in southwestern Wyoming has been identified as a priority area for conservation by the BLM and the WGFD. The woodlands of the Little Mountain Ecosystem have been affected by multiple disturbance types over the last 20 years. Active management of these ecologically important woodlands has sought to rejuvenate decadent aspen stands and reduce conifer expansion in successional aspen stands through prescribed fire and mechanical thinning. The area also experienced wildfires and multiple drought years over the last decade.

The BLM Rock Springs Field Office asked the USGS to conduct research that provides baseline information on the Little Mountain Ecosystem woodlands. This project is designed to acquire information on woodland cover type and the extent and timing of various disturbance types and their effects on woodland productivity. A long-term objective of this research is to determine the feasibility of developing a program for monitoring both abrupt and gradual forest and woodland change by using the archive of satellite imagery that covers large areas of southwestern Wyoming. We expect this work to generate multiple datasets for the USGS and WLCI partners. Outcomes will help WLCI LPDTs with evaluating and prioritizing aspen treatments, allow us to delineate effects of natural disturbance and identify long-term trends in woodland productivity at a landscape scale, and identify areas of the landscape that are most susceptible to change. Finally, a broad aim of this work is to identify ecosystem response to disturbance and climate variability and to contribute to the literature of recent ecosystem change.

In FY2014, we secured funding to purchase digital plant-canopy imagers for rapid assessments of vegetation treatments and structural changes. Each unit consists of a digital hemispheric (fisheye) camera, a global positioning system, and a radiation sensor (for measuring the light available for photosynthesis). We revisited the majority of our 2013 field plots and collected nine canopy photos per plot from which we will calculate canopy cover and leaf area index. This information provides a permanent record of each plot and will be used to assess canopy condition of woodland stands. The 2013 and 2014 data will be used to model (relate) ground measurements with recent satellite data. After model calibration, we will apply this information to a time series of satellite data to identify areas of stability and change.

Products Completed in FY2014

- Compiled and analyzed 2013 and 2014 field data on stand and canopy structure.
- Established field protocol for using digital plant-canopy imagers in Effectiveness Monitoring.
- Calibrated preliminary models (logistic regression) used to produce maps of deciduous and coniferous woodlands at a 10-meter resolution.
- Assembled a 27-year Landsat satellite imagery record of the project area to use in a trend analysis.

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Using Science to Help the National Park Service Interpret a Wildlife Resource (New in FY2014)

Consistent with the National Park Service's philosophy, Fossil Butte National Monument (fig. 9) is managed to protect the monument's resources and provide opportunities for public enjoyment. Fossil Butte National Monument was created primarily to protect paleontological resources; however, the mandate of the agency's enabling legislation "to conserve the scenery and the natural and historic objects and the wildlife therein…" also recognizes the importance of natural process, native wildlife species, and the habitats on which they depend. Sizeable herds of elk spend part of the fall and winter within the Monument's boundaries (fig. 10) and provide numerous viewing opportunities for visitors. Collaboration among the USGS, the National Park Service, the BLM, and the WGFD led to a long-term study of elk movements and spatial distribution in the Fossil Butte area. We used data collected during this research to enhance the monument's interpretive and educational program.

Elk on the move at Fossil Butte National Monument. Photo courtesy of Fossil Butte National Monument.

In FY2014, we developed an interpretive handout (fact sheet) that provides visitors with relevant information about general elk ecology in Wyoming and more specific information regarding seasonal and diurnal movements of elk. Not only will our fact sheet facilitate a deeper understanding of this wildlife resource, it aims to address the interests of 17,000−20,000 visitors each year, many of whom are pleased with the opportunity to see and learn about wildlife at Fossil Butte National Monument. The fact sheet includes a map that shows movements of radio-collared elk both at the monument and elsewhere in the region (fig. 10).

Product Completed in FY2014

- Olexa, E.M., Soileau, S.C., and Allen, L.A., 2014, Observations of elk movement patterns on Fossil Butte National Monument: WLCI Fact Sheet 6, 2 p., http://pubs.usgs.gov/wlci/fs/6/.

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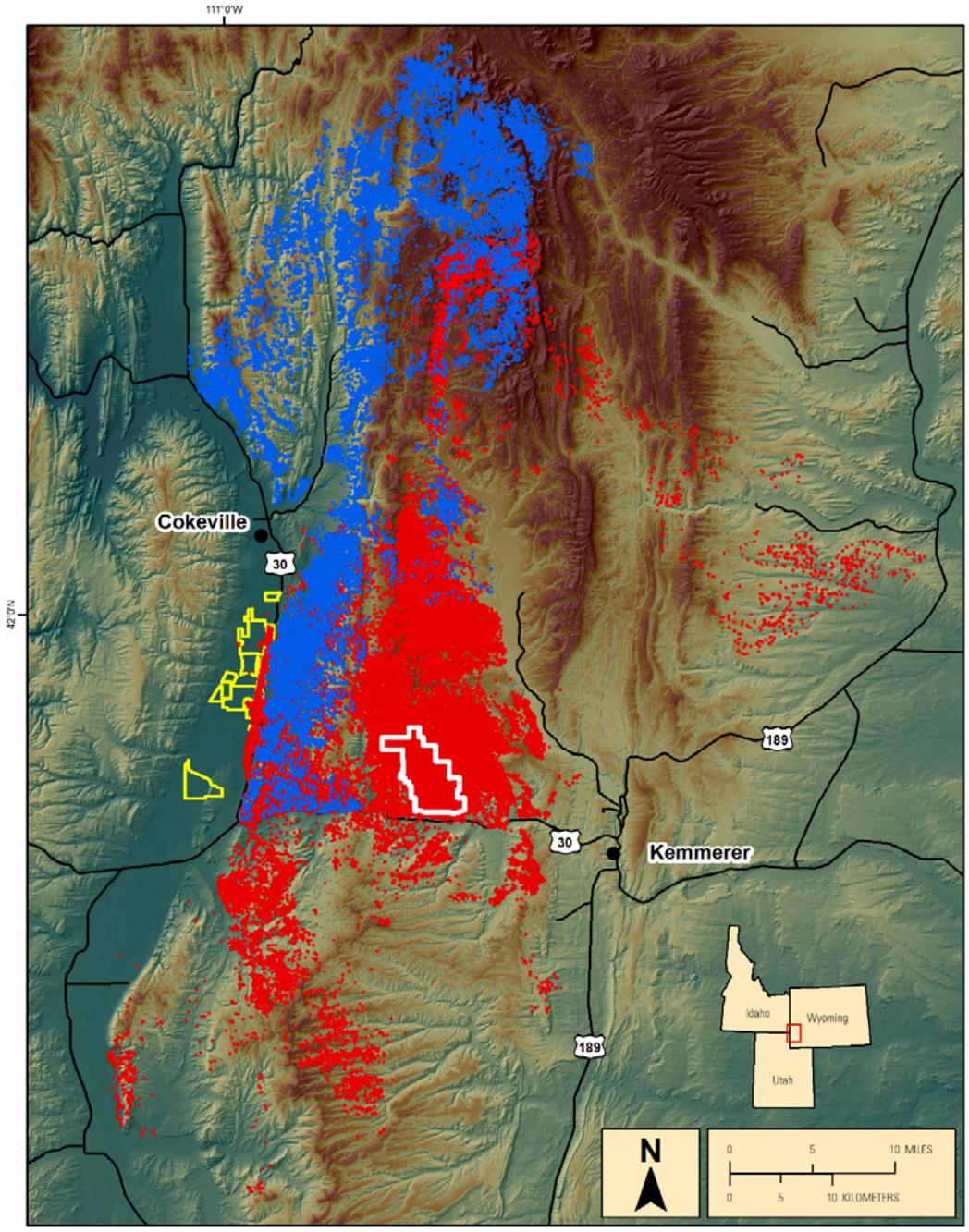

