USGS
science for a changing world

U.S. Geological Survey Science for the Wyoming Landscape Conservation Initiative—2013 Annual Report

Open-File Report 2014–1213

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

Cover photographs: (Front cover, background) Looking down into the Big Piney headwaters and (front cover, inset) young Colorado River cutthroat trout found during fish surveys of the South Beaver drainage. Both drainages are study areas for a new U.S. Geological Survey study to evaluate effects of energy development on native fish communities in the Upper Green River watershed in southwestern Wyoming. Photos by Carlin Girard, University of Wyoming. (Back cover) Fontenelle Creek headwaters in the Salt River Range, Lincoln County, Wyoming. Photo by Kirk Miller, U.S. Geological Survey.

U.S. Geological Survey Science for the Wyoming Landscape Conservation Initiative—2013 Annual Report

By Zachary H. Bowen, Cameron L. Aldridge, Patrick J. Anderson, Timothy J. Assal, Carleton R. Bern, Laura R.H. Biewick, Gregory K. Boughton, Anna D. Chalfoun, Geneva W. Chong, Marie Dematatis, Bradley C. Fedy, Steven L. Garman, Stephen Germaine, Matthew G. Hethcoat, Collin Homer, Christopher Huber, Matthew J. Kauffman, Natalie Latysh, Daniel Manier, Cynthia P. Melcher, Kirk A. Miller, Christopher J. Potter, Spencer L., Schell, Michael J. Sweat, Annika Walters, and Anna B. Wilson

Open-File Report 2014–1213

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 2014

Suggested citation: Bowen, Z.H., Aldridge, C.L., Anderson, P.J., Assal, T.J., Bern, C.R., Biewick, L.R.H., Boughton, G.K., Chalfoun, A.D., Chong, G.W., Dematatis, Marie, Fedy, B.C., Garman, S.L., Germaine, Stephen, Hethcoat, M.G., Homer, Collin, Huber, Collin, Kauffman, M.J., Latysh, Natalie, Manier, Daniel, Melcher, C.P., Miller, K.A., Potter, C.J., Schell, S.L., Sweat, M.J., Walters, Annikia, and Wilson, A.B., 2014, U.S. Geological Survey science for the Wyoming Landscape Conservation Initiative—2013 annual report: U.S. Geological Survey Open-File Report 2014–1213, 60 p., *http://dx.doi.org/10.3133/ofr20141213*.

ISSN 2331-1258 (online)

Contents

Figures

Tables

Conversion Factors

Inch/Pound to SI

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)

SI 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
Antelope bitterbrush	*Purshia tridentata*	Mountain mahogany	*Cercocarpus montanus*
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 sparrow	*Artemisiospiza belli*
		Sage thrasher	*Oreoscoptes montanus*
Currant species	*Ribes* spp.	Serviceberry	*Amelanchier alnifolia*
Curl-leaf mahogany	*Cercocarpus ledifolius*	Snowberry	*Symphoricarpos spp.*
Deer mouse	*Peromyscus maniculatus*	Thirteen-lined ground squirrel	*Ictidomys tridecemlineatus*
Elk	*Cervus canadensis*	Uinta ground squirrel	*Urocitellus armatus*
Gooseberry species	*Rhus* spp.	Sumac species	*Rhus* spp.
Greater sage-grouse	*Centrocercus urophasianus*		

Acronyms Used in this Report

BLM	U.S. Bureau of Land Management
CT	Coordination Team (for the Wyoming Landscape Conservation Initiative)
FY	Fiscal Year (Federal FY2013 was October 1, 2012 through September 30, 2013)
GIS	Geographic information system
GPS	Global positioning system
IA	Integrated Assessment
IAMD	Interagency Monitoring Database
IAMT	Interagency Monitoring Team
ISR	In-situ recovery
LME	Little Mountain Ecosystem
LPDT	Local Project Development Team
NPL	Normally Pressured Lance Formation
NDVI	Normalized difference vegetation index
NWISWeb	National Water Information System Web site
SGCN	Species of Greatest Conservation Need
STAC	Science and Technical Advisory Committee
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WDEQ	Wyoming Department of Environmental Quality
WGFD	Wyoming Game and Fish Department
WLCI	Wyoming Landscape Conservation Initiative
WGQMN	Wyoming Groundwater Quality Monitoring Network

Acknowledgments

The authors thank the Wyoming Landscape Conservation Initiative's Science and Technical Advisory Committee and the Coordination Team for their ideas and advice regarding this report, and the authors acknowledge the Wyoming Game and Fish Department and the U.S. Bureau of Land Management for supporting the U.S. Geological Survey's WLCI efforts by providing data and other information. The authors also wish to thank Paul Griffin and Leslie Richardson for their thorough reviews.

U.S. Geological Survey Science for the Wyoming Landscape Conservation Initiative—2013 Annual Report

By Zachary H. Bowen,[1] Cameron L. Aldridge,[2] Patrick J. Anderson,[1] Timothy J. Assal,[1] Carleton R. Bern,[3] Laura R.H. Biewick,[4] Gregory K. Boughton,[5] Anna D. Chalfoun,[6] Geneva W. Chong,[7] Marie Dematatis,[8] Bradley C. Fedy,[9] Steven L. Garman,[10] Stephen Germaine,[1] Matthew G. Hethcoat,[6] Collin Homer,[11] Christopher Huber,[1] Matthew J. Kauffman,[6] Natalie Latysh,[12] Daniel Manier,[1] Cynthia P. Melcher,[1] Kirk A. Miller,[5] Christopher J. Potter,[4] Spencer L. Schell,[1] Micahel J. Sweat,[5] Annika Walters,[6] and Anna B. Wilson[13]

Introduction and U.S Geological Survey Roles in the WLCI

Wyoming Landscape Conservation Initiative: Conserving Natural and Cultural Legacies

Southwest Wyoming is a cornucopia of wildlife, habitat, open spaces, and outdoor recreational opportunities. It also supports agricultural economies and is endowed with an abundance of energy resources. Although energy exploration and development have been taking place in the region since the late 1800s, the pace of energy development has increased significantly since the early 2000s. This in turn is driving rapid urban and exurban development. As all development increases, so does the concern that landscape-level changes will diminish wildlife habitat and the quality of human life in the region. This concern prompted Federal, State, and local agencies to undertake the Wyoming Landscape Conservation Initiative (WLCI), the mission of which is to implement a science-based, multi-disciplinary program of conservation planning, long-term monitoring, on-the-ground habitat projects, and public outreach for assessing, conserving, and(or) enhancing the terrestrial and aquatic habitats of Southwest Wyoming (fig. 1) while facilitating responsible development.

[1] U.S. Geological Survey, Fort Collins Science Center, Fort Collins, Colo.
[2] Colorado State University, Natural Resource Ecology Laboratory, Fort Collins, Colo., in cooperation with U.S. Geological Survey, Fort Collins Science Center, Fort Collins, Colo.
[3] U.S. Geological Survey, Geophysics and Geochemisty Science Center, Denver, Colo.
[4] U.S. Geological Survey, Central Energy Resources Science Center, Denver, Colo.
[5] U.S. Geological Survey, Wyoming-Montana Water Science Center, Cheyenne, Wyo.
[6] U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit, Dept. of Zoology and Physiology, University of Wyoming, Laramie, Wyo.
[7] U.S. Geological Survey, Northern Rocky Mountain Science Center, Jackson, Wyo.
[8] Cherokee Services Group, contracted to U.S. Geological Survey, Fort Collins Science Center, Fort Collins, Colo.
[9] Environment and Resource Studies, University of Waterloo, Waterloo, Ont., Canada
[10] U.S. Geological Survey, Geosciences and Environmental Change Science Center, Denver, Colo.
[11] U.S. Geological Survey, Earth Resources Observation and Science Center, Sioux Falls, S.D.
[12] U.S. Geological Survey, Core Science Analytics and Synthesis and Libraries, Denver, Colo.
[13] U.S. Geological Survey, Central Mineral and Environmental Resources Science Center, Denver, Colo.

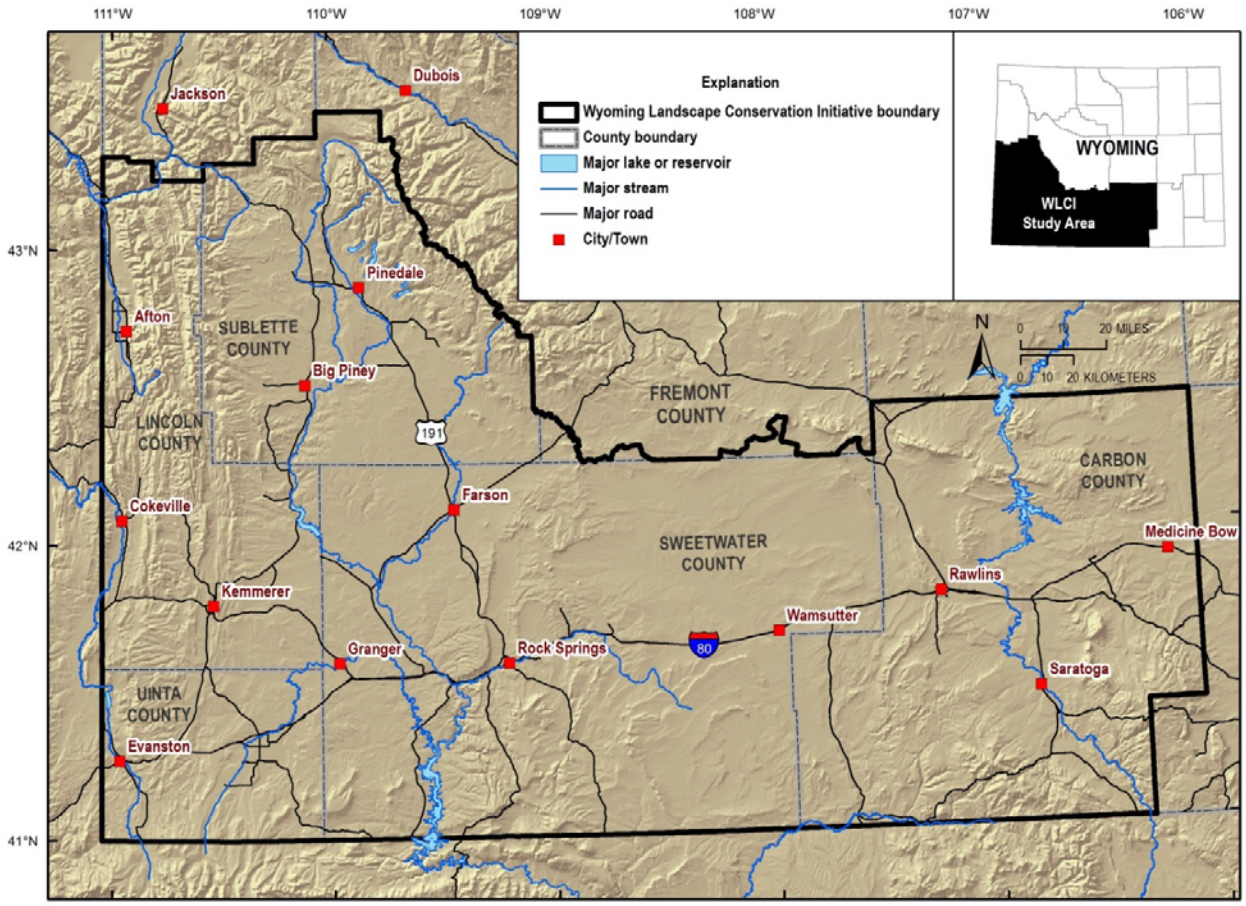


Figure 1. The Wyoming Landscape Conservation Initiative (WLCI) region, including county boundaries, major drainages, roads, and cities/towns.

Building Strength through Partnerships, Cooperation, and Stakeholder Involvement

The WLCI was initiated in 2008. In the six years since then, there has been tremendous success in working towards the Initiative's mission, and it is expected that the work will continue in the foreseeable future. A landmark feature of the WLCI effort is the involvement of myriad partners, cooperators, and stakeholders. Official partners entered into a cooperative agreement through a memorandum of understanding that outlined the WLCI mission, objectives, organization, and operations. It also stipulated the roles and responsibilities of the various WLCI leadership teams. Partners provide representatives to the WLCI leadership teams, share existing and new data and related information, provide field and technical expertise, and bring a variety of other strengths and capabilities to the overall WLCI effort. The WLCI partners with land holdings and(or) resource-management responsibilities conduct the planning, decision-making, and implementation of management actions and best management practices across the WLCI region.

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.

Official WLCI Partners

- Bureau of Land Management
- U.S. Geological Survey
- U.S. Fish and Wildlife Service
- Wyoming Game and Fish Commission (policy-making board for Wyoming Game and Fish Department)
- Wyoming Department of Agriculture
- U.S. Forest Service
- Commissions for Carbon, Sweetwater, Lincoln, Uinta, Fremont, and Sublette counties
- Nine Conservation Districts
- National Park Service
- Natural Resources Conservation Service

WLCI Cooperators and Stakeholders

- U.S. Bureau of Reclamation
- Wyoming Department of Environmental Quality
- Wyoming State Land Board
- Jonah Interagency Mitigation and Reclamation Office
- Pinedale Anticline Project Office
- The Nature Conservancy
- Trout Unlimited
- County weed and pest agencies
- Energy- and mineral-development companies
- Private landowners

The U.S. Geological Survey: What We Bring to the WLCI Effort

The U.S. Geological Survey (USGS) is responsible for providing a solid foundation of science-based information, tools, and technical assistance for informing and supporting WLCI partner planning, decision-making, and management actions. Since WLCI implementation, the USGS Science Team (hereafter, Science Team) has been represented by dozens of scientific investigators, technical experts, and field staff from eight major disciplines: hydrology, geology, biology, social science, geography/mapping, remote sensing/geographic information systems (GIS), data and information management, and Web-application development. To help facilitate partner communications and to assist with and coordinate WLCI activities conducted by WLCI partners, the USGS provides a full-time liaison to the WLCI Coordination Team (CT). On the basis of existing and new science findings, the liaison helps to inform adaptive management strategies, best management practices, and prioritization of habitat restoration and enhancement projects developed by WLCI partners. The liaison also helps to ensure the integration of new and existing knowledge and technologies, and facilitates the dissemination, interpretation, and use of USGS science and technical assistance

U.S. Geological Survey Roles in the WLCI

- Provide a multi-disciplinary team of scientists and technical experts.
- Conduct science and technical assistance activities and develop tools that help to inform and support WLCI partner planning, decision-making, and on-the-ground management actions.
- Provide a liaison to the WLCI Coordination Team to
  - facilitate coordination, communication, and activities among WLCI partners,
  - integrate new information and technologies with planning, decision-making, and management actions, and
  - facilitate dissemination, interpretation, and use of U.S. Geological Survey findings, products, and tools.
- Lead the Interagency Monitoring Team.

products for WLCI partners, collaborators, and stakeholders. Finally, the USGS provides the leadership for a recently formed Interagency Monitoring Team (IAMT), the mission of which is to standardize and coordinate WLCI monitoring activities and build a centralized Interagency Monitoring Database (IAMD).

Strategy and Framework for WLCI Science: Building Knowledge from a Strong Foundation

Prior to WLCI implementation, a series of workshops were held (see D'Erchia, 2008) to provide potential WLCI partners and leadership teams opportunities to identify major management needs and associated objectives that pertained to the WLCI region (table 1). The outcomes of these workshops fell into four major themes and became the foundation of USGS WLCI science.

- Identify and assess the cumulative environmental effects (current and future) associated with development activities and other major drivers of landscape change.
- Develop and test 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.

The WLCI partners also identified five priority habitats that would be focal to WLCI science, habitat projects, monitoring, and conservation activities. They further stipulated that Wyoming's wildlife Species of Greatest Conservation Need (SGCN) (Wyoming Game and Fish Department, 2010) would be priority targets of WLCI science and other activities.

WLCI Priority Habitats

Sagebrush steppe	Riparian
Mixed mountain shrublands	Aquatic
Aspen	

Identifying management needs, objectives, and focal habitats/species culminated with a collaborative effort between the USGS and other WLCI partners to develop a list of potential short- and long-term science and technical assistance activities that would help partners to achieve their management objectives. The USGS then developed its WLCI Science Strategy (Bowen, Aldridge, Anderson, Chong, and others, 2009), which provides a conceptual framework (fig. 2) for organizing and guiding USGS science and technical assistance activities conducted to help meet the objectives of WLCI partner management needs (table 2). With the six management needs serving as the foundation, the framework comprises two tiers of science activities—Baseline Synthesis and Targeted Monitoring and Research—and a tier of Integration and Coordination activities. These tiers are implicitly iterative so that new knowledge and technologies may be incorporated into ongoing USGS work and WLCI partner planning and decision-making. Our Data and Information Management is ongoing to support all activities, and in turn the knowledge gained is applied to the ongoing evaluation of WLCI activities and decision-making regarding future activities.

Major Components of USGS Science and Technical Assistance Activities for Addressing WLCI Management Needs

- Conduct an ongoing synthesis of baseline data for use in comprehensive assessments of historical/current and(or) potential future status and trends of priority habitats and species, agricultural interests, and energy and minerals across the WLCI region.
- Establish a framework, indicators, and an integrated database for long-term monitoring of ecosystem status and trends across the WLCI region.
- Conduct effectiveness monitoring to evaluate whether on-the-ground habitat enhancement or restoration projects implemented by WLCI partners achieve intended objectives.
- Conduct research to elucidate the mechanisms that drive changes in the status and trends of focal habitats and species.
- Develop Web-based applications for making accessible the myriad WLCI data, maps, models, publications, and other products.
- Provide support to partner conservation planners and decision-makers.

The Baseline Synthesis is an ongoing, large-scale effort to synthesize baseline data for assessing current and historical status and trends of ecosystem conditions and climatic patterns across the WLCI region. A crucial facet of this work is the acquisition, compilation, and integration of existing and new data for ascertaining baseline conditions (including mapping natural resource distributions and developing status indices), conducting landscape-scale assessments, and projecting future conditions. The Baseline Synthesis also entails modeling potential trajectories of habitat and wildlife populations under future scenarios of energy development and other land uses, as well as climate change. The Targeted Monitoring and Research work, also ongoing, has three main arms: (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 and other factors affect Wyoming's SGCN.

Our program of Integration and Coordination is accomplished through regular communications and meetings with WLCI leadership teams, land managers, and others to ensure maximum efficiency and usefulness of WLCI partner and USGS science activities. This work also includes ensuring that new data are integrated with existing data, and that USGS science results, techniques, and products are considered in partner planning and management actions. Ultimately, the results, products, and tools produced by USGS are incorporated into Web-based systems and services through our Data and Information Management activities. These activities include developing, maintaining, and enhancing the WLCI Web site, the WLCI data clearinghouse and project tracker, USGS servers and storage capacities, and USGS-developed software applications for visualizing (mapping) assessment and other spatial data, managing events, and partner communications. In turn, all the data, products, and tools are made available to WLCI partners and collaborators for supporting their planning, decision-making, and programmatic evaluations.

Table 1. Major management needs, objectives, and short- and long-term activities identified by partners of the Wyoming Landscape Conservation Initiative during workshops and meetings prior to initiative implementation. Management need and objective pairs (for example, 1A) listed below correspond to U.S. Geological Survey science and technical assistance activities conducted to date.

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-/long-term disturbances, fire, invasive species, livestock grazing). B. Develop new methods or improve/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/occurrence of energy/mineral resources based on most current information for viable deposit types/assessment units. D. Develop methods to assess full costs (exploration, extraction, use) of energy/mineral development.
2. Identify condition and distribution of key wildlife species/habitats, and species habitat requirements	A. Identify key aquatic/terrestrial species or assemblages (including indicator, umbrella, socially/economically important, or special status species). B. Assess baseline conditions and determine landscape-level habitat requirements for important aquatic/terrestrial species (special status, keystone, economically/socially important). C. Use Wyoming Game and Fish Department's Strategic Habitat Plan as a foundation to delineate spatiotemporal habitat distribution, map key/high-quality habitats for key species/assemblages. D. Identify key areas of conservation concern/priority by mapping important, sensitive, and rare habitats, critical habitats (including nesting, rearing, wintering, spawning, migration) required for long-term persistence of key wildlife species. E. Identify vulnerability/sensitivity of key habitats/areas to key drivers of change. F. Relate habitat characteristics to animal distribution/population dynamics (an index of habitat quality) to assess effects of key drivers of change on aquatic/terrestrial wildlife/habitats.
3. Evaluate wildlife and livestock responses to development	A. Evaluate direct effects of energy development and other major drivers on physiology/demographic performance of wildlife (individual species and species groups) and livestock. B. Evaluate indirect effects of habitat alteration on wildlife/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/edge effects that influence wildlife behavior and population structure/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/ restoration practices in different habitat types/precipitation zones. B. Evaluate/guide refinement of Best Management Practices. C. Evaluate relationships between observed resource responses and management activities (restoration, reclamation, and habitat-improvement projects). D. Design a framework for objectively developing the most effective restoration/enhancement projects on a landscape scale.

Table 1. Major management needs, objectives, and short- and long-term activities identified by partners of the Wyoming Landscape Conservation Initiative during workshops and meetings prior to initiative implementation. Management need and objective pairs (for example, 1A) listed below correspond to U.S. Geological Survey science and technical assistance activities conducted to date.—Continued

Management Need	Objectives
5. Develop an integrated inventory and monitoring strategy	A. Develop inventory/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/protocols. C. Integrate WLCI inventory/ monitoring programs with other local, State, and Federal efforts. D. Make inventory/monitoring information accessible to WLCI partners/resource managers through data-management framework/data clearinghouse. E. Integrate inventory/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/implement a project tracking/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/outreach on WLCI habitat improvement/science activities.

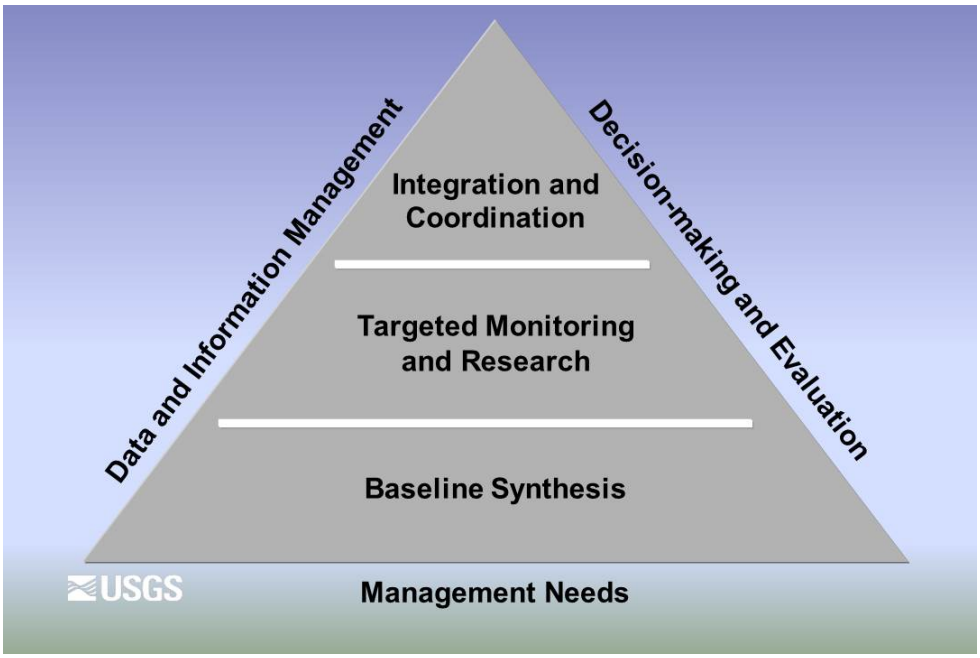


Figure 2. The U.S. Geological Survey's framework for guiding its research, assessment, and monitoring of ecosystem components. The Management Needs identified by the Wyoming Landscape Conservation Initiative (WLCI) partners form the foundation of the five major U.S. Geological Survey's WLCI science activities: (1) Baseline Synthesis, (2) Targeted Monitoring and Research, (3) Integration and Coordination, (4) Data and Information Management, and (5) 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.

Table 2. Summary of Wyoming Landscape Conservation Initiative (WLCI) management objectives (see table 1) addressed by science and technical assistance activities conducted by the U.S. Geological Survey's Science Team in Fiscal Year (FY) 2013. Activity status as of September 30, 2013, and focal species and(or) habitats addressed by the activity are provided. Activity titles and page numbers are hotlinked so that users may go directly to reports on activities of particular interest.

Management needs/objectives addressed	Activity title	Status at end of FY2013	Focal species and(or) habitat	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	*23*
1A−C; 2A−B, F; 3A; 5A	*Modeling land use/cover change*	Ongoing	Greater sage-grouse, pygmy rabbit, mule deer; all focal habitats	*24*
1A−C; 2B, F	*Assessing energy resources*	Ongoing	N/A	*26*
1A−C; 2B, F	*Assessing mineral resources*	Ongoing	N/A	*27*
1A, D; 2B; 3A−B,C; 4B; 5A, C−D	*Important agricultural lands in southwestern Wyoming*	Ongoing	N/A	*29*
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	*31*
1A−B; 3B−D; 4C; 5B,C	*Remote sensing and vegetation inventory and monitoring*	Ongoing	Sagebrush species, sagebrush steppe	*33*
1A−B; 4C; 5B−D	*Long-term monitoring of surface water and groundwater hydrology*	Ongoing	Riparian, aquatic	*35*
1A−B; 3B; 4C; 5B−D	*Wyoming groundwater-quality monitoring network*	Ongoing	N/A	*37*
1A−B; 4C; 5B	*A retrospective assessment of groundwater occurrence in the Normally Pressured Lance Formation and a field reconnaissance of existing water wells in the study area*	Ongoing	Aquatic	*38*

Table 2. Summary of Wyoming Landscape Conservation Initiative (WLCI) management objectives (see table 1) addressed by science and technical assistance activities conducted by the U.S. Geological Survey's Science Team in Fiscal Year (FY) 2013. Activity status as of September 30, 2013, and focal species and(or) habitats addressed by the activity are provided. Activity titles and page numbers are hotlinked so that users may go directly to reports on activities of particular interest.—Continued

Management needs/objectives addressed	Activity title	Status at end of FY2013	Focal species and(or) habitat	Page no.
Effectiveness Monitoring activities				
1A; 2A−C,E−F; 3A−C; 4A−D; 5A−E	*Applying greenness indices to evaluate sagebrush treatments*	Ongoing	Sagebrush species, sagebrush steppe	*39*
1A; 2A−D,F; 3A−C; 4A−D; 5A−E	*Mapping mixed mountain shrub communities*	Ongoing	Mountain and curl-leaf mahogany, serviceberry, chokecherry, antelope bitterbrush, mixed mountain shrubland	*42*
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/ nesting habitat)	*43*
1A; 2A−B; 3A−C; 4A−D; 5A−E	*Occurrence of cheatgrass associated with habitat projects*	Suspended[1]	Cheatgrass, sagebrush steppe	
1A; 2A−F; 3A−C; 4A−D; 5A−E	*Landscape assessment and monitoring of semi-arid woodlands*	Ongoing	Aspen	*44*
1A; 2A−F; 3A−C; 4A−D; 5A−E	*Aspen regeneration associated with mechanical removal of subalpine fir*	Ongoing	Aspen, conifer species	*45*
1A; 2A−F; 3A−D; 4A−D; 5A−E	*Herbivory, stand condition, and regeneration rates of aspen on burned and unburned plots*	Ongoing	Aspen	*46*

Table 2. Summary of Wyoming Landscape Conservation Initiative (WLCI) management objectives (see table 1) addressed by science and technical assistance activities conducted by the U.S. Geological Survey's Science Team in Fiscal Year (FY) 2013. Activity status as of September 30, 2013, and focal species and(or) habitats addressed by the activity are provided. Activity titles and page numbers are hotlinked so that users may go directly to reports on activities of particular interest.—Continued

Management needs/objectives addressed	Activity title	Status at end of FY2013	Focal species and(or) habitat	Page no.
Mechanistic Studies of Wildlife				
1A–B; 2A–F; 3A–C; 4C; 5A–D	*Pygmy rabbit*	Ongoing	Pygmy rabbit, sagebrush steppe	*47*
1A–B; 2A–F; 3A–C; 4C; 5A–D	*Greater sage-grouse*	Ongoing	Greater sage-grouse, sagebrush steppe, sage-grouse core areas	*48*
1A–B; 2A–F; 3A–C; 4C; 5A–D	*Sagebrush-obligate songbird community*	Ongoing	Brewer's sparrow, sage sparrow, sage thrasher, sagebrush steppe	*49*
1A–B; 2A–F; 3A–C; 4C; 5A–D	*Mule deer*	Ongoing	Mule deer, mixed mountain shrubland (crucial winter habitat)	*50*
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	*52*
Data and Information Management activities				
5D; 6A–D	*Data management framework and clearinghouse* (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	*55*
6B–D	*Conservation project data model*	Ongoing	N/A	*57*
6A–D	*Outreach and graphic products*	Ongoing	N/A	*58*

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

Identifying and Prioritizing USGS Science and Technical Assistance Activities

The primary means for identifying and prioritizing USGS WLCI science and technical assistance are the short- and long-term research activities originally developed by WLCI partners in collaboration with the USGS and outlined in the USGS Science Strategy (tables 1 and 2). To the extent that WCLI budgets have allowed, the Science Team has initiated or completed a majority of the proposed activities (table 2). As new information and technologies are gained, some of the ongoing activities have needed retooling or a shift in emphasis, and some new activities have been implemented to reflect emerging needs or priorities. Needs for new directions are identified through meetings with the WLCI leadership committees and teams responsible for overseeing and guiding the WLCI effort, including the Executive Committee, Coordination Team, Science and Technical Advisory Committee (STAC), Steering Committee, Local Project Development Teams (LPDTs), and IAMT. Also, each year, the STAC, Steering Committee, and LPDTs meet to identify the habitat enhancement and restoration priorities for the following year. In turn, these priorities also help to guide USGS WLCI science activities. This iterative process of review and refinement helps to ensure that USGS science remains highly relevant to partner needs, new information, and changing conditions.

Resource monitoring activity is further guided by the IAMT. This team of WLCI partner representatives was developed at the request of the Executive Committee and STAC to gather information, provide summaries, and consult and coordinate with stakeholders regarding 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/acquire, and organize data in a centralized Interagency Monitoring Database (IAMD), and to analyze data and other information from past and current monitoring activities conducted throughout the WLCI region. Information on IAMT activity is accessible through the monitoring page of the WLCI Web site (see the *Long-term Monitoring Framework and Indicators* section of this report). Gathering additional information and updating the IAMD through ongoing and new monitoring activities is a continuous IAMT task. The IAMT members are expected to be familiar with monitoring efforts within their agencies, participate in conference calls and meetings that afford opportunities for guiding the format and content of the IAMD, provide updates on monitoring activities within their agencies, and contribute to the IAMT's utility and success.