Figure 10. Annual movements of the West Green River elk herd. Fossil Butte National Monument (white outline) is a small but ecologically important portion of this herd's range. Red represents movements of elk captured and radio-collared at the monument and blue represents movements of elk captured and radio-collared near Cokeville, Wyoming, on Bureau of Land Management lands, respectively. Previously, managers believed that elk foraging at Cokeville Meadows National Wildlife Refuge (yellow outlines) were part of the herd unit that winters near Cokeville; the data, however, indicate that these elk do not migrate to the refuge, possibly because transportation corridors restrict their westward movements.

Development and Evaluation of Synthetic High-Resolution Satellite Imagery for Effectiveness Monitoring

To evaluate habitat conditions and trends, land management agencies in the WLCI region require objective, detailed information describing the characteristics of vegetation dynamics, such as changes in biomass, species composition, or the timing of green-up. Assessing the efficacy of management activities and the duration of their effectiveness has been problematic due to the lack of high-resolution spatial and temporal satellite imagery capable of revealing patterns in vegetation responses and changes in forage production. Vegetation indices, such as the normalized difference vegetation index (NDVI) derived from satellite imagery, can be used to monitor seasonal and interannual changes in plant phenology and biomass associated with habitat altering activities and climatic conditions; however, investigation across large spatial extents at fine temporal and spatial scales was impractical until recently.

Data-fusion methods that blend temporally high-frequency satellite data with spatially high-resolution satellite data can provide the fine-resolution, spatiotemporal data required to evaluate habitat responses to management activities at the landscape level. Specifically, we blended Moderate Resolution Imaging Spectroradiometer (MODIS sensor aboard the Terra satellite; 250-m to 1-km pixels; acquired every day) data with high-resolution Thematic Mapper (TM sensor aboard the Landsat 5 satellite; 30-m pixels; acquired every 16 days) data to develop fine-resolution spatiotemporal data for evaluating habitat responses to management activities at the landscape level (fig. 11). This method has been successfully applied to heterogeneous landscapes, including forested areas and croplands, but had not been tested in areas dominated by semiarid shrub-steppe.

Initiated in FY2011 (see pages 84−88 in Bowen and others, 2013), this project culminated in FY2014 with a journal article detailing our methods and outcomes. We collaborated with the National Park Service and the BLM to test our methods for southwestern Wyoming, including a portion of the WLCI region. Predicted NDVI estimates were accurate and highly correlated with actual values across several land cover types. The synthetic imagery produced by blending the data provides the high spatial resolution managers need to identify treatment areas, the high temporal resolution often needed to track dynamic vegetation conditions, and the large spatial extent needed for monitoring at landscape scales. Our work suggests that managers of semiarid rangelands have alternatives to traditional methods when it comes to assessing and monitoring the living plant biomass of rangelands.

Product Completed in FY2014

- Olexa, E.M., and Lawrence, R.L., 2014, Performance and effects of land cover type on synthetic surface reflectance data and NDVI estimates for assessment and monitoring of semi-arid rangeland: International Journal of Applied Earth Observation and Geoinformation, v. 30, p. 30−41, at http://www.sciencedirect.com/science/article/pii/S0303243414000105, doi:10.1016/j.jag.2014.01.008.