Primary Foci of the WLCI Interagency Monitoring Team

- Guide interagency monitoring efforts across the WLCI landscape by providing expertise on monitoring issues, designs, methods, and technologies.
- Build an Interagency Monitoring Database by acquiring and organizing monitoring data, including development of an infrastructure for housing and serving the data.
- Analyze monitoring data.
- Communicate with WLCI leadership teams to share and incorporate analysis results and adapt the database framework as needed.

A Guide to Using the FY2013 U.S. Geological Survey WLCI Annual Report

The USGS has produced a comprehensive annual report on 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, 2014). Past reports may be accessed at the URLs listed below. This is the sixth annual report, and details USGS science and technical assistance activities conducted in FY2013. The FY2013 activities, as they relate to the WLCI management needs (table 1) and other WLCI activities, are summarized in Table 2.

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/*

To help WLCI partners focus on accomplishments, products, and take-home messages of USGS work, this report provides two major components: (1) overall FY2013 Highlights; and (2) individual one- to two-page reports for each activity. Users wanting an overview of USGS activities and major accomplishments in FY2013 will benefit from reading the *Highlights of USGS FY2013 Accomplishments* section below. Users more interested in specific activities or more information on individual projects will benefit from reading the individual reports of interest. The individual reports are not meant to provide comprehensive background and methods or detailed results; rather, they are snapshots of project objectives, overall approaches, take-home messages of findings, and major products. The individual reaports also indicate which organizations are using or may use the outcomes and products, and(or) how they are being applied. Users seeking more comprehensive information may visit the WLCI Web site at *http://www.wlci.gov/* and search on activities of interest to access this information. Users also may wish to use the many URLs provided herein for accessing USGS and outside products published in FY2013. At the end of the report is a list of references cited in this document.

A description of the work planned for FY2014 is available on the WLCI Web site under each ongoing project. Significant USGS Science Team accomplishments also continue to be presented at WLCI meetings and science workshops, which are generally made available on the WLCI Web site. In addition, all WLCI products to date are listed on the WLCI Web site. The contacts for WLCI Coordination, Science Integration, Decision-making, and Evaluation work continue to be Patrick Anderson (970-226-9488; *andersonpj@usgs.gov*), Zachary Bowen (970-226-9218; *bowenz@usgs.gov*), and Frank D'Erchia (303-236-1460; *fderchia@usgs.gov*).

Highlights of USGS FY2013 Accomplishments

In FY2013, the USGS initiated or continued work on 25 individual, but integrated, WLCI science and technical assistance activities. All activities focus on addressing one or more of the six management needs identified by WLCI partners (tables 1 and 2) and(or) on providing tools and technical assistance to WLCI partners. Our work continues to address questions and issues at multiple spatial scales, from individual habitat-treatment sites to the entire WLCI landscape and beyond. What follows are the highlights of major FY2013 USGS accomplishments and introductory summaries of new projects initiated in FY2013.

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

Major Themes of the Baseline Synthesis in FY2013

- Compile and catalog existing and new data on WLCI resource distributions and conditions.
- Conduct assessments of WLCI energy, mineral, agricultural, and other resources.
- Develop geospatial data for modeling land cover and use as they relate to sage-grouse and energy development.
- Develop a simulation model for projecting effects of alternative future energy-development scenarios.
- Conduct a multi-disciplinary Integrated Assessment of resource conditions and drivers of change across the WLCI region, and provide the associated Web-based tools for using the assessment.

In FY2013, the USGS continued work on four Baseline Synthesis activities and initiated work on a new activity (table 2). Major accomplishments included ongoing acquisition and cataloging of existing and new data for natural and agricultural resources, assessments of energy and mineral resources, and modeling of land cover and land use as it pertains to sage-grouse habitat and surface disturbance associated with energy development. We also refined a simulation model we developed for projecting future patterns of energy development, and we enhanced our WLCI Integrated Assessment (IA) and associated Web services for using the model and associated materials. Additionally, we demonstrated the IA and its use to each of the LPDTs and sought feedback from them to ensure its ease of use and usefulness; enhancements based on that feedback will be incorporated during FY2014. *These activities directly address management needs to identify key drivers of change (particularly energy and mineral development, and climate change) and the condition/distribution of key wildlife species and habitats, and species' habitat requirements (tables 1 and 2). They also support activities designed to address several objectives under management needs 4–5.*

Important Agricultural Lands in Southwestern Wyoming (new in FY2013)—A new Baseline Synthesis project was initiated in FY2013 to provide information on the historical, ecological, and socioeconomic values of agricultural lands in Southwest Wyoming. Agriculture, both ranching and farming, is one of Wyoming's most profitable industries, but it is also one at great risk from land-use changes affecting the region. This project expands on the agricultural productivity database that we compiled previously for the WLCI. In FY2013, we identified and compiled agricultural data and information and began the work of incorporating this information into the IA. *This work addresses the management need to evaluate wildlife and livestock responses to development. It also contributes to the information needed for addressing management needs 1–2 and 4–5 (tables 1 and 2).* Taking important agricultural land values into consideration will further support local-to-regional planning and decisions regarding land-use and conservation actions.

Wheat is an important crop in Wyoming. Photo by Caleb Carter, University of Wyoming Extension.

Major FY2013 outcomes of our Baseline Synthesis work included publication of USGS Data Series 800, which compiles the land cover/land use data (see *http://pubs.usgs.gov/ds/800/pdf/ds800.pdf*), and a journal article describing characteristics of the Mowry Shale and Frontier formation in the Rocky Mountain region of Wyoming, Colorado, and Utah, which harbor coalbed methane and shale gas resources (see *http://aapgbull.geoscienceworld.org/content/97/6/899.full*). The land cover/land use geospatial data produced include energy development infrastructure and scars, roads, sage-grouse leks, and sage-grouse core areas. Final drafts of two USGS products were reviewed, including Part B of the WLCI Energy Map (depicts oil, gas, oil shale, uranium, and solar resources), and a report that describes Wyoming's lead role in the United States for uranium production.

Collectively, the myriad interdisciplinary data sources and associated products produced from our Baseline Synthesis work provide WLCI partners and the LPDTs with crucial 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 being used in our landscape assessments, and they will be available for comparison to future monitoring data for detecting trends in natural resource conditions and cumulative effects of land-use change. The land cover/land use data depict current and historical patterns of sage-grouse habitat in relation to energy development, and these data feed into our simulation model for posing "what-if" scenarios to evaluate possible outcomes of alternative land-use strategies and practices on habitat and wildlife. These products should prove very useful to planners seeking guidance for locating energy development projects and conserving sage-grouse core areas. The energy and mineral assessment products, as well as data from our climate change modeling (completed in FY2012, with publications forthcoming) are also slated for incorporation into the WLCI IA for identifying areas with high-to-low resource values and high-to-low levels of change to aid in conservation planning and decision-making. The LPDTs are using the compiled, analyzed data to guide

their development of conservation strategies and their prioritizations of areas for conservation and(or) restoration at a range of spatial scales.

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

Long-Term Monitoring Activities

In FY2013, the USGS continued work on five Long-Term Monitoring activities (table 2). Milestone accomplishments were development of a WLCI inventory and monitoring framework, and initiating development of the IAMD, monitoring strategies and protocols, and analytics. We also continued (1) developing and refining methods; including use of remote sensing and other emerging technologies, for landscape-scale monitoring; (2) modeling (mapping) sagebrush steppe habitat across the WLCI region and ascertaining trends in major system components (such as percent cover of sagebrush, herbaceous vegetation, and bare ground); (3) establishing and maintaining on-the-ground networks for monitoring surface and groundwater quality and streamflow; and (4) conducting trend analyses of ecosystem components. For the IAMD, our goal is to use data representing multiple indicators (biotic and abiotic) for assessing overall condition of and trends in WLCI habitats and wildlife populations. *Collectively, these activities directly address the management need to develop an integrated inventory and monitoring strategy (tables 1 and 2). They also indirectly address several objectives for management needs 1–4, and they are integral to addressing management need 6.*

Major Themes of Long-Term Monitoring in FY2013

- Develop an infrastructure and centralized database for coordinating interagency inventory and monitoring activities across the WLCI region.
- Use existing and emerging technologies for developing landscape-scale approaches to natural resource monitoring.
- Establish and maintain monitoring networks for terrestrial and aquatic resources.
- Conduct analyses of trends in ecosystem components. Provide results of water monitoring on U.S. Geological Survey's NWISWeb site.

Major FY2013 outcomes of our Long-Term Monitoring work included (1) the beta (draft) version of a Web-based application developed for displaying and accessing geospatial monitoring data, and (2) a database of monitoring references, which will be accessible next year through the monitoring page of the WLCI Web site (at *http://www.wlci.gov/monitoring*). We also drafted a USGS Fact Sheet for communicating to partners the purposes, challenges, and approaches of resource monitoring, which will be provided to partners, LPDTs, land managers, and others once it is published. Two key products of the sagebrush mapping and monitoring work were developed, including (1) a published journal article (see *http://remotesensing.spiedigitallibrary.org/article.aspx?articleid=1735848*) that describes the approaches used and results to date, and (2) a manuscript on forecasting sagebrush habitat as it relates to sage-grouse, with publication expected in 2014. As in other years, sampling results of surface

and groundwater monitoring were published online at the USGS National Water Information System Web site (NWISWeb) at *http://waterdata.usgs.gov/wy/nwis/nwis*, and a USGS report detailing the characteristics of groundwater sampled was drafted. Data collected as part of the groundwater assessment in the Normally Pressured Lance (NPL) Formation Project Area also were published on NWISWeb and used for drafting a potentiometric surface map (a visual representation of water levels in the aquifer) for the project area.

The sagebrush mapping and monitoring work has already been of great use to agencies in Wyoming as they grapple with questions pertaining to sage-grouse conservation and energy development, including refinements in sage-grouse core areas. As a lynchpin for most of the WLCI science and monitoring activities, the IAMD will be useful to WLCI partners and scientists not only for ascertaining long-term trends in a given set of indicators, but also for conducting future assessments of cumulative effects of land-use and climate changes. The water data collected under the auspices of the WLCI add to the overall network of water monitoring in Wyoming funded by the Wyoming Department of Environmental Quality and the U.S. Environmental Protection Agency, and because our monitoring network targets areas where energy development is occurring or slated to occur, they may serve as a warning system if energy development affects water resources.

Effectiveness Monitoring Activities

In FY2013, we expanded and delivered crucial products for each of our six ongoing Effectiveness Monitoring activities. We enlarged our study of greenness (plant phenology) indices by integrating it with our sagebrush mapping and monitoring study (*Remote Sensing and Vegetation Inventory and Monitoring*; table 2), the overall objectives of which are to (1) characterize additional vegetation trends—such as potential effects of climate change and soil moisture on plant phenology and productivity—in some of our existing sagebrush steppe monitoring sites, and (2) provide baseline information for evaluating the efficacy of reclamation projects.

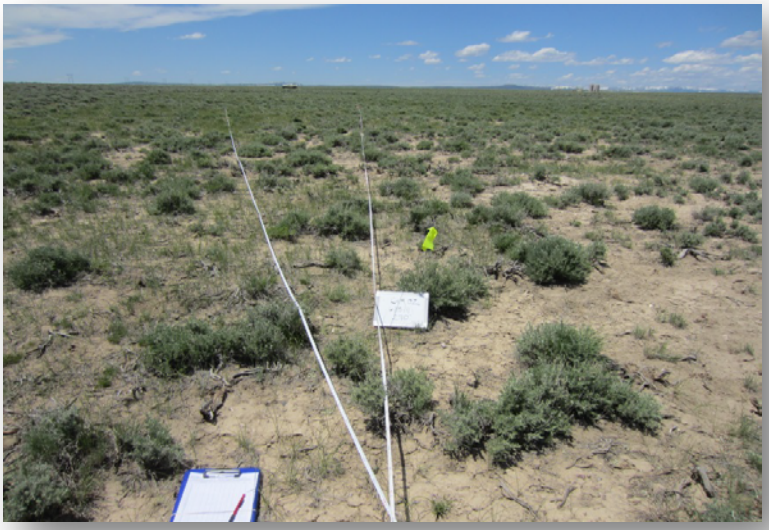
We also completed the initial phase of our mountain shrub-mapping project in the Big Piney-La Barge mule deer winter range by delivering the map and associated geospatial data to the LPDTs and the Wyoming Game and Fish Department (WGFD). The map will help the WGFD and

Major Themes of Effectiveness Monitoring in FY2013

- Integrate our plant phenology and long-term sagebrush monitoring studies to identify trends in sagebrush steppe attributable to changes in climate and soil moisture.
- Develop a map of mixed mountain shrub community within the Big Piney-La Barge mule deer range and deliver it to WLCI partners, and begin developing a model for predicting shrub community occurrence across the entire area.
- Expand the spatial scopes of our aspen treatment and monitoring studies, and deliver the associated maps and spatial data to WLCI partners.
- Combine data on sage-grouse habitat use and nearby energy infrastructure to provide insights on potential influence of energy development on sage-grouse use patterns in areas treated with mowing or herbicides.

LPDTs to address monitoring and management objectives outlined in the Wyoming Range Mule Deer Habitat Plan (Damm and Randall, 2012). With the eventual goal of expanding our mountain shrub mapping results to the entire Big Piney-La Barge area, we tested our ability to map the area based on model predictions. We accomplished this by combining our 2011–2013 field data with remotely sensed imagery to model the probability of mountain shrub presence. When completed, the map should further support LPDTs and the WGFD in their endeavors to conserve and enhance mule deer winter range.

We ascertained the proximity of energy development infrastructure to our sage-grouse pellet-survey transects to provide a landscape context for interpreting our monitoring results of sage-grouse use in areas treated with herbicides to enhance their suitability for sage-grouse broods. This was accomplished by digitizing (from National Agriculture Imagery Program satellite imagery) all roads, well pads, and pipelines within 1 kilometer (km) of the transects and then incorporating those data with our 2009–2013 pellet survey data. We presented the results to WLCI partners and LPDTs to provide insights on how energy development may be influencing patterns of sage-grouse habitat use.



Sampling vegetation and sage-grouse use in a sagebrush treatment area. Photo by Pat Anderson, U.S. Geological Survey.

An important accomplishment of our herbivory and aspen regeneration study in the Little Mountain Ecosystem (LME) was the development of maps of stand metrics and indices of stand condition by combining all of our 2009–2013 data on browsing intensity and stand characteristics. The results of this effort were presented to the Bureau of Land Management (BLM), WGFD, and other entities to help them identify risk factors for aspen and evaluate treatment options for achieving aspen habitat-management objectives. We also expanded our study of conifer removal (to promote aspen regeneration and productivity) in the Sierra Madre Range by adding new study sites in the Little Snake Conservation District and other public and private lands. Subsequently, we delivered maps of the expanded areas and associated geospatial data to our WLCI partners and presented results to the Carbon County LPDT.

Finally, our study of techniques for assessing and monitoring semi-arid woodlands in the LME was expanded to include Pine Mountain (under jurisdiction of the Rock Springs BLM Field Office). The 2013 field season culminated with the delivery of maps and geospatial data to WLCI partners at a Southwest Wyoming aspen workshop. The more proximate goal of this work is to develop a remote-sensing-based program for identifying and monitoring effects of drought and other disturbances, including baseline geospatial data that WLCI partners and LPDTs can use in evaluating and prioritizing aspen treatments. The ultimate goal is to contribute to the growing body of scientific knowledge on ecosystem responses to climate change.

Collectively, our Effectiveness Monitoring activities directly address the management need to evaluate effectiveness of habitat treatment projects, as well as restoration, reclamation, and mitigation activities (tables 1 and 2). These activities are also integral to our long-term monitoring efforts, including evaluation of potential monitoring approaches, development of techniques that use emerging technologies for maximizing the efficiency and efficacy of monitoring efforts, and selection of indicators suitable for monitoring ecosystem trends. These activities also indirectly support objectives associated with management needs 2−3.

Mechanistic Studies of Wildlife

In FY2013, we continued four ongoing Mechanistic studies of wildlife (pygmy rabbits, sage-grouse, sagebrush-obligate songbirds, and mule deer) and initiated a new study (native fish communities) to evaluate responses of wildlife to energy development. All species targeted in this work are Wyoming SGCN, and the greater sage-grouse has been proposed for listing as a threatened species under the Endangered Species Act. For all of these species, Wyoming (especially the WLCI region) encompasses some (if not almost all) of the most important remaining habitat. Much of this work focuses on inter-seasonal habitat requirements, how these animals move across the landscape, factors that alter or impair their movements, and how energy development alters other factors that influence their populations and long-term persistence. Animal movements are crucial for accessing seasonal habitats (such as winter range, nesting and brood-rearing habitats), finding mates, dispersing, and maintaining genetic diversity. Disruptions of animal movements due to habitat loss and fragmentation put populations at risk of extirpation. Another important aspect of this work is to identify other factors that strongly influence wildlife populations, including cycles in predator-prey dynamics and climate, which often require specialized analyses.

Major Themes of Wildlife Research in FY2013

- Develop and validate a pygmy rabbit habitat model that portrays effects of energy development infrastructure on pygmy rabbit habitat and occupancy.
- Develop models for projecting sage-grouse population persistence under current and potential future energy-development scenarios and climate patterns.
- Evaluate effects of predators on sagebrush-obligate songbird abundance and nest survival and how energy development plays into these relationships.
- Evaluate migration movements of radio-collared mule deer in relation to varying levels of energy development.
- Ascertain effects of habitat and water-quality characteristics on native fish communities affected by varying levels of energy development.

The ultimate goal of these wildlife studies is to incorporate their results into the WLCI IA. This will add a significant dimension to the growing body of information being amassed to help inform the BLM, WGFD, and other resource

management agencies when evaluating alternative scenarios of energy development or habitat restoration, and when addressing long-term population and species viability in Wyoming and elsewhere. *Collectively, these studies directly address the management needs to evaluate wildlife and livestock responses to development and to identify the condition and distribution of key wildlife species, habitats, and habitat requirements; they also help to address management needs 1, 2, and 5* (table 1). The many outcomes of this work, including published papers, datasets, and comprehensive maps (with their associated spatial datasets and models), are being used to guide habitat-conservation planning and implementation efforts in Wyoming and beyond.

Influence of Energy Development on Native Fish Communities (new in FY2013)—Information on how energy development affects native fish communities is limited. To address that knowledge gap, we implemented a comparative study for ascertaining differences between drainages influenced by low and high levels of energy development. Specifically, we are measuring habitat and water-quality characteristics that influence fish distributions and population dynamics in the Upper Green River watershed. Our objective is to assess fish vulnerability and sensitivity to habitat changes driven by energy development. Initial results indicate that percent shrub cover is lower and suspended sediment levels are greater in drainages where levels of energy development are greater. The data also indicate that densities of cutthroat trout and mottled sculpin are lower in drainages more affected by development, but mountain sucker populations are similar regardless of development levels. This work also entails assessment of fish habitat availability and connectivity, which will be used in conjunction with aerial imagery to quantify the total footprint of energy development along streams.

In FY2013, we completed a 3-year pygmy rabbit survey in four major gas-field areas, and we initiated surveys at a fifth site identified by the BLM Kemmerer Field Office as a high-priority. The survey data were used to validate a pygmy rabbit habitat map and model that we developed, which incorporate both anthropogenic disturbances and natural features to help us understand how surface disturbances affect rabbit habitat. The data also were used to evaluate effects of habitat structure on rabbit distribution and to identify potential overlap between pygmy rabbit habitat and potential future energy development.

For the sage-grouse project, we continued refining models that explain the effects of energy development and climate patterns on sage-grouse populations. We also began to develop spatial models for projecting the probability of sage-grouse persistence under current and potential future landscape scenarios. The combined outcomes of our ongoing sage-grouse work have resulted in one of the most comprehensive assessments of sage-grouse to date, including a Wildlife Monograph that addresses habitat prioritization needs for at-risk wildlife (using sage-grouse as an example) across seasons and large landscapes. Publication of this monograph is expected in FY2014.

Prior work on our sagebrush-obligate songbird study revealed a negative relationship between well-pad density and songbird abundance and nesting success. In FY2013, we continued our work to elucidate these relationships by monitoring hundreds of nests and viewing hours of infrared video recordings (to enable 24-hour surveillance of songbird nests) to document nest predation and identify predator species. We also conducted predator surveys and measured habitat patch metrics in relation to well-pad density and songbird nest survival. Preliminary results indicate that populations of nest predators (rodents in particular) increase as development intensity increases, which in turn increases

predation on songbird eggs and nestlings. Two manuscripts detailing this work have been prepared for publication in peer-reviewed journals.

To address questions about effects of energy and residential development on mule deer migrations, we have been tracking movements of 206 radio-collared mule deer in the Pinedale Anticline, Atlantic Rim, and Platte Valley areas. To identify levels of development encountered by each collared deer, we also developed a database that depicts the timing and location of development around these areas. Initial results indicate that rates of mule deer movement increase in more developed areas as the deer detour around development; in turn, the deer spend less time foraging and the overall functions of migration routes are reduced. In FY2014, this work will culminate with identifying threshold levels of development below which mule deer migrations may continue relatively unaffected along established routes.

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

A landscape-scale undertaking like the WLCI requires a comprehensive data clearinghouse and associated Web services for data and information sharing, as well as a variety of tools for displaying and(or) serving maps, results, reports, and other outcomes of WLCI partner activities. Collectively, these needs are encapsulated by the management need to develop a data clearinghouse and information management framework (table 1). Our three ongoing Data and Information Management activities not only address this need, but also 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 data-management system—and our associated Web services.

In FY2013, we upgraded our capabilities for discovering, cataloging, and harvesting previously undiscovered existing data for addition to the WLCI clearinghouse in ScienceBase, and we enhanced the interactive capacities of our Web services for discovering, uploading/downloading, visualizing, and(or) using catalogued information, data, documents, and other items. We routinely updated the information and locations of ongoing and new WLCI research studies and habitat projects, added new data collected as part of current WLCI activities, and refined the metadata associated with each database. We also upgraded the capabilities

Major Themes of Data and Information Management in FY2013

- Continue upgrading and enhancing the WLCI Web site, the WLCI data clearinghouse, and associated Web services, including search functions, mapping tools, and interactive capabilities.
- Continue adding new data and other information to the WLCI archives housed in ScienceBase, the U.S. Geological Survey system of cataloging and hosting data and information resources.
- Continue communications with WLCI leadership teams and partners to help ensure that WLCI information and technical assistance needs are met.

and interface of our virtual collaboration space—myUSGS—that the CT uses for organizing, storing, and tracking habitat project information and associated documents and photographs.

Part of our Data and Information Management work each year entails routine communications with the WLCI CT and Communication Team to identify emerging information and technical needs, including public outreach, and potential modifications or enhancements to the WLCI Web site and associated capabilities for addressing those needs. This may include updating or adding new meeting notes, press releases, and other project artifacts to the WLCI Web site. In FY2013, we also updated and enhanced the WLCI Web site's display capabilities of the WLCI bibliography and project information catalogued in the data clearinghouse.

Individual Reports: Baseline Synthesis Activities

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

The comprehensive assessment is a collaborative, two-part effort to compile and analyze resource data to support WLCI needs and efforts. The first part of the assessment is to direct data synthesis and assessment activities so they will inform and support LPDTs and the WLCI CT in their conservation planning efforts, including developing conservation priorities and strategies, identifying priority areas for future conservation actions, supporting the evaluation and ranking of conservation projects, and evaluating spatial and ecological relationships between proposed habitat projects and WLCI priorities. In FY2013, data and information provided by LPDTs and collected as part of the comprehensive assessment were used to prioritize WLCI habitat projects proposed for FY2014. We also used this information to draft the WLCI Conservation Action Plan and BLM's WLCI annual reports for 2012 and 2013.

The second part of the assessment is designed to support decision-making at the WLCI programmatic level and conservation planning at a landscape scale with a multi-disciplinary IA of factors likely to affect successful conservation and management across the WLCI region. The IA may be used to identify areas of high conservation and restoration value and areas with high development potential, based on the current landscape. It also may be used to consider scenarios of potential future development, which may be used for evaluating the conservation and restoration potential of a given area. Finally, the IA provides WLCI partners or other entities a framework for conducting future reassessments and evaluations of change. It addresses priority resources in the WLCI region and their condition, agents of change, and potential future condition 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, but the IA does not preclude users from incorporating local knowledge into finer-scale assessments to inform local management projects for land uses and resource values not considered in this initial effort. In FY2013, we met with each of the four LPDTs to receive feedback on the IA, which will be incorporated in FY2014. Additional improvements to the IA Web site were also completed to enhance its interactive environment.

Products Completed in FY2013

- WLCI conservation project maps for the BLM WLCI 2012 and 2013 annual reports and posters for the WLCI Executive Committee Meetings.
- New and revised spatial products associated with WLCI conservation priorities and actions.
- Continued development of the WLCI IA Web application, at *http://www.wlci.gov/integrated-assessment*.

Contacts: Tim Assal, 970-226-9134, *assalt@usgs.gov*; Patrick Anderson, 970-226-9488, *andersonpj@usgs.gov*; Zack Bowen, 970-225-9218, *bowenz@usgs.gov*; Marie Dematatis, 970-226-9217, *mdematatis@usgs.gov*

Modeling Land Use/Cover Change

Forecasting future patterns in energy development can help inform conservation-management decisions. Identifying (1) areas with a high potential for development, (2) areas likely to remain undisturbed, and (3) overall landscape patterns can help guide the location and types of future habitat management projects. Also, evaluating alternative energy development patterns (such as wider spacing between oil/gas pads, or fewer pads in more concentrated areas) may help to meet conservation objectives by influencing patterns in future development. The goal of this work is to provide a simulation model for assessing different assumptions about future energy development and the resulting effects on wildlife habitat.

The simulation model has been developed and enhanced to accommodate a range of experimental forecasts. The model uses geospatial data of existing land cover, well pads, roads, sage-grouse leks, and sage-grouse core areas along with current and future energy fields. Regulations for well spacing determine the simulated locations of future well pads and the associated road infrastructure. At annual time steps, the footprint of new pad scars and roads are added to the landscape. Direct and indirect effects on wildlife habitat are assessed using known disturbance effects for individual wildlife species and their habitat-pattern requirements.

In FY2013, we fine-tuned the model through comparisons with existing energy fields and evaluation of surface disturbance for different plausible oil/gas pad spacing requirements. Starting with estimates of energy development patterns in 1970, we used spacing regulations to simulate development patterns over a 42 year period (to 2012) and compared them to real-world patterns. Underlying processes of the model were fine-tuned to better emulate current (2012) conditions, thus enhancing the ability of the model to simulate "real" patterns (fig. 3, for example). Using the fine-tuned version of the model, applications pertaining to alternative spacing of well pads have illustrated key trends in the amount of undisturbed sagebrush habitat with increased spacing.

Results of the current and future potential spacing applications will be of use by WLCI LPDTs for prioritizing habitat projects, and they will be made available to BLM and other land management agencies to illustrate potential management needs and effects of alternative spacing regulations.

Products Completed in FY2013

- Garman, S.L., and McBeth, J.L., 2014, Digital representation of oil and natural gas well pad scars in southwest Wyoming: U.S. Geological Survey Data Series 800, 7 p., at *http//dx.doi.org/10.3133/ds800/*.
- Garman, S.L., Simulation model: U.S. Geological Survey Fact Sheet (in review).
- Garman, S.L., Simulation applications of alternative oil/gas pad spacing regulations in Southwest Wyoming (in preparation for submission to peer-reviewed journal).

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

Figure 3. An evaluation of the potential for projecting patterns of future oil and gas development. *A* The actual oil and gas well-pad scars and roads present in the Jonah Infill gas field in 2012, and *B* the simulated projection of the same area. The simulation started in 1970 with 21 pad scars and only county roads, and ended with the scars and roads projected to occur by 2012. Black lines represent roads and blue dots represent well-pad scars. The number of pads simulated for each decade matched historical trends, but pad placement was guided by pad-density specifications for the Jonah field. Overall, the projection did a good job of mirroring the actual development pattern in 2012.

Assessing Energy Resources

Energy development infrastructure in Southwest Wyoming. Photo by Dan Manier, U.S. Geological Survey.

The USGS Energy Resources Program assesses energy resources, including coal, oil and gas, and uranium, as well as environmental effects of energy development. Future effects of energy development in Southwest Wyoming will depend on the energy resources developed and their locations. To identify where energy development is most likely to occur, it is important to apply a geologic understanding to emerging extraction patterns for each energy type. Our studies include (1) maintaining and enhancing a compilation of public and proprietary subsurface petroleum (well) data for the Greater Green River Basin; (2) developing new GIS (map) products to portray geologic studies of energy resources; (3) assessing the oil and gas potential in parts of the Niobrara Formation that underlie the WLCI area; and (4) studying future coal availability in the Washakie Basin. Overall, results of this project provide updated perspectives on energy development in the WLCI region and insights on future development.

In FY2013, we continued assembling a comprehensive, publicly available, online inventory of energy resource data. Energy resource maps, geodatabases, documentation, and spatial data-processing capabilities were published on the USGS Web site. The Energy Map of Southwestern Wyoming (part B), will be completed in FY2014. It focuses on oil and gas, oil shale, uranium, and solar energy resources, and will include layers portraying infrastructure, protected lands, and sensitive areas. The subsurface geology of Southwest Wyoming was compiled in a Geographix® (petroleum-geology geospatial software) database that allows (1) correlation of data pertaining to multiple well logs and the subsurface structure in geologic cross sections and (2) integration with seismic-reflection data for new interpretations of basin structure and the architecture of sedimentary facies. These new interpretations will provide insights on the potential for undiscovered sources of natural gas. We also continued to provide technical input and expertise regarding potential development of oil and gas, coal, coal-bed methane, uranium, and oil-shale resources in the WLCI area to address IA needs and questions pertaining to current oil and gas field projects, such as the Normally Pressured Lance gas field in the Green River Basin.

Products Completed in FY2013

- Biewick, L.R.H., Jones, N.R., and Wilson, A.B., 2013, Energy map of southwestern Wyoming—Energy data archived, organized, integrated and accessible: U.S. Geological Survey General Information Product 145, 21 slides, at *http://pubs.usgs.gov/gip/145/.* (This is part A of a 2-part map.)
- Kirschbaum, M.A., and Mercier, T.J., 2013, Controls on the deposition and preservation of the Cretaceous Mowry Shale and Frontier Formation and equivalents, Rocky Mountain Region, Colorado, Utah, and Wyoming: American Association of Petroleum Geologists Bulletin, v. 97, p. 877−898, at *http://aapgbull.geoscienceworld.org/content/97/6/899.full*.