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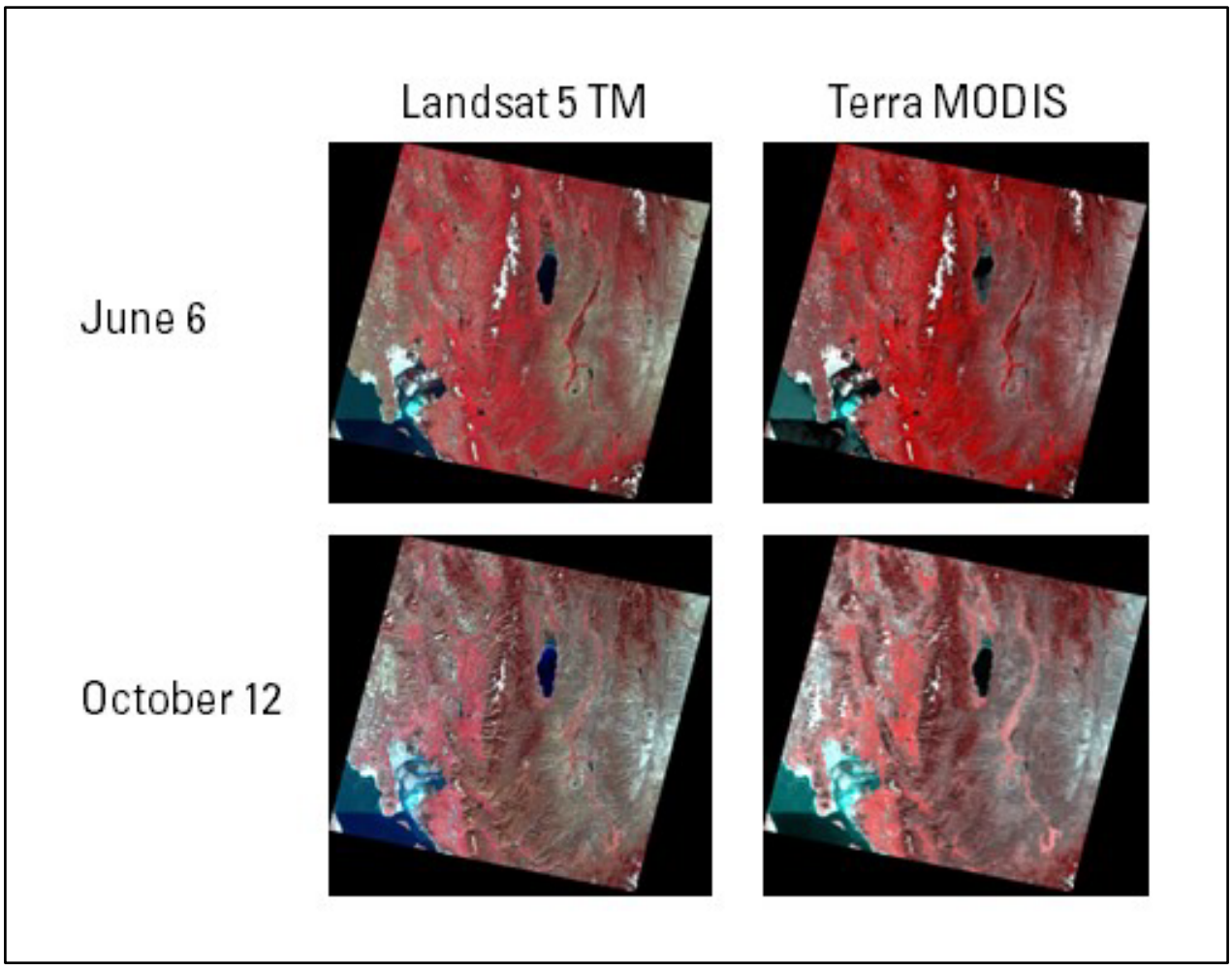

Figure 11. Comparing false-color infrared image pairs of the same area recorded in the spring and fall of 2006 by the Thematic Mapper (TM) sensor aboard the Landsat 5 satellite and the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the Terra satellite. The TM images are high resolution (30-meter pixels) but captured only every 16 days, whereas the MODIS images are low resolution (pixel size ranges from 250 meters to 21 kilometers) but are captured daily. In the false-color images, red and pink indicate the presence of green vegetation, clearly illustrating the changes from spring green-up to fall senescence. For this project, the Spatial and Temporal Adaptive Reflectance Fusion Model (STARFM) algorithm was used to fuse TM and MODIS images to predict red and near-infrared surface reflectance for an analysis of changes in vegetation cover that provides a greater spatiotemporal resolution than either image type alone could provide. For more information on TM and MODIS, please refer to U.S. Geological Survey (2005, 2012).

Pygmy Rabbit

The pygmy rabbit is a Wyoming Species of Greatest Conservation Need and a species of concern in each State where it occurs. Data gaps for this species include (1) population performance among habitats of varying quality, (2) effects of landscape-scale habitat fragmentation, and (3) effects of natural gas development on habitat occupancy and populations. Pygmy rabbits are patchily distributed, with subpopulations inhabiting irregularly distributed patches of tall, dense sagebrush. Threats to their populations include degradation and fragmentation of sagebrush habitat. It is unclear whether pygmy rabbits in marginal habitats contribute to the local population. Generating data-driven information to help address these questions is the goal of USGS pygmy rabbit research in Wyoming.

In FY2014, we finished developing a pygmy rabbit habitat model based on field-collected data, and an associated species distribution map. We also completed the second (final) year of rabbit surveys in the BLM Kemmerer Field Office area and are using the data to evaluate the predictive accuracy of our Statewide pygmy rabbit distribution map and to develop a pygmy rabbit habitat map for a specific area of interest to partners with the BLM (Kemmerer Field Office) and WGFD. Using 2012 imagery from the National Agriculture Imagery Program, we completed digitizing all natural gas infrastructure associated with our 3-year surveys on four major Wyoming gas fields and initiated analysis of these data. Finally, we tested a new geographic positioning technology (built into small backpack units) that we mounted on a sample of pygmy rabbits in the Kemmerer area.

Our pygmy rabbit research validates existing pygmy rabbit habitat maps, adds distribution information, and provides information about the potential for spatial overlap between occupied habitats and energy development (natural gas and wind). We continue to study effects of gas field infrastructure on pygmy rabbit distributions and to investigate the role of landscape-scale habitat fragmentation and patchiness on pygmy rabbit movements and metapopulation dynamics. Collectively, this work will continue to provide resource managers with new information about pygmy rabbit distributions, habitat associations, and responses to natural gas development.

Products Completed in FY2014

- Germaine, Steve, Ignizio, Drew, Keinath, Doug, and Copeland, Holly, 2013, Predicting occupancy for pygmy rabbits in Wyoming—An independent evaluation of two species distribution models: Journal of Fish and Wildlife Management, v. 5, p. 298−314, at http://fwspubs.org/doi/full/10.3996/022014-JFWM-016.
- Completed field data collection in the Carter Lease area near Kemmerer, Wyo., for this study's habitat-use component.
- Full digitization of gas field infrastructure surrounding our pygmy rabbit gas field survey plots.

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U.S. Geological Survey (USGS) wildlife ecologist, Steve Germaine, with an adult pygmy rabbit just fitted with a global positioning system unit to track its movements. Photo by Joslin Heyward, USGS.