Contacts: Laura R.H. Biewick, 303-236-7773, *lbiewick@usgs.gov*; Christopher J. Potter, 848-445-6359, *cpotter@usgs.gov*

Assessing Mineral Resources

Numerous mineral deposits, including uranium, are located within the WLCI area, mostly within 19 mineralized areas (fig. 4). Understanding the extent of mineralization and historic mining activity allows us to predict the likelihood of continued or future mining development and its effects, as 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, the current state of the industry is, with a few notable exceptions, mostly dormant in the WLCI study area. While there are hundreds of open claims and leases, there are only a few exploration projects, and even fewer active mining operations. An exception to the dormant state of mining is the increased demand for uranium by *in-situ* recovery (ISR), and for industrial minerals, such as sand/gravel and aggregate, which are placing new demands on the landscape.

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

Metals mining (base and precious metals, both underground and placer) in the WLCI area appears to be non-existent, unless it occurs on a small-scale on private lands. No phosphate mines are currently being operated within the study area, although there is some activity just to the west in Idaho. (The largest former phosphate mines in Southwest 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/Green Mountain area in the Great Divide Basin where traditional surface (open-pit) uranium mining operations have given way to in-situ recovery (ISR) projects. The Lost Creek ISR (Ur-Energy, Inc.) began production in 2013 in the Great Divide Basin area. Several large companies are mining trona (a form of sodium carbonate) underground and processing it to make soda ash. The trona occurs in the center of the Green River basin where underlain by the Wilkins Peak member of the Eocene-age Green River Formation. The increasing demands for sand/gravel and aggregate are being driven by natural gas development in the northwestern part of the WLCI region.

In FY2012, we completed our uranium assessment and submitted it for review as two separate papers. In FY2013, these papers were submitted for USGS publication. Final reports summarizing the remaining mineral resources, including sand and gravel, were prepared and will be reviewed in FY2014. The assessments will help focus land management on the areas most likely to be affected by future mining development or in reclamation of past extraction activities.

Products Completed in FY2013

- Biewick, L.R.H., and Wilson, A.B., 2014, Energy map of southwestern Wyoming, Part B—Oil, gas, oil shale, uranium, and solar: U.S. Geological Survey Data Series XXX (in revision).
- Wilson, A.B., 2014, Uranium in the Wyoming Landscape Conservation Initiative study area, Southwest Wyoming: U.S. Geological Survey Open-File Report 2014-XXXX (in press).
- Wilson, A.B., 2013, Mineral resources of the Wyoming Landscape Conservation Initiative (WLCI) study area—Past, present, and future: Geological Society of America Abstracts with Programs, Denver, Oct. 2013, v. 45, no. 7, p. 539.

Contact: Anna Wilson, 303-236-5593, *awilson@usgs.gov*

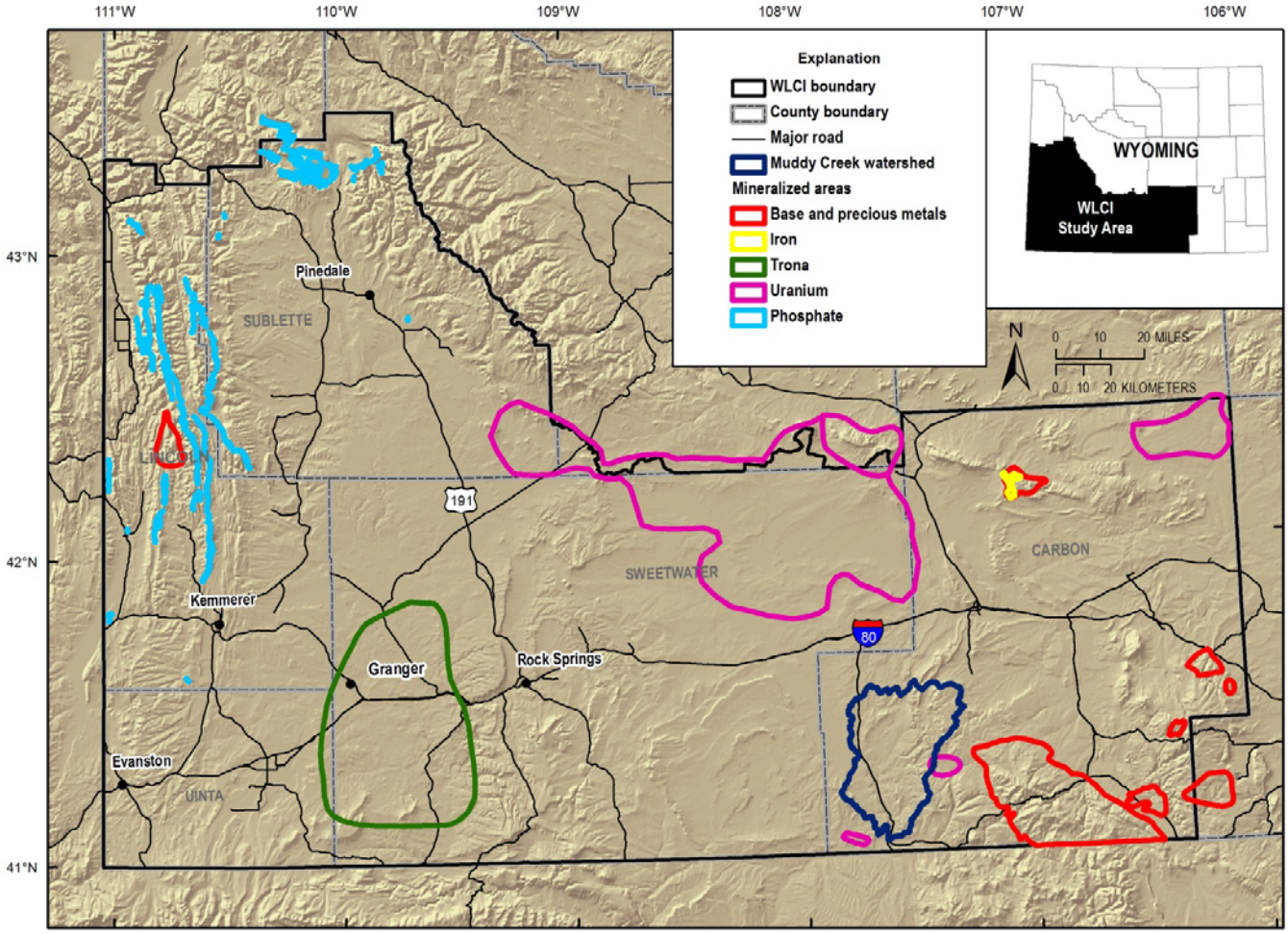


Figure 4. Locations of U.S. Geological Survey's study areas and mineralized areas associated with Baseline Synthesis activities in the Wyoming Landscape Conservation Initiative (WLCI) region.

Important Agricultural Lands in Southwestern Wyoming (New in FY2013)

Agriculture is one of Wyoming's most profitable industries and has a strong presence in the WLCI area, accounting for nearly 18 percent of the State's agricultural lands. Understanding the value of agriculture is important when evaluating landscapes for conservation planning and local development, particularly when other landscape uses may compete with agriculture. This understanding can help to ensure that the values of all land uses can be fully considered instead of focusing on single or few land uses.

Cattle grazing on a ranch recently placed under a conservation easement in the Green River Valley, Wyoming. Photo courtesy of Mark Goecke, Wyoming Game and Fish Department.

To aid decision-makers with difficult land-use choices, researchers previously worked with WLCI partners to develop the WLCI IA, which displays the importance of many resource values on a readily accessible Web-based map. The IA currently contains information on agricultural importance within the WLCI study area but is limited in scope by incorporating only the productivity of agricultural lands. Economists with the USGS were tasked with exploring ways to expand this information to include historical, ecological, and socioeconomic values of important agricultural lands within the WLCI area.

In FY2013, we identified and collected existing data on these new measures of agricultural importance in the WLCI region, keeping in mind our goal of incorporating this information in the Web-based map and the multi-criteria index of resources that comprise the main products of the IA. This work will provide a more integrated and comprehensive information inventory that can aid WLCI partners and other stakeholders in addressing their planning questions and enhance the overall capacity of the WLCI Data Clearinghouse and Information Management Framework. It also will provide greater support for decision-makers on WLCI teams and committees, including the LPDTs, which facilitate local involvement with organizations within the region. In this effort, the USGS coordinated with the Natural Resource Conservation Service, National Conservation Easement Database, WGFD, Wyoming Department of Revenue, BLM, Wyoming State Engineer's Office, National Agricultural Statistics Service, Wyoming Department of Agriculture, Bureau of Economic Analysis, and assessors' offices in Uinta, Lincoln, Carbon, Sweetwater, and Sublette Counties to compile relevant, existing data into one location for this project.

Objectives

- Coordinate with WLCI partners and other agencies to compile data on the productivity, historical, ecological, and socioeconomic values of important agricultural lands within the WLCI region.

- Evaluate landscape-level limitations and usefulness of the compiled data on important agricultural lands in the WLCI area.
- Use the compiled data in the IA to improve the information available about important agricultural lands in the WLCI area.

Methods

Our USGS economists conducted a literature review and met with a small group of WLCI members to decide how the IA would benefit from a more holistic view of important agricultural lands within the WLCI area. We then worked closely with a number of Federal, State, and local government agencies to compile relevant, existing data and house it in one location. The data were then evaluated for potential usefulness and possible inclusion in the Web-based IA index map. Future work will consist of developing a way to categorize this compiled information by importance to users. This will probably require discussions with key WLCI stakeholders and USGS geospatial analysts to integrate the information in the WLCI Data Management framework and Web-based IA map.

Study Area

Our study area is the entire WLCI area, including Carbon, Lincoln, Sublette, Sweetwater, and Uinta Counties within southwestern Wyoming (fig. 1).

Work Accomplished in FY2013 and Implications of Initial Findings

We reviewed the literature on characterizing important agricultural lands, compiled relevant and existing data, and wrote a brief methods report explaining these data. Initial lessons indicate that collaboration with WLCI members is needed to successfully incorporate this compiled information into the Data Management framework and Web-based IA mapping tool. Specifically, to inform users about important agricultural lands in a meaningful way, we must develop a method for defining level(s) of importance for the compiled data. We also found that not all of the compiled data are equally useful. For example, we discovered county-level data (such as profits and employment) on socioeconomic importance of agriculture in terms of regional economic indicators, but this may be too broad-scale for integration in the IA Web-based tool, which displays information at a scale much smaller than the county level.

Products Completed in FY2013

- Compiled agricultural datasets from many organizations and government agencies.
- A literature review of, and interviews with experts about, agricultural history, ecology, productivity, and socioeconomics of Wyoming and elsewhere.
- Methods were developed, baseline data were described, and simple analyses were conducted.
- All products completed in FY2013 will eventually be incorporated into a final report or manuscript when the project is completed.

Contact: Chris Huber, 970-226-9219, *chuber@usgs.gov*

Individual Reports: Long-Term Monitoring Activities

Framework and Indicators for Long-Term Monitoring

The focus of this work is habitat monitoring, with the ultimate goal of facilitating coordinated regional assessments of the WLCI region. Our primary objective is to use data representing the status and trends of multiple important indicators (fauna, flora, and abiota) for assessing the overall condition and health of habitats and wildlife populations across the WLCI region. Based on recent directions from WLCI leadership committees, we are enhancing our efforts to compile data that represent selected resource values to be used for directly assessing landscape conditions. Our approaches include data development and analysis as well as ongoing partner communications to provide relevant information for assessing the status of and trends in Southwest Wyoming's natural resources.

Progress made on several independent, yet related, USGS WLCI science and technical assistance activities contribute to regional monitoring, including Remote Sensing and Vegetation Inventory, Effectiveness Monitoring, Mechanistic Studies of Wildlife, and the WLCI IA. For example, an assessment of temporal changes in sagebrush cover and a comprehensive map of surface disturbances were developed. We aim to integrate indicators developed through these and other USGS activities with additional data from WLCI partners and other sources to improve the collective quality of and benefits from this information for assessment and monitoring efforts. Habitat-mapping products that the USGS has developed through the use of remote-sensing are currently available to our WLCI partners, and additional applications are being developed to enhance the value of the associated data.

In FY2013, we continued to expand the integration of data from many sources, including local stakeholders, and to develop approaches for integrating the data to support regional assessments. Working directly with the WLCI IAMT, we developed a Web application for displaying and accessing geospatial data and had WLCI partners review the draft version. Vegetation data representative of habitat conditions have been provided, and data representing surface disturbances are being developed. Other data will be added as they become available. We completed a WLCI Monitoring Reference database and initiated development of an online interface for using the database; in 2014, the software development will be completed and the database will be made publically available through the WLCI Web site. Because pygmy rabbits and mixed mountain shrub communities are high priorities among WLCI partners, and because they are important for monitoring overall resource conditions in the WLCI region, we also provided financial support to our Pygmy Rabbit and Mapping Mixed Mountain Shrub Communities activities for enhancing their efforts to sample and model the status or condition and distribution of pygmy rabbits and mountain shrub communities. Lastly, we drafted a USGS Fact Sheet to explain the purpose, challenges, and implications of resource monitoring and to demonstrate our multi-faceted approach to monitoring; publication is expected in late 2014. Whereas specific applications and decisions have yet to be established, we have created the foundation for interagency monitoring that is supported by USGS remote-sensing applications and data analyses and is informed by data from multiple sources, including WLCI partners and the USGS. Through the interagency partnership (especially the IAMT), additional data will be developed in FY2014. Through internet applications and outreach, we are communicating directly to partners about the efforts and values associated with monitoring resource status and trends.

A portion of the landscape near Big Piney, Wyoming, vegetated with native (rabbitbrush, Wyoming sagebrush) and invasive (halogeton among others) species along a two-track road. The image was captured during a field inventory documenting the response of vegetation to infrastructure developed across the Wyoming Landscape Conservation Initiative area. Photo by Dan Manier, U.S. Geological Survey.

Products Completed in FY2013

- Web-based monitoring geodata portal (in review; will become available in 2014 at *www.wlci.gov/monitoring*).
- Manier, D.J., Anderson, P.J., Chong, G., and others, (draft) Monitoring Habitats and Wildlife Populations in Southwestern Wyoming. U.S. Geological Survey Circular.

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

Remote Sensing and Vegetation Inventory and Monitoring

This work focuses on developing and implementing remote-sensing protocols that allow monitoring of change in sagebrush habitat, with the goal of supporting affordable, repeated assessments of the entire WLCI region. This work quantifies predictions of vegetation cover in 1-percent intervals for all shrubs, sagebrush species, herbaceous vegetation, litter, and bare ground. Based on samples collected both in the field and from remotely-sensed imagery, the USGS can evaluate and quantify the amount and distribution of change in these components over time. This information is crucial for understanding patterns of change in sagebrush habitats across the WLCI study area. These products are currently the primary operational, wall-to-wall vegetation monitoring strategy for WLCI, and provide input to a broad spectrum of WLCI research and applications.

Accomplishments in FY2013 included a successful field-sampling effort to re-measure vegetation components along more than 260 marked transects divided among two QuickBird satellite scenes to detect annual changes measured on the ground. In addition to the ground measurements, these areas also were sampled successfully from both the QuickBird imagery (samples at a 1.6-m pixel resolution) and imagery from the recently launched Landsat 8 satellite (samples at a 30-m pixel resolution). Using data collected on the ground and by satellite enabled us to develop models that quantify changes in vegetation components over large areas. Intensive trend analyses were conducted using these data to establish whether we could track changes in vegetation components over time and relate those changes to changes in precipitation. By comparing repeated field measurements to repeated satellite measurements, we were able to use remotely sensed imagery to detect change across years and seasons from 2008 to 2012. Results also indicated that those changes could be correlated to precipitation (Homer and others, 2013).

We also conducted a comprehensive examination of historical changes in five sagebrush components between 1985 and 2003 in the southwestern WLCI region. We then used linear models to relate precipitation patterns with this 28-year record of change so that forecasted scenarios of vegetation change up to the year 2050 could be used to quantify future effects on sage grouse habitat (Homer and others, in revision). Results indicated a potential 4 percent loss in sagebrush due to reduced precipitation (fig. 5), and an associated 12-percent loss in sage grouse nesting habitat. This work is being expanded to provide similar products for the entire WLCI area to help elucidate potential effects of climate change on sagebrush habitats.

Products Completed in FY2013

- Quickbird and Landsat image collections for WLCI areas.
- Measurement of 260 marked transect plots for ongoing monitoring research.
- Homer, C.G., Meyer, D.K., Aldridge, C.A., and Schell, S., 2013, Detecting annual and seasonal changes in a sagebrush ecosystem with remote sensing derived continuous fields: Journal of Applied Remote Sensing, v. 7, no. 1, at *http://remotesensing.spiedigitallibrary.org/article.aspx?articleid=1735848*.
- Homer, C.G., Xian, G., Aldridge, C.L., Meyer, D.K., Loveland, T.L. and O'Donnell, M., Forecasting sagebrush ecosystem components and greater sage-grouse habitat for 2050—Capitalizing on 28 years of Landsat satellite imagery and climate data: Ecological Indicators (in revision).

Contacts: Collin Homer, 605-594-2714, *homer@usgs.gov*; Cameron Aldridge, 970-226-9433, *aldridgec@usgs.gov*

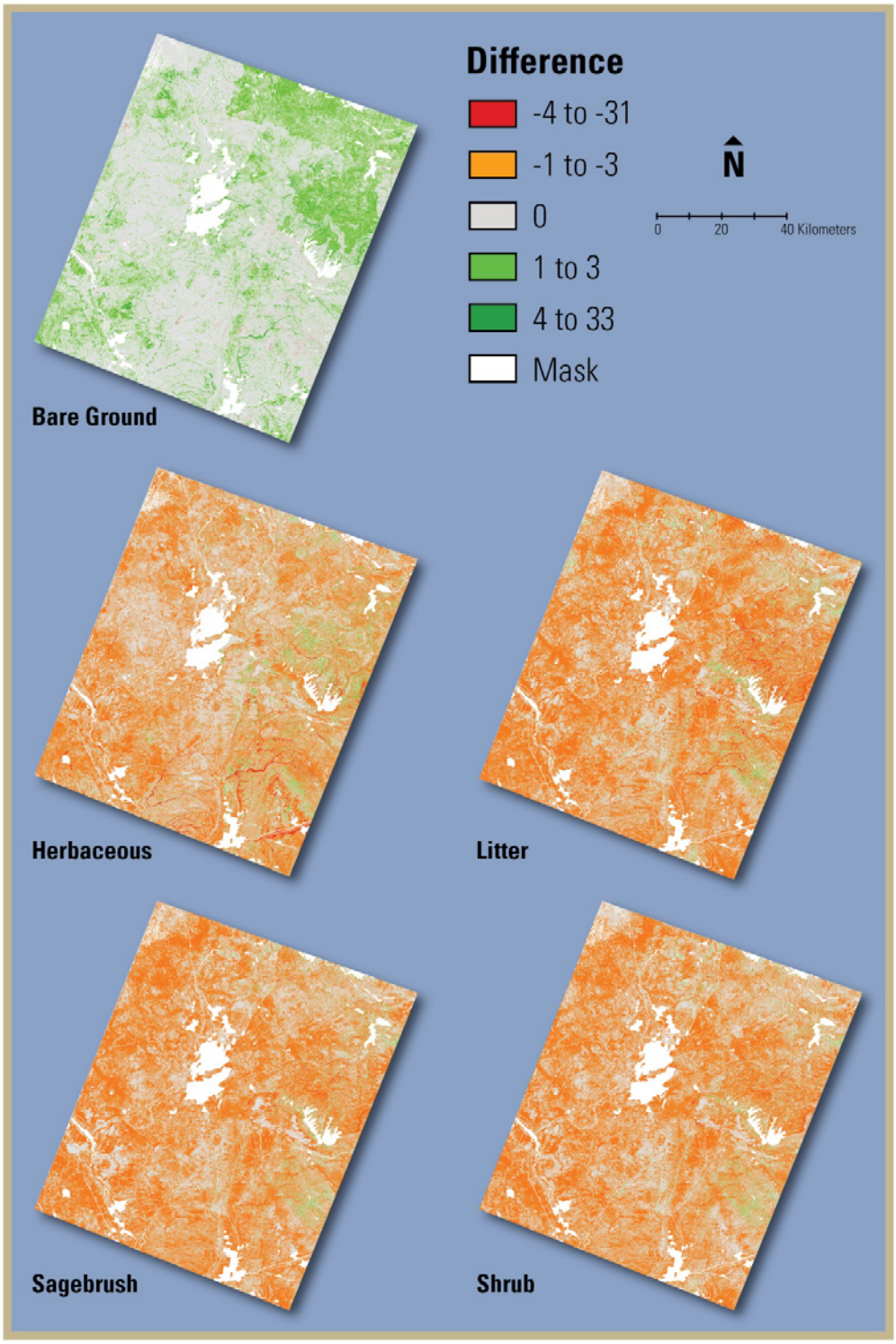


Figure 5. Changes in predicted spatial distributions of sagebrush habitat components between 2006 and 2050 (using the A1B climate scenario; Intergovernmental Panel on Climate Change, 2007) across the southwestern WLCI study area. Component reductions are represented in red and orange tones and increases in green tones. In this example, bare ground is forecast to increase in 2050, with decreases in herbaceous, litter, sagebrush, and overall shrub cover.

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

Riparian and aquatic ecosystems in semi-arid landscapes like southwestern Wyoming contribute significantly to regional biodiversity. Long-term monitoring data for surface-water quality and groundwater levels are needed for assessing possible effects of changing land uses, land cover, and climate on those ecosystems. With WLCI funding, each year surface-water quality is monitored at four sites and groundwater levels are monitored at one site (fig. 6). The monitoring locations were selected to provide baseline characterization of the upper Green River Basin and the Muddy Creek Watershed. The data are being 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).

Site of U.S. Geological Survey streamgage on Fontenelle Creek near Fontenelle, Wyoming. Photo by U.S. Geological Survey.

In FY2013, 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 one site in the Green River Basin. In cooperation with and funded by the State of Wyoming, Bureau of Land Management, and Bureau of Reclamation, additional surface-water quality and quantity data were collected. When combined with WLCI monitoring activities, these water-resources data support resource management and research in the WLCI study area and the region.

Products Completed in FY2013

For all monitoring sites (see URLs below), preliminary real-time data were provided in FY2013 and final data were published in FY2014 via the USGS NWISWeb at *http://waterdata.usgs.gov/wy/nwis/nwis*. The FY2014 reports for individual streamgages and wells are as follows:

- *http://waterdata.usgs.gov/wy/nwis/nwisman/?site_no=09205000*
- *http://wdr.water.usgs.gov/wy2013/pdfs/09217000.2013.pdf*
- *http://wdr.water.usgs.gov/wy2013/pdfs/09258050.2013.pdf*
- *http://wdr.water.usgs.gov/wy2013/pdfs/09258980.2013.pdf*
- *http://wdr.water.usgs.gov/wy2013/pdfs/413850109150601.2013.pdf*

Contact: Kirk Miller, 307-775-9168, *kmiller@usgs.gov*

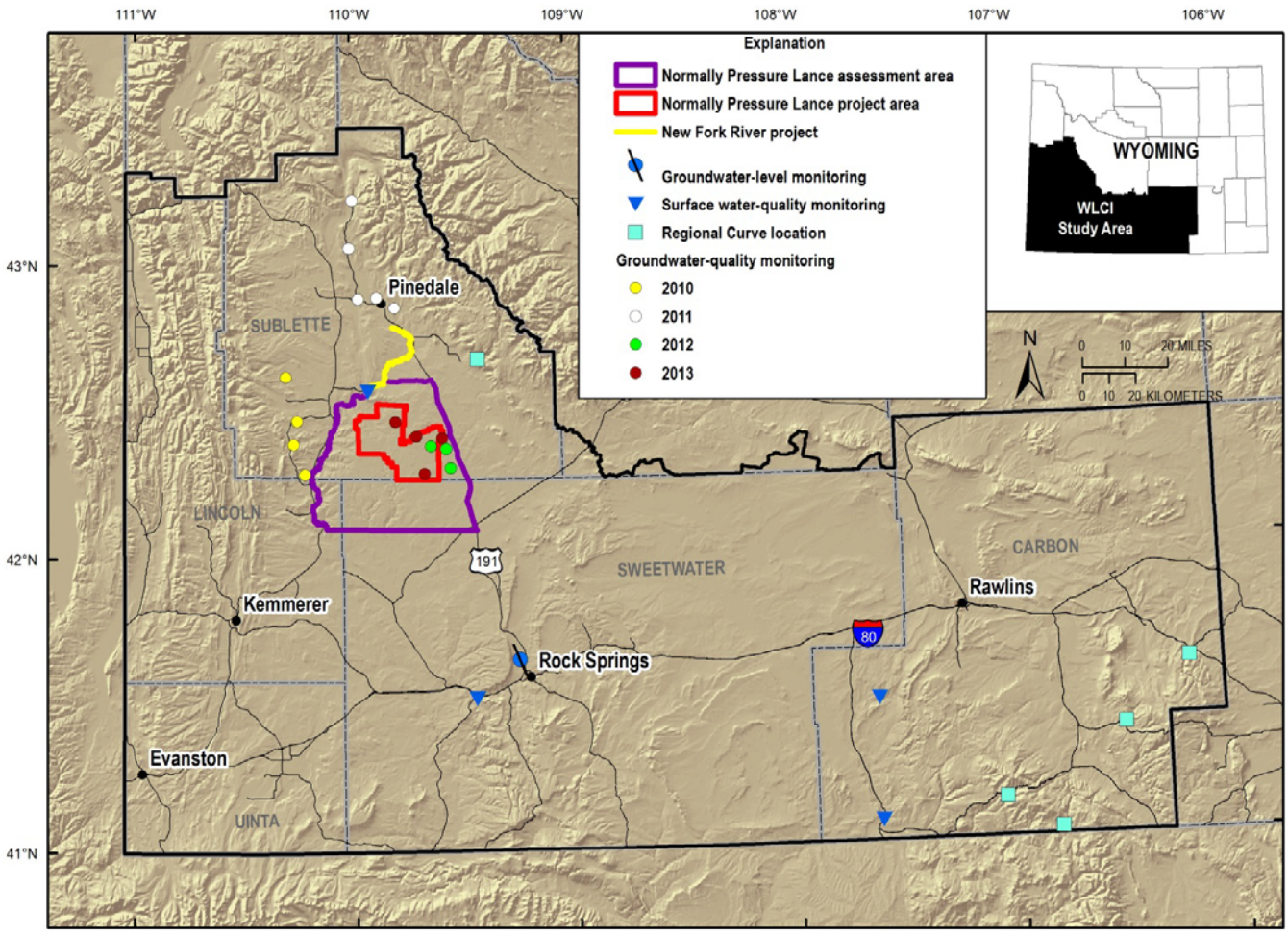


Figure 6. Locations of U.S. Geological Survey's field-based study areas associated with Long-term Monitoring projects during FY2013 in the Wyoming Landscape Conservation Initiative (WLCI) region.

Wyoming Groundwater-Quality Monitoring Network

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

The USGS is working in cooperation with the Wyoming Department of Environmental Quality (WDEQ) on the Wyoming Groundwater Quality Monitoring Network (WGQMN), the goal of which is to collect water-quality samples at 20–30 wells within each of 33 priority areas. 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. WLCI funding allows for additional wells to be sampled in priority areas within the Green River watershed.

Flowing stock well in the Green River Basin, August 2013. Photo by Gregory Boughton, U.S. Geological Survey.

Groundwater samples collected for the WGQMN exceeded State and Federal water-quality standards for numerous constituents. The WDEQ 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 24 wells in the Green River watershed, including 4 wells sampled in FY2013. The data are available on the USGS NWISWeb site (see the first URL below).

Products Completed in FY2013

- 2013 groundwater-quality data, publically available at *http://nwis.waterdata.usgs.gov/wy/nwis/qw*.
- Boughton, G.K., 2014, Groundwater quality characteristics for the Wyoming Groundwater-Quality Monitoring Network, November 2009 – September 2012 (in press).

Contact: Gregory K. Boughton, 307-775-9161, *gkbought@usgs.gov*

A Retrospective Assessment of Groundwater Occurrence in the Normally Pressured Lance Formation and a Field Reconnaissance of Existing Water Wells in the Study Area

Riparian and aquatic ecosystems in semi-arid landscapes, such as like southwestern Wyoming, contribute significantly to regional biodiversity. Long-term monitoring data for surface water quality and groundwater levels are needed for assessing possible effects of changing land uses, land cover, and climate on those ecosystems. With WLCI funding, groundwater levels (depth to water and shut-in pressure head) are being measured in wells in the proposed NPL Formation Project Area. The data are collected according to USGS methods (Cunningham and Schalk, 2011).

In FY2013, shut-in water pressures were measured in seven flowing wells, and depth to water was measured in five wells. When combined with WLCI monitoring activities, these water-resources data support resource management and research in the WLCI study area and the region, and will support BLM and other land and resource managers with planning and decision-making.

Products Completed in FY2013

- Preliminary data for all monitoring sites.
- Final data were published on USGS NWISWeb at *http://waterdata.usgs.gov/wy/nwis/nwis*.
- A preliminary potentiometric surface map was drafted using data collected in 2012 and 2013.

Contact: Michael Sweat, 307-775-9174, *mjsweat@usgs.gov*

Measuring shut-in pressure on a flowing well to determine height of water column above land surface datum. Photo by Mike Sweat, U.S. Geological Survey.

Applying Greenness Indices to Evaluate Sagebrush in the WLCI Region

Weather and climate affect terrestrial wildlife habitat through their influences on plant productivity. Plant phenology—the timing of life-history events such as green-up, flowering and senescence—provides one indicator of the timing and magnitude of plant productivity. Climate change may alter plant phenology and species composition, which may alter the availability of forage and cover for WLCI species of concern, such as elk, mule deer, pronghorn, and greater sage-grouse, as well as forage for livestock. In turn, these changes could influence wildlife habitat use, in which case plant phenology could be used as a seasonal indicator of habitat condition.