Mechanistic Modeling for Greater Sage-Grouse

Persistence of the greater sage-grouse depends on the quantity, quality, and distribution of habitat within its range and prioritizing their habitats for protection and long-term viability of their populations is a high priority for managers. In previous years, Fedy and Aldridge (2011) conducted a long-term analysis of sage-grouse population trends across the WLCI area and all of Wyoming, identifying fluctuations and quantitatively addressing many concerns associated with analyzing large time-series databases. Subsequently, Fedy and others (2014) completed a large habitat-selection modeling effort using resource selection functions to predict the probability of habitat use across Wyoming. In FY2014, we expanded on our previous work to better understand resources and threats that drive long-term viability of sage-grouse populations. More specifically, we expanded on our trend analyses, beginning with a Statewide demographic viability analysis for exploring which populations are stable or decreasing and predicting population trends into the future. We are assessing sage-grouse population responses to threats on the landscape, including effects of spatial patterns in oil and gas development and the timing and type of grazing (using more than 30 years of grazing allotment data). We also continue to explore how climate, fire, and other threats affect sage-grouse population trends.

In addition to our trend modeling, we have developed an empirically based support tool that synthesizes existing habitat information from resource-selection function models to help identify key factors limiting sage-grouse persistence in Wyoming. We have drafted a modeling framework that allows us to evaluate population sources, sinks, and population trends; risk of local extirpation; and the adequacy of habitat protection, such as core areas, for sage-grouse population persistence. We are working with USGS colleagues to develop future landscape scenarios related to energy development and climate-induced changes in sagebrush habitat of the WLCI region. The scenarios will allow us to explore how these threats may affect the long-term persistence of sage-grouse populations in Wyoming. Combined, our research products will provide managers with a better understanding of which sage-grouse populations will remain most viable in the near future, and they will provide insights about factors potentially limiting the long-term viability of sage-grouse populations.

Products Completed in FY2014

- Homer, C.G., Xian, George, Aldridge, C.L., Meyer, D.K., Loveland, T.L., and O'Donnell, Michael, Forecasting sagebrush ecosystem components and greater sage-grouse habitat for 2050— Learning from past climate patterns and Landsat imagery to predict the future: Ecological Indicators, v. 55, p. 131−145, doi:10.1016/j.ecolind.2015.03.002.
- O'Donnell, M.S., Aldridge, C.L., Fedy, B.C., and Doherty, K.E., 2015, Wyoming greater sage-grouse habitat prioritization—A collection of multi-scale seasonal models and geographic information systems land management tools: U.S. Geological Survey Data Series 891, 28 p., http://dx.doi.org/10.3133/ds891.
- Fedy, B.C., Doherty, K.E., Aldridge, C.L., O'Donnell, Michael, Beck, J.L., Bedrosian, Bryon, Gummer, D.L., Holloran, M.J., Johnson, G.D., Kaczor, N.W., Kirol, C.P., Mandich, C.A., Marshall, David, McKee, Gwyn, Olson, Chad, Pratt, A.C., Swanson, C.C., and Walker, B.L., 2014, Habitat prioritization across large landscapes, multiple seasons, and novel areas—An example using greater sage-grouse in Wyoming: Wildlife Monographs, v. 190, no. 1, p. 1–39, doi: 10.1002/wmon.1014.

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Mechanistic Understanding of Energy Development Effects on Songbirds

In the WLCI region, the quality and condition of sagebrush steppe is a concern given the extent of rangewide land-use change, habitat conversion, and rapid energy development in sagebrush systems. Three migratory songbird species are considered near-obligates of sagebrush shrublands: Brewer's and sagebrush sparrows and sage thrasher, all of which are designated Species of Great Conservation Need in Wyoming (Wyoming Game and Fish Department, 2010) and nest in Green River Basin. In collaboration with the WGFD, we initiated this multiphase project to address the WLCI management need to identify the condition and distribution of sagebrush songbird habitats and key drivers of change in those habitats.

Adult sage thrasher perched on a sagebrush shrub in the Pinedale Anticline Project Area. Photo by Dave Showalter Nature Photography©.

In Phase I (2008 to 2009) of this project, we documented diminishing nest survival of all three songbird species along an increasing gradient of natural gas well density in the Jonah and Pinedale Anticline Project Area. In Phase II (2011 to 2012), we evaluated songbird nest survival in relation to natural gas well density and the activity of important nest predators by installing 24-hour infrared video cameras at nests and conducting surveys of the main predators across the same energy development gradient. We recorded nine species depredating eggs and nestlings, and 75 percent of all depredations were made by rodents. During our surveys, chipmunk detections decreased with gas well density, whereas mouse and ground squirrel detections increased. Nest survival of Brewer's and sagebrush sparrows decreased with increased predator activity.

Collectively, our results suggest that natural gas development alters the local activity and (or) abundance of key rodent nest predators, thereby increasing risk of songbird nest predation. During FY2014, we continued monitoring nests, identifying predator species, and assessing predator abundance at the same study sites across the same energy development gradient to ascertain the spatial and temporal consistency of our previous results. Data analyses are underway, and we have initiated Phase III to ascertain *why* the activity and (or) abundance of key rodent nest predators increase along a gradient of increasing gas well density. Understanding specific mechanisms behind effects of energy development on sagebrush songbirds will lead to more explicit management and mitigation recommendations for effectively maintaining songbird populations in the WLCI area and beyond, while also broadening our understanding of the Green River Basin ecosystem.

Products Completed in FY2014

- Hethcoat, M.G., and Chalfoun, A.D., 2015, Energy development and avian nest survival in Wyoming, USA—A test of a common disturbance index: Biological Conservation, v. 184, p. 327−334, doi:10.1016/j.biocon.2015.02.009.
- Hethcoat, M.G., and Chalfoun, A.D., Toward a mechanistic understanding of human-induced rapid environmental change—A case study linking energy development, avian nest predation, and nest predators: Journal of Applied Ecology (in review).

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Mule Deer: Identifying Threshold Levels of Development that Impede Wyoming Ungulate Migrations

Migratory ungulates are susceptible to effects of development along their migration corridors. For example, impermeable barriers such as tall fences preclude movements of migratory populations. Most forms of development in the West, however, represent semipermeable barriers, and their influences on migration remain unclear. This study entails using fine-scale mule deer movement data to evaluate the influence of anthropogenic barriers on the animals' migratory behaviors. Our efforts include evaluating the rate of travel, duration of stopovers, and route fidelity of deer migrating across a gradient of development in Southwest Wyoming (fig. 12A−D).

In FY2014, we analyzed mule deer movement metrics and use of migration stopover sites. Our results indicate that mule deer tolerate moderate levels of development along short portions of their migration routes without behavioral effects; however, deer increase their rates of movement if more intense development has occurred along longer portions of their routes. Results from this study will allow managers to understand how to balance development with maintaining migratory corridors in Southwest Wyoming and elsewhere in the West. In addition, our work is helping to document the Red Desert to Hoback mule deer migration corridor (see http://migrationinitiative.org/content/red-desert-hoback-migration-assessment). The BLM, WGFD, and some nongovernmental organizations are using this information to guide fencing modifications, habitat enhancements, and revisions to their resource management plan.

Products Completed in FY2014

- Wyckoff, T.B., 2014, Identifying threshold levels of development that impede Wyoming ungulate migrations: presented at the Annual Wyoming Cooperative Fish and Wildlife Unit Partners Meeting, April 24, 2014, Laramie, Wyo.
- Wyckoff, T.B., Kauffman, M.J., Albeke, S.E., and Sawyer, Hal, 2014, Identifying threshold levels of development that impede mule deer migrations: presented at The Wildlife Society Wyoming Chapter and Central Mountains and Plains Section Joint Annual Meeting, August 26−28, 2014, Sheridan, Wyo.

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U.S. Geological Survey researcher, Matthew Kauffman, releases a radio-collared mule deer doe that had been captured in the southern Wyoming Range of western Wyoming. Photo by Gary Fralick, Wyoming Game and Fish Department.

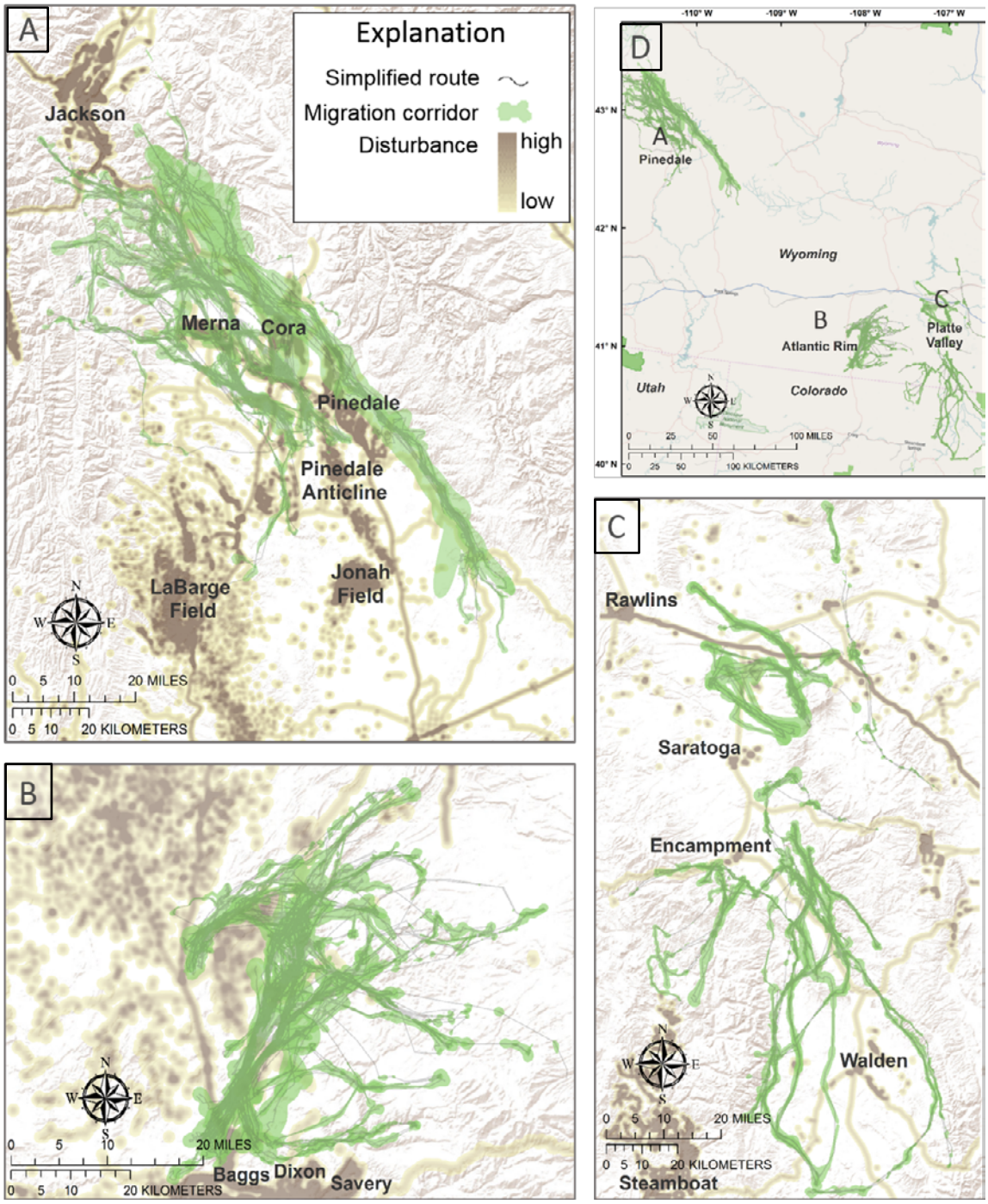

Figure 12. Migration routes and the intensity of disturbance (development) along those routes for three study areas from which mule deer migration movement data were collected in Southwest Wyoming: (A) Pinedale, (B) Atlantic Rim, and (C) Platte Valley, and (D) locator map to show where sites A–C are located in relation to each other and neighboring States. Dark green lines represent recorded locations of radio-collared deer, and light green polygons represent the deer-use area as derived from a model that accounts for deer movements and time. Map created by Teal B. Wyckoff, University of Wyoming.