In 2012, we established three phenology sampling sites in QuickBird Site 1 (fig. 7; also see page 30 in Homer and others, 2009, at *http://pubs.usgs.gov/of/2008/1027/pdf/ofr2008-1027.pdf*). In 2013, we collected our first full growing season of plant phenology and soil moisture data. The study area was established in direct coordination with the Rock Springs BLM Field Office, and our research there will be ongoing. Each site has normalized difference vegetation index (NDVI) sensor units aimed at shrubs and interspace perennial vegetation, and each site has a soil-moisture array to measure soil moisture beneath and between vegetation at three depths (Carleton Bern, U.S. Geological Survey, February 2014, unpublished data).

Our objective is to characterize native vegetation phenology (fig. 8) and correlate our near-surface NDVI measurements with soil moisture and remotely sensed (satellite) greenness data. We will provide this information to managers that may use this information to (for example) characterize "background" greenness and compare that with greenness in reclaimed areas to assess their productivity and habitat quality. Both applications also will contribute to overall climate and phenology science.

Near-surface normalized difference vegetation index (NDVI) sensor with view dominated by mutton grass (*Poa fendleriana*). Photo by Geneva Chong, U.S. Geological Survey.

Products Completed in FY2013

- Chong, G.W., Steltzer, H. Shory, R., Petach, A., and Wallenstein, M., 2012, Timing is everything: using near-surface and remote sensing to monitor vegetation phenology in sagebrush steppe: American Geophysical Union Annual Meeting, San Francisco, Calif., December 3−7, 2012, poster B11C-0441.
- Three phenology monitoring arrays were re-deployed at QuickBird Site 1 (two sites with six Mantis sensor platforms, one site with five Mantis sensor platforms). The soil moisture monitoring arrays are left in-situ through the winter. We currently have plant phenology and soil moisture datasets from the site for 2012 and 2013. These sites were established in collaboration with Homer and Aldridge and the Rock Springs BLM Field Office in 2012.

Contacts: Geneva W. Chong, 307-201-5425, *geneva_chong@usgs.gov*; Patrick J. Anderson, 970-226-9488, *andersonpj@usgs.gov*

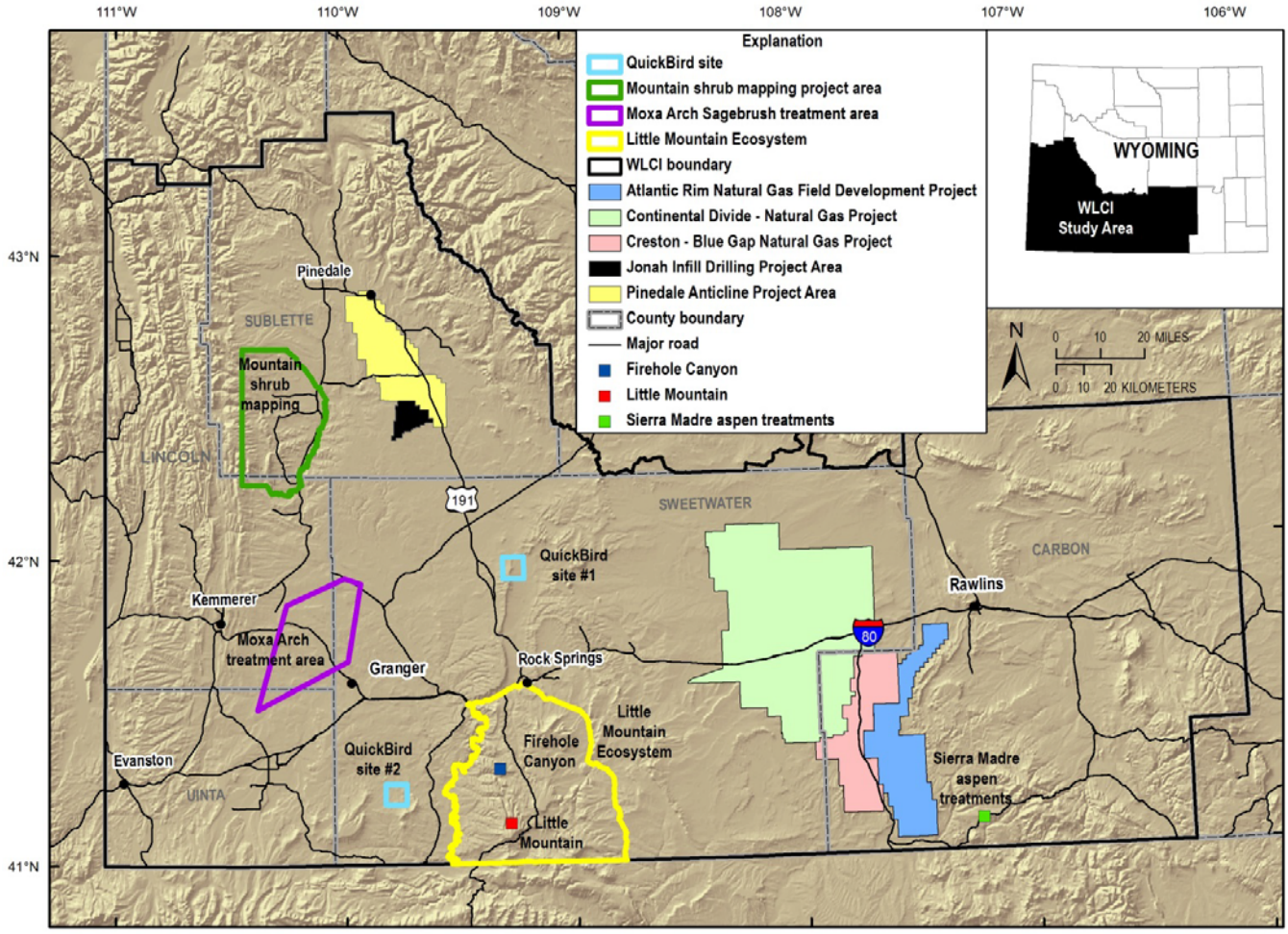


Figure 7. Locations of the U.S. Geological Survey's FY2013 field-based study areas associated with Effectiveness Monitoring activities and Mechanistic Studies of Wildlife in the Wyoming Landscape Conservation Initiative (WLCI) region.

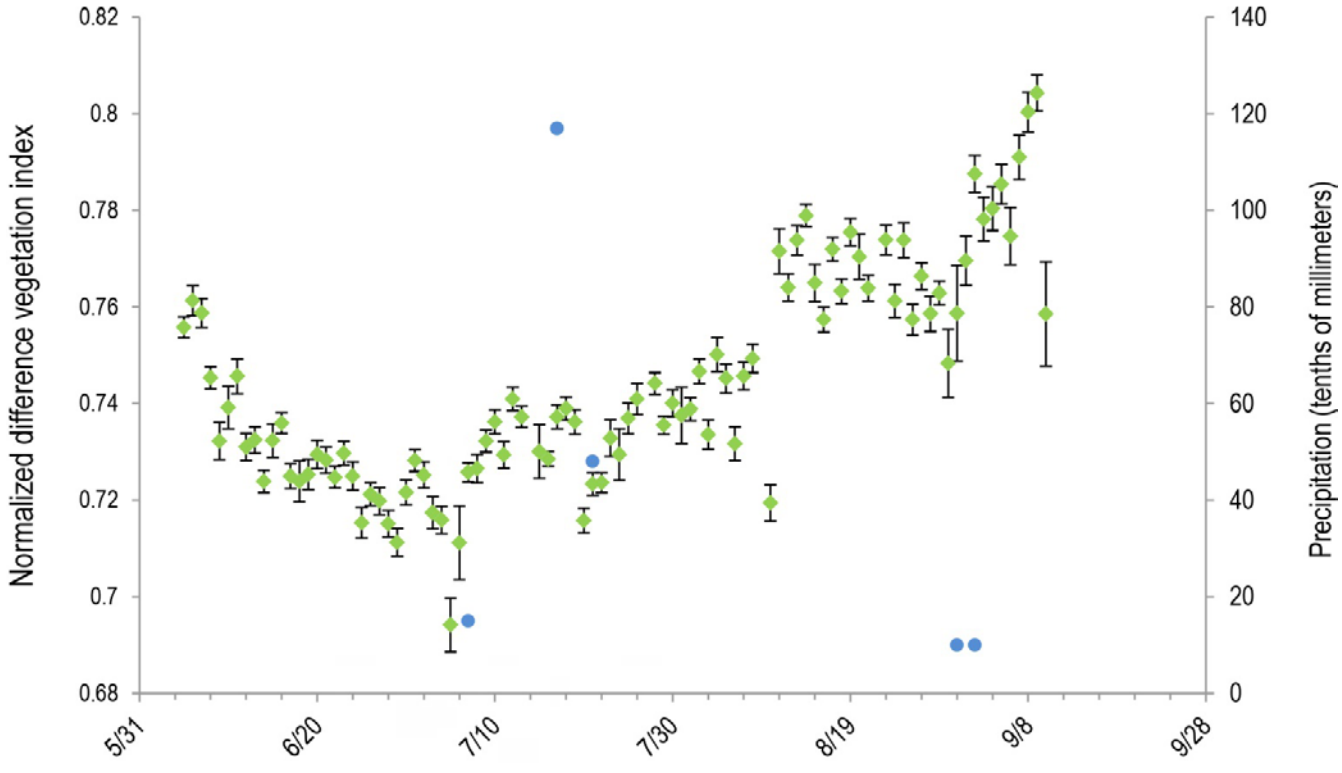


Figure 8. Near-surface normalized difference vegetation index (NDVI) (green diamonds; larger values represent more greenness) and precipitation (blue circles) values from a sensor (QuickBird Site 1, area 000, sensor 2392186) placed over mutton grass (*Poa fendleriana*), by date in 2012.

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 focal vegetation communities and is associated with numerous WLCI conservation priority areas and habitat projects. The current extent and condition of mountain shrub patches is unknown in the majority of the WLCI area, so trends in condition and mechanisms driving condition are also unknown. Ongoing monitoring of selected stands indicate an overall decline, with hypotheses as to what is causing the decline ranging from persistent drought, to herbivory and, possibly, factors associated with increased energy development. Our long-term objectives are to measure the distribution and current conditions of mixed mountain shrub communities and evaluate 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 FY2013, we continued surveys 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). This area was selected to take advantage of existing assessment and monitoring data acquired by WLCI partners. Mapping efforts were expanded to include currant/gooseberry and sumac species in addition to the target species sampled in 2012: serviceberry, curl-leaf and mountain mahogany, chokecherry, antelope bitterbrush, and snowberry.

Mule deer in mountain shrub habitat. Photo by Marie Dematatis, Cherokee Services Group, Contracted to U.S. Geological Survey.

Two methods were used to map mountain shrub patches in the field. Either the patch boundaries were walked while marking the patch polygon with a global positioning system (GPS) unit, or patches were hand drawn on topographic maps while attributing an associated GPS point with photographic documentation. Shrub density and browse intensity were estimated for each shrub patch, and the data collected in FY2011 and FY2012 were prepared for analyses. We used field and remotely sensed satellite imagery to build models of site (habitat) suitability for mountain shrub occurrence to test our ability to expand our mapped area. Maps and other information from this work will be used to support WLCI partners in their conservation planning and effectiveness monitoring of habitat treatments. The development of statistical mapping approaches will contribute to the science of spatial analyses and vegetation/habitat mapping.

Products Completed in FY2013

- Completed maps and created metadata from the combined 2012 and 2013 field mapping effort.
- Completed statistical maps from field data and remotely sensed data.

Contacts: Geneva W. Chong, 307-201-5425, *geneva_chong@usgs.gov*; Patrick J. Anderson, 970-226-9488, *andersonpj@usgs.gov*

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 (for example, prescribed burns, mowing, or herbicide applications) best support sage-grouse habitat needs. This study is designed to evaluate (1) sage-grouse use of past and current vegetation treatments and (2) how treatment type, design, location, and site-based ecological variation might 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 on habitat and forage by creating a mosaic of sagebrush stands in 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 this study within the Moxa Arch area (fig. 7) 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 are conducted within 4- × 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 was measured at all belt transects.

We continued seasonal pellet surveys through FY2013 and incorporated all data into a single database. From National Agriculture Imagery Program satellite imagery, we digitized all energy infrastructure (roads, pipelines, and well pads) within 1 km of our belt transects. With this information, we were able to analyze the proximity of energy infrastructure to each transect. We discussed preliminary findings with WLCI partners and LPDT members.

Product Completed in FY2013

- 2009 to 2013 pellet transect database and infrastructure GIS-based maps.

Contact: Patrick Anderson, 970-226-9488, *andersonpj@usgs.gov*; Marie Dematatis, 970-226-9217, *mdematatis@usgs.gov*

Sage-grouse pellet transect within the Moxa Arch Natural Gas Development Area. Photo by Marie Dematatis, Cherokee Services Group, contracted to the U.S. Geological Survey.

Landscape Assessment and Monitoring of Semi-Arid Woodlands in the Little Mountain Ecosystem

The BLM and WGFD have identified the LME in southwestern Wyoming as a priority area for conservation. Woodlands of the LME have been affected by multiple disturbance types over the last 20 years. Objectives of active woodland management have included rejuvenation of decadent aspen stands and reductions of conifers encroaching in successional aspen stands by using prescription burning and mechanical thinning. The area also has been affected by wildfires and multiple drought years over the last decade.

Personnel with the BLM Rock Springs Field Office asked USGS scientists to develop research that measures the baseline condition of the LME woodlands. This project will provide information on woodland cover type and extent and the timing and effects of various disturbance types 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/woodland changes by using archived satellite imagery for large areas of Southwest Wyoming. The work is expected to generate multiple datasets for the USGS and WLCI partners, and it will help WLCI LPDTs to evaluate and prioritize aspen treatments. Furthermore, we will use remotely sensed imagery to delineate treatment effects and establish long-term trends in woodland productivity at a landscape scale. An assessment such as this can 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.

A field transect in aspen forest on Pine Mountain, Wyoming, used to collect information on woodland condition. Photo by Tim Assal, U.S. Geological Survey.

In FY2013, we expanded the project to include aspen and conifer woodlands on Pine Mountain, also located in the jurisdiction of the BLM Rock Springs Field Office. Field data were collected on woodland stand structure and local site characteristics to relate measurements of live and dead basal area to satellite imagery. We acquired additional imagery from the Landsat 8 satellite, which launched in February 2013.

Products Completed in FY2013

- Maps and data, presented to WLCI partners at the Southwest Wyoming Aspen Workshop on Little Mountain.
- Field data collected to relate woodland condition to reflectance measured by satellite images.

Contacts: Timothy J. Assal, 970-226-9134, *assalt@usgs.gov*; Patrick J. Anderson, 970-226-9488, *andersonpj@usgs.gov*

Aspen Regeneration Associated with Mechanical Removal of Subalpine Fir

The WLCI has supported numerous aspen habitat treatments in the Sierra Madre Range of south-central Wyoming to reduce conifer cover, increase aspen densities, and diversify stand dynamics. WLCI partners are seeking information on how aspen and under-canopy vegetation have responded to those treatments, the relationship between soil chemistry and mechanical removal of conifers, and the response of invasive species to soil and litter disturbance associated with mechanical removal. To address these and similar questions, in FY2008 the USGS developed a study in the Sierra Madre Range (fig. 7) to investigate aspen regeneration, herbivory, and growth rate, and to document interactions between soil disturbance and under-canopy vegetation after mechanical treatments. Aspen sucker density and growth rate from the Sierra Madre treatment site will be compared with other aspen-restoration projects being conducted in the WLCI area.