Influence of Energy Development on Native Fish Communities

The rapid expansion of natural gas development in Southwest Wyoming has raised concerns about how that development affects key wildlife species and habitats. The overall goal of this project is to determine how the presence and intensity of oil and natural gas development are affecting habitat and water quality, and how they, in turn, can influence the presence and abundance of native fish species. The project addresses the WLCI management needs to identify the condition and distribution of key wildlife species and habitats, and species habitat requirements, and to evaluate wildlife and livestock responses to development. Our approach is a comparative study examining subwatersheds affected by different levels of oil and gas development (fig. 13). We are collecting data on aquatic habitat quality, water quality, and fish community structure. The water-quality component of the project is being conducted in collaboration with water-quality scientists at the USGS Columbia Environmental Research Center.

In FY2014, we continued to collect field data (led by Richard Walker, a new Ph.D. student) and began analyzing data collected in previous years (led by Carlin Girard, a finishing M.S. student). Compared to subwatersheds with lower levels of development, we found that surface-water quality was reduced in subwatersheds with higher levels of development, as indicated by elevated concentrations of polycyclic aromatic hydrocarbons and dissolved salts, increased suspended sediment loads, higher temperatures, and lack of sensitive macroinvertebrate families. We also found that fish species' distributions were related to habitat characteristics, with cover and substrate being important factors for the more sensitive species. As a result, one important mechanism by which oil and natural gas development appears to be affecting aquatic habitats and communities is through development-associated surface disturbance leading to increased sedimentation in surface water and decreased riparian cover. This knowledge can help land managers target their conservation efforts toward reducing sediment loads and maintaining stream cover.

Dry Piney Creek, one of the fish and aquatic habitat sampling sites for this study, in an area affected by oil and gas development. Photo by Annika Walters, U.S. Geological Survey, Cooperative Fish and Wildlife Research Unit, University of Wyoming.

Products Completed in FY2014

- Girard, C.E., and Walters, Annika, 2014, The Dry Piney study—Energy development effects to native fish communities along the Wyoming Range: presented at the February 2014 meeting of the Colorado and Wyoming American Fisheries Society, Laramie, Wyo., and the April 2014 meeting of the Western American Fisheries Society meeting, Mazatlan, Mexico (invited).
- Walters, Annika, and Girard, C.E., 2014, Differential vulnerability of fish to energy development: presented at the May 2014 meeting of the Society for Freshwater Science, Portland, Ore.

- Walters, Annika, 2014, Exploring the effects of oil and gas development for aquatic habits and native fish communities in the Wyoming Range: public presented at the National Park Service Research Center, Jackson, Wyo., August 2014 (invited).
- Girard, C.E., The effects of oil and gas development on water quality, aquatic habitat, and native fish in streams along the Wyoming Range: Laramie, Wyo., University of Wyoming, Department of Zoology and Physiology, M.S. thesis (draft).

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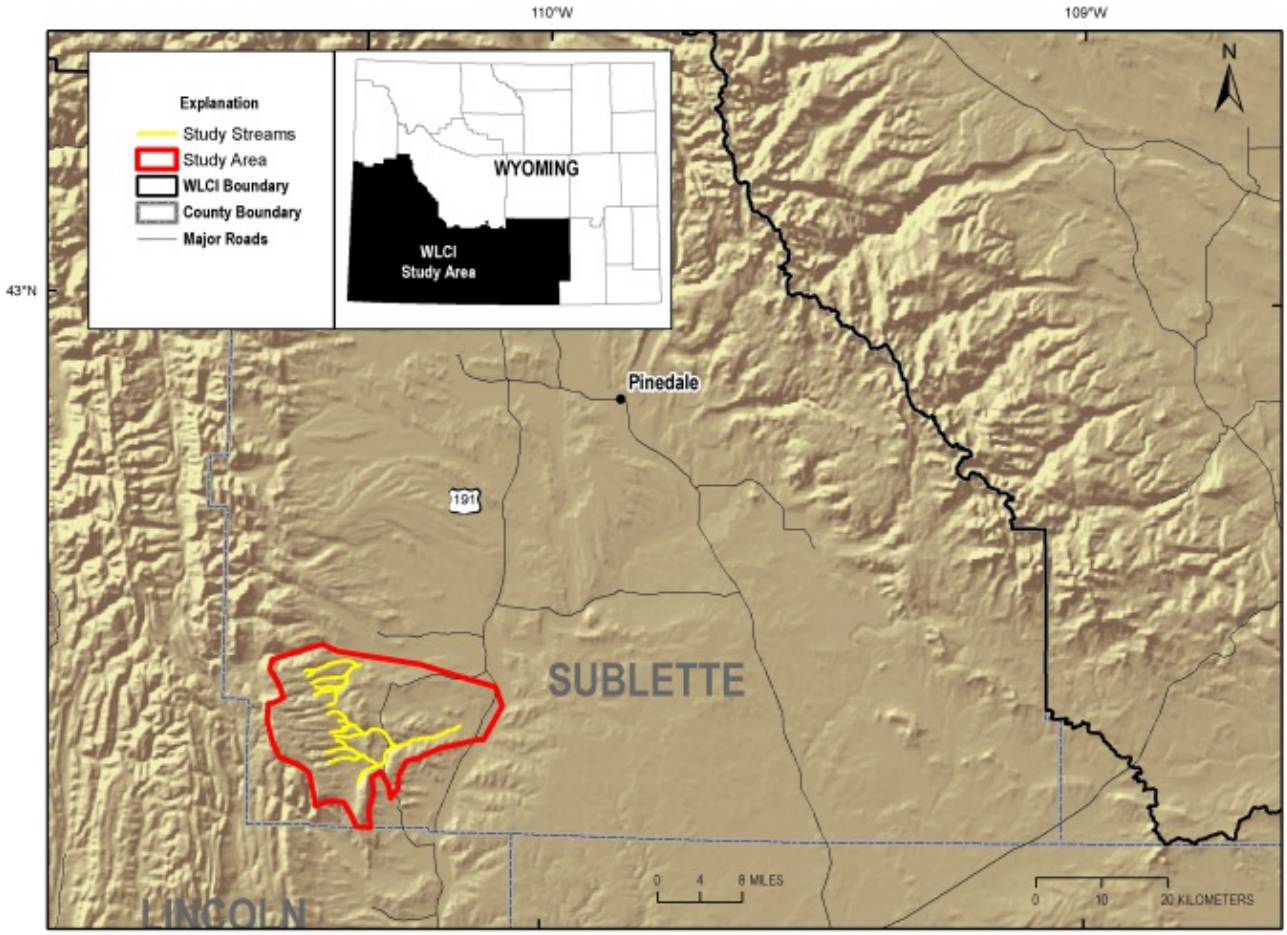

Figure 13. Study area and study streams for evaluating the influence of energy development on native fish communities. South Beaver drainage is to the north and Dry Piney drainage is to the south. Map by Carlin Girard, University of Wyoming. WLCI, Wyoming Landscape Conservation Initiative.

Individual Reports: Data and Information Management

Data Management Framework and Catalog

Managing, analyzing, providing, and using data and information resources assembled or generated for the WLCI are essential for supporting WLCI goals. This project addresses those needs by providing online tools for (1) discovering and using existing data and information; (2) cataloging, preserving, and archiving those resources; and (3) making them available to WLCI researchers, decision-makers, and the public. A WLCI Data Catalog (Catalog) hosted by USGS is available at www.wlci.gov. The Catalog includes information about and access to data sets, projects, publications, and Web sites relevant to the WLCI. This Catalog is continuously maintained and enhanced to meet user needs, capitalize on technological innovations, and ensure that information resources are current and relevant. This includes routinely seeking and adding new or updated data and metadata. We also periodically harvest data from provider systems to capture updated data and other resources.

The WLCI Data Catalog is built into the USGS ScienceBase infrastructure, which provides the data-management and Web-servicing capabilities for the Catalog. ScienceBase undergoes continuous refinement to enhance science project management and to advance information resources. Other WLCI applications developed through the ScienceBase infrastructure and capabilities include the WLCI Integrated Assessment, Long-Term Monitoring mapping tools, Interactive Maps that portray biological and energy data, and the Western Energy Citation Clearinghouse, all of which are available on the WLCI Web site. The myUSGS wiki system is another online component of the Data Management Framework that provides the WLCI community with tools for managing documents, conducting and recording discussions, organizing materials, managing community access, and easing the process of organizing events. The WLCI Coordination Team is using myUSGS to store, organize, and track information associated with WLCI habitat conservation projects. We routinely upload updated information on WLCI science projects and habitat conservation projects.

In FY2014, we continued to improve the WLCI Data Catalog and enable access to and use of WLCI data and maps, as well as locations, summaries, and key results of science and habitat conservation projects. We also added updated information about WLCI projects and new publications to the WLCI Data Catalog and made it available through the WLCI Web site. This requires using Web services and metadata preparation in the WLCI Data Catalog to improve completeness and uniformity for distribution and display.

Products Completed in FY2014

- The WLCI Data Catalog was maintained and enhanced, and the data-management tools and capabilities were advanced to promote efficiency in and progress of WLCI efforts.
- New and updated USGS Science and Partner Habitat Conservation Project information was added to the WLCI Data Catalog and made available through the WLCI Web site.
- Web services were enhanced to serve data and information more efficiently from the WLCI Data Catalog to WLCI Web site.

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Web Application Development for Data and Information Management

Each year the USGS Science Team produces publications reporting data and findings collected in the WLCI region. The WLCI partners and decision-makers expressed a need to access more comprehensive views of scientific information resulting from WLCI science and habitat projects. To promote use of and accessibility to data and other information associated with published scientific reports, in prior years we developed user-friendly tools for mapping geospatial data in an interactive environment, accessing data documentation (metadata), and downloading data. This exposes a wider audience to WLCI data and other information than previous tools did. We also improved the integration of those data with other scientific data. For example, both energy and biological data for the WLCI region are available through the WLCI Web site (www.wlci.gov), and integration of these data allow users to better visualize where energy development is or may overlap with important wildlife habitats or other natural resources.

In FY2014, we developed three online map viewing applications, now available on the WLCI Web site, to display geospatial data pertinent to the WLCI region.

(1) A time-sequenced map that shows progressive oil and gas well development from 1900–2008 within the original WLCI boundary (see fig. 2 in Bowen, Aldridge, Anderson, Assal, and others, 2009). These data were acquired from the Wyoming Oil and Gas Conservation Commission and processed by the USGS (Biewick, 2009).

(2) A map produced by the USGS GAP Analysis Program that displays predicted distributions for a subset of Wyoming's highest conservation priority species listed in the Wyoming State Wildlife Action Plan (Wyoming Game and Fish Department, 2010). The National Gap Analysis Program generates predicted species distributions across the United States to help decision-makers, managers, and scientists to assess species' conservation status and plan conservation actions and research. The maps were created using a deductive model to predict areas suitable for occupation within a species range.

(3) A map (fig. 14) that displays a subset of the energy data portrayed by Biewick and Jones (2012) in their "Energy Map of Southwestern Wyoming, Part A—Coal and Wind," which comprises more than 100 spatial data layers associated with wind and coal energy production, as well as information about coal mines and coal geology. The map also includes data layers developed by the Wyoming Game and Fish Department that portray sage-grouse distribution, core management areas, and electrical transmission-line corridors that represent the State of Wyoming's preferred alternative for routing transmission lines across the sage-grouse core management areas.

Products Completed in FY2014

- Oil and gas development in southwestern Wyoming, 1900–2008.
- Species distributions in southwestern Wyoming.
- Wind and coal energy development in southwestern Wyoming.

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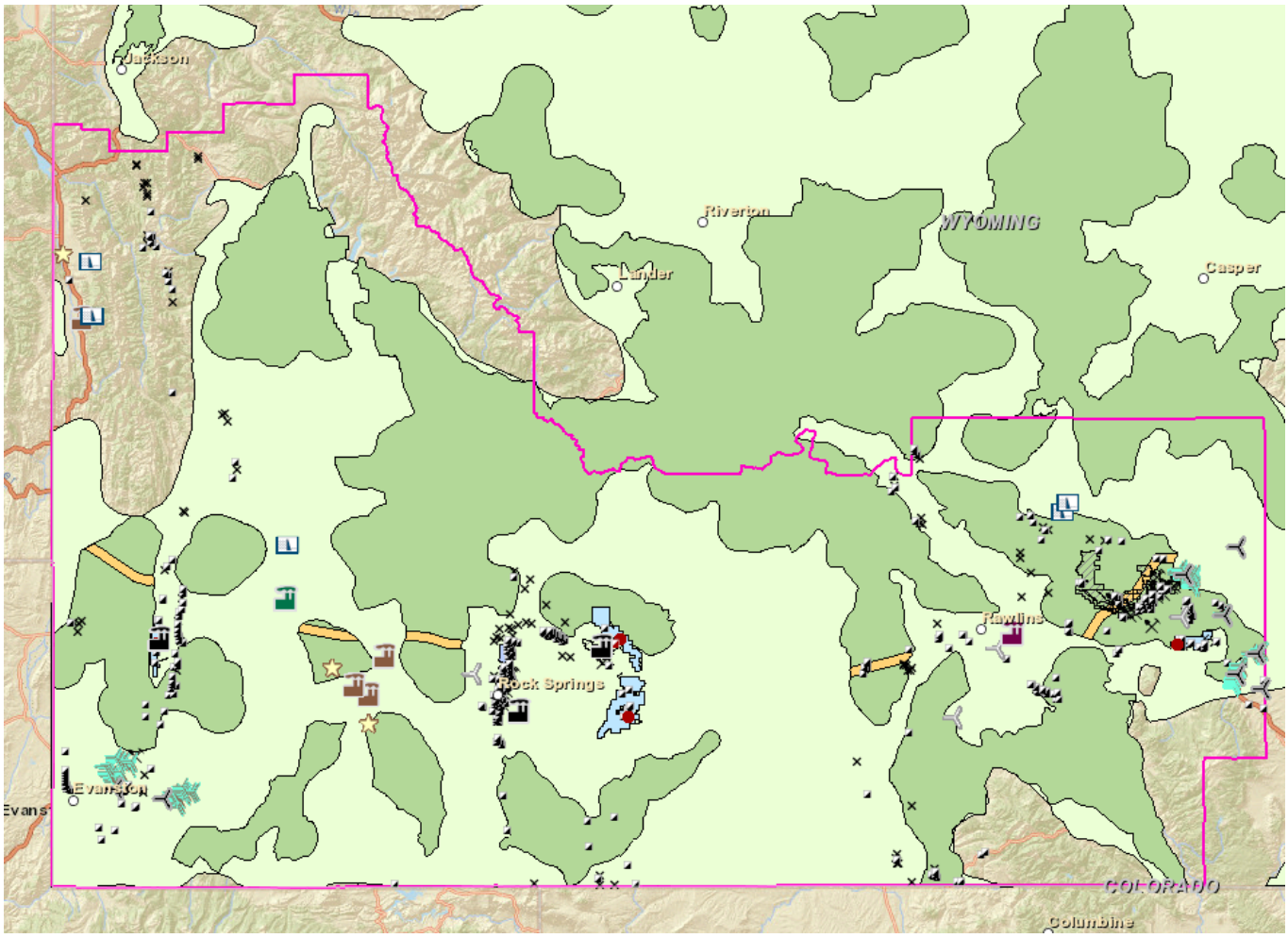

Figure 14. Screen shot of the interactive energy map of the Wyoming Landscape Conservation Initiative (WLCI) region (encompassed by the pink line) in southwestern Wyoming. Data layers displayed include sage-grouse distribution (lighter and darker green areas), sage-grouse core management areas (darker green only; data from the Wyoming Game and Fish Department), power plants (including coal, co-generation, diesel, natural gas, and hydroelectric), existing and proposed (as of May 2012) wind generation projects, transmission lines, coal mines, and more. To access explanations of what the map shows, including symbols, and display it in greater detail, go to https://www.wlci.gov/wlciMapviewer/maps/map?map=EnergyDevelopment.

Outreach and Graphic Products

A multipartner project as large as the WLCI requires excellent intra- and interagency communication, as well as dissemination of products and other information to those interested in learning about the WLCI, gleaning information for informing and supporting planning and decisions, and tracking project progress. To meet that need, the USGS developed a Web site for the WLCI at www.wlci.gov. This Web site provides information about ongoing activities and facilitates user discovery (search functions) of additional resources, including workshops, publications, reports, newsletters, data, and both habitat conservation and science projects. With aid from the USGS Data and Information Management Team, the WLCI Coordination Team and Communication Team manage the Web site's content.

The rapid acquisition of data and other information resources, ongoing product development, and evolutions of WLCI science projects and conservation activities necessitate regular maintenance and refinement of the WLCI Web site, as well as resolution of technical issues that may arise. It also necessitates that the USGS Data and Information Team (Data Team) works closely with the WLCI Coordination and Communication Teams to maintain information relevancy and identify outreach needs. In FY2014 our work focused on meeting those needs, which continues to be accomplished in three important ways.

First, authorized Data Team members routinely add and update information and products on the WLCI Web site, including project descriptions and results, photographs, press releases, and meeting notes and agendas. Second, Data Team representatives regularly communicate and (or) meet with the WLCI Executive Committee and the WLCI Coordination and Communication Teams to remain informed about WLCI activities and assist these entities in their efforts to identify and develop necessary modifications for the WLCI Web site, including effective methods for managing, advertising, disseminating, and improving accessibility of WLCI data, products, and other information. Third, Data Team representatives participate in ad-hoc committees assembled for managing and coordinating special events and activities. Methods associated with this work are published in professional articles and agency reports to ensure that they are available for application in future science and conservation projects.

Products Completed in FY2014

- Refinement of and support for WLCI Web site, using Web services to dynamically display cataloged information in the WLCI Data Catalog.
- Improved data and information records cataloged in WLCI Data Catalog for display in WLCI Web site.
- Advanced Web servicing capabilities allowing dynamic use of cataloged information items, such as project information and citations, in WLCI Web site.

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Biewick, L.R.H., and Jones, N.R., 2012, Energy map of southwestern Wyoming, Part A—Coal and wind: U.S. Geological Survey Data Series 683, 18 p., at http://pubs.usgs.gov/ds/683/.

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