We measured vegetation during the summer of 2008 prior to conifer removal at 45 randomly selected plots established across a gradient of aspen and conifer density and canopy cover, including pure stands of aspen. We sampled conifer and aspen canopy cover, herbaceous biomass and composition, aspen recruitment, and soils (Bowen, Aldridge, Anderson, Assal, and others, 2009). Post-treatment monitoring was implemented in 2009 and continued through 2012. The monitoring included measurements to determine how aspen and herbaceous plant species are responding to the treatment and whether soil disturbances and litter accumulation from logging activities affect short- and long-term recovery of aspen (Bowen, Aldridge, Anderson, Assal, and others, 2011). In 2011, the sampling effort included the collection of core and disc samples from live aspen to determine aspen stand chronology and radial growth (Bowen, Aldridge, Anderson, Assal, and others, 2013). The study was expanded in 2012 to map and incorporate vegetation responses at additional treatment areas associated with the Little Snake Conservation District, and with lands under the jurisdictions of the BLM, the U.S. Forest Service (USFS), and private landowners. Vegetation sampling was conducted within treatment areas on public land by using the methods outlined in Bowen, Aldridge, Anderson, Chong, and others (2009). In 2013, data were compiled and summary statistics were presented to WLCI partners.

Project partners include the Little Snake Conservation District, the BLM Rawlins Field Office, and the USFS Brush Creek/Hayden Ranger District. Results of this work will be used to establish targets for aspen regeneration in future aspen habitat projects, and to help WLCI LPDT members design and develop future treatments.

Aspen treatment site, Little Snake Conservation District, Wyoming. U.S. Geological Survey photo.

Products Completed in FY2013

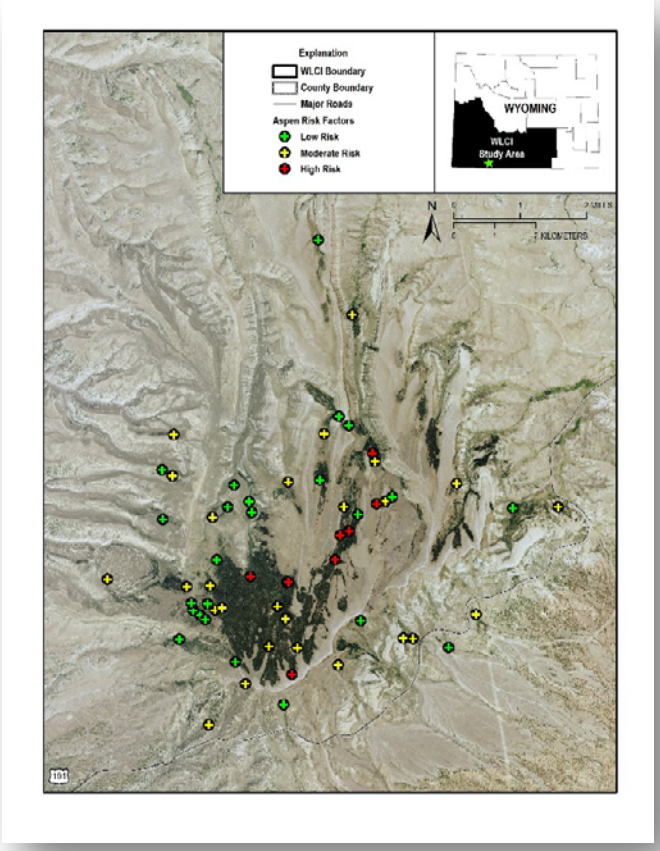
- Map of aspen treatments and associated GIS files incorporating GPS field data presented to WLCI partner.
- Summary statistics were generated and results were presented to the Carbon LPDT.

Contact: Patrick J. Anderson, 970-226-9488, *andersonpj@usgs.gov*; Marie Dematatis, 970-226-9217, *mdematatis@usgs.gov*

Herbivory, Stand Condition, and Regeneration Rates of Aspen on Burned and Unburned Plots in the Little Mountain Ecosystem

Since 1990, more than 2 million dollars have been spent on habitat-restoration and enhancement projects in the LME (figs. 7 and 9). Many of these efforts have focused on restoring aspen communities to maintain or improve water quality and to enhance ungulate habitat. During 2009, biologists from the WGFD Green River Regional Office established long-term monitoring plots on Little Mountain (figs. 7 and 9) to evaluate whether the increased number of ungulates using those stands is in balance with targets set for aspen regeneration. The WGFD is collecting data for developing an index of live to dead trees. The USGS is supporting this effort by measuring stand composition to study herbivory patterns at locations associated with historical burns (wildfires and prescribed fires) and at unburned locations. In 2009, burned and unburned stands were randomly selected based on stand size (patch area and shape) and location (Aspen Mountain, Pine Mountain, and Miller Mountain) across a gradient of conditions and degrees of conifer encroachment. Measurements of stand composition collected by the USGS include dominant and subdominant canopy structure, size classification, age structure, regeneration, and conifer encroachment.

In 2010, sampling efforts were expanded to 60 additional sites on Little Mountain to evaluate aspen condition and stand composition in different ecological and hydrological settings. In 2011, we focused our efforts on recording tree heights and retrieving core and disc samples from aspen and conifers. During 2012, age chronologies and establishment dates were reconstructed for aspen and common conifer species. In 2013, we analyzed stand structure, age chronologies, canopy composition, herbivory, and aspen regeneration for each previously sampled plot. This information was used to develop an index of risk factors. Findings and related map products have been shared with WLCI partners to support conservation planning and the development of aspen-habitat treatments. Partners on this project include the BLM Rock Springs Field Office, WGFD, and Wyoming Natural Diversity Database.



Product Completed in FY2013

- A series of maps (and associated GIS files) displaying stand metrics and an index of risk factors.

Contacts: Patrick J. Anderson, 970-226-9488, *andersonpj@usgs.gov*; Tim Assal, 970-226-9134, *assalt@usgs.gov;* Marie Dematatis, 970-226-9217, */mdematatis@usgs.gov*

Figure 9. Risk factors of aspen stands in the Little Mountain Ecosystem, Sweetwater County, Wyoming. Map created by Marie Dematatis, Cherokee Services Group,Contracted to U.S. Geological Survey. (WLCI, Wyoming Landscape Conservation Initiative)

Individual Reports: Mechanistic Studies of Wildlife

Pygmy Rabbit

Pygmy rabbits are a Wyoming SGCN, and information about how they respond to landscape-scale habitat fragmentation and ongoing energy development is incomplete. Pygmy rabbits are distributed in a patchy manner across the landscape, with small "colonies" of rabbits inhabiting irregularly distributed patches of tall, dense sagebrush. Movements among suitable sagebrush patches are necessary for successful breeding, dispersal, and maintenance of genetic diversity. Threats to pygmy rabbit populations include loss or degradation of suitable habitat patches and habitat fragmentation in the form of barriers to movements between patches.

Providing scientific information to help address these threats is at the core of USGS pygmy rabbit research in Wyoming. In FY2013, we continued to refine a new USGS pygmy rabbit habitat map that accounts for anthropogenic disturbance in addition to natural features. We also completed the third and final year of pygmy rabbit surveys in four major Wyoming gas field areas (Atlantic Rim-Continental Divide-Creston, Jonah, Moxa Arch, and the Pinedale Anticline Project Area) (fig. 7), and we completed the first full year of survey work in the BLM Kemmerer Field Office area in an effort to develop a pygmy rabbit habitat suitability map for an area identified as high priority by project partners with the BLM and WGFD.

To date, pygmy rabbit research conducted by the USGS in Wyoming has validated existing pygmy rabbit habitat maps, added distribution information, and provided information about the potential for conflicts (spatial overlap) between wind energy development and pygmy rabbits. We continue to study the influence of gas field infrastructure on pygmy rabbit distributions, and to investigate the role of landscape-scale habitat configuration (that is, 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 gas energy development.

Products Completed in FY2013

- Germaine, S., and Ignizio, D., 2012, Gas energy development and pygmy rabbits in Wyoming, presented at Restoring the West Conference, October 16–17, 2012, Logan, Utah.
- Field-data collection completed for our study of the effects of gas field development on pygmy rabbit site occupancy.
- WLCI-wide Pygmy rabbit habitat model and map completed; currently being validated.

Contact: Stephen Germaine, 970-226-9107, *germainesa@usgs.gov*

U.S. Geological Survey technicians (L) Jeremy Wood and (R) Jeff Jewell prepare to set a live trap for pygmy rabbits. Photo by Steve Germaine, U.S. Geological Survey.

Greater Sage-Grouse

Persistence of the greater sage-grouse depends on the quantity, quality, and distribution of habitat within its range (semi-arid sagebrush steppe). In past years, we conducted a long-term analysis of sage-grouse population trends across the WLCI area and the rest of Wyoming. We identified key time periods in historical sage-grouse population fluctuations and quantitatively addressed many analysis concerns associated with using very large time-series databases. Additionally, we have been attempting to understand the timing and mechanisms that influence those population fluctuations, specifically climate and patterns in energy development. Ongoing work includes exploring the effects of climate patterns and changes in the density and distribution of oil and gas wells on sage-grouse population trends within the WLCI and across Wyoming. Our goal is to evaluate existing datasets for correlations with sage-grouse population trends. Results from these efforts will help to inform management and planning efforts for development within sage-grouse habitats.

More recently, we have been attempting to build upon work we completed to develop seasonal habitat models for greater sage-grouse across Wyoming. This novel habitat-selection modeling effort used resource-selection functions to model the probability of habitat use and identified important habitats and priority conservation areas for sage-grouse. The result is one of the most comprehensive assessments of sage-grouse habitat requirements compiled to date. A manuscript is tentatively approved for publication, and awaiting final publication in the journal, "Wildlife Monographs." We also hired a post-doctoral fellow at the University of Washington to develop a spatially based population viability assessment framework for sage-grouse within the WLCI area and across Wyoming. We are integrating demographic data with the seasonal habitat models, allowing us to conduct spatial evaluations of long-term sage-grouse population persistence in current landscapes and under future scenarios. This research will provide managers with a better understanding of which sage-grouse populations may remain most viable in the near future. It also will provide insights on factors potentially limiting long-term viability of other populations.

Greater sage-grouse nest. Photo by Cameron Aldridge, Natural Resource Ecology Center, Colorado State University, in cooperation with U.S. Geological Survey.

Products Completed in FY2013

- O'Donnell, M.S., Fedy, B.C., Doherty, K.E., and Aldridge, C.L., 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 (in review).
- Fedy, B.C., Doherty, K.E., Aldridge, C.L., O'Donnell, M., Beck, J.L., Bedrosian, B., Gummer, D., Holloran, M.J., Johnson, G.D., Kaczor, N.W., Kirol, C.P., Mandich, C.A., Marshall, D., McKee, G., Olson, C., Swanson, C.C., and Walker, B., 2014, Habitat prioritization across large landscapes, multiple seasons, and novel areas—An example using greater sage-grouse in Wyoming: Wildlife Monographs (in press).

Contact: Cameron Aldridge, 970-226-9433, *aldridgec@usgs.gov*; Brad Fedy, *bfedy@uwaterloo.ca*

Mechanistic Understanding of Energy Development Effects on Songbirds

In Phase I of this work, we documented a negative relationship between the abundance and nest survival of the three sagebrush-obligate songbirds (Brewer's sparrow, sagebrush sparrow, and sage thrasher, all of which are Wyoming SGCN) and density of natural gas wells in the Jonah and Pinedale Anticline gas fields. In Phase II, we are testing the hypothesis that altered assemblages of nest predators are driving changes in songbird abundance and nest survival. Understanding the mechanisms behind changes associated with energy development will help to inform management and mitigation recommendations for effective conservation of sagebrush songbird populations. This project is being conducted in collaboration with and is partially supported by the WGFD. Results will be used to update the Wyoming State Wildlife Action Plan and recommend mitigation strategies for sagebrush songbirds breeding in and around energy fields.

During FY2013, we generated fragmentation metrics (surrounding habitat loss, amount of edge, patch shape complexity, and mean patch size) for nests monitored in 2008, 2009, 2011, and 2012, deployed 24-hour infrared video cameras to identify primary nest predators, and surveyed our study areas for those predators. We then analyzed nest survival in relation to well density, the fragmentation metrics, and activity of important nest predators. The amount of habitat loss within 1 square kilometer of nests was closely associated with well density and was a better predictor of daily nest survival than well density itself. Nest survival rates of all three species decreased with increased habitat loss. Nine species were recorded preying on eggs and nestlings, the majority of which (75 percent) were rodents. As surrounding habitat loss increased, detections of mice and ground squirrels also increased, but chipmunk detections decreased. Nest survival for Brewer's and sagebrush sparrows was lower where predator activity was greater. Our results indicate that natural gas development alters the local activity and(or) abundance of key rodent nest predators, thereby increasing risk of nest predation on sagebrush-obligate songbird nests. On-going work will test alternative hypotheses for explaining these relationships.

Still shot from a video taken of a nest predation event by a deer mouse (*Peromyscus maniculatus*). Photo by Matt Hethcoat, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming.

Products Completed in FY2013

- 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: Conservation Biology (in review).
- Hethcoat, M.G., and Chalfoun, A.D., What are indices indexing? A test using avian nest survival and energy development: Ecological Applications (in review).
- Hethcoat, M.G., Chalfoun, A.D., 2013, Nest predation and energy development: What's coming down the pipe for sagebrush-obligate songbirds?, presented at Joint meeting of the American Ornithologists' Union and Cooper Ornithological Society, Chicago, Ill., August 13-17 2013, (won Best Student Presentation Award), paper 33 at *http://www.fieldmuseum.org/sites/default/files/2013AB_37.pdf*.

Contacts: Matthew Hethcoat, 307-766-2091, *mhethcoa@uwyo.edu*; Anna D. Chalfoun, 307-766-6966, *achalfou@uwyo.edu*

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

Many forms of development (for example, fences, and roads) are semi-permeable, and making informed decisions about their potential effects on the persistence of ungulate migration routes is difficult. This study is designed to evaluate the influence of energy and housing development on the behavior of migrating mule deer. Our goal is to identify threshold levels of development that impair migration. The approach is to evaluate migratory behavior (for example, rate of travel or stopping over) of deer monitored across a gradient of development.

In FY2013, we processed movement data for 206 GPS radio-collared deer in three study areas, including the Pinedale Anticline, Atlantic Rim, and Platte Valley (fig. 10). We also created a time-stamped GIS database of development, which we have used to estimate the level of development experienced by each radio-collared deer. Previous work from this study indicated that in corridors with more intensive development, animals often detoured from established routes, increased their rate of movement, and reduced stopover use (Sawyer and others, 2013). Study findings suggest dramatic differences in development levels across the three study areas and similar behavioral responses of migrating deer to development. Overall, our results indicate that semi-permeable barriers caused by development diminish the functionality of ungulate migration routes. Our results also emphasize the importance of managing semipermeable barriers to sustain ungulate migrations amid continuing development.

Product Completed in FY2013

- Kauffman, M.J., 2012, The ecology and conservation of migratory ungulates, presented at the annual conference of The Wildlife Society, October, 12, 2012, Portland, Oreg.
- Wyckoff, T., Kauffman, M., Albeke, S., and Sawyer, H., 2013, Evaluating the influence of development on mule deer migrations, presented at the Wyoming Chapter of The Wildlife Society, October 30, 2013, Rock Springs, Wyo.

Contact: Matthew Kauffman; 307-766-5415; *mkauffm1@uwyo.edu*

Mule deer on the move during their fall migration along the base of the Wind River Range, Wyo. Photo by independent photographer, Joe Riis.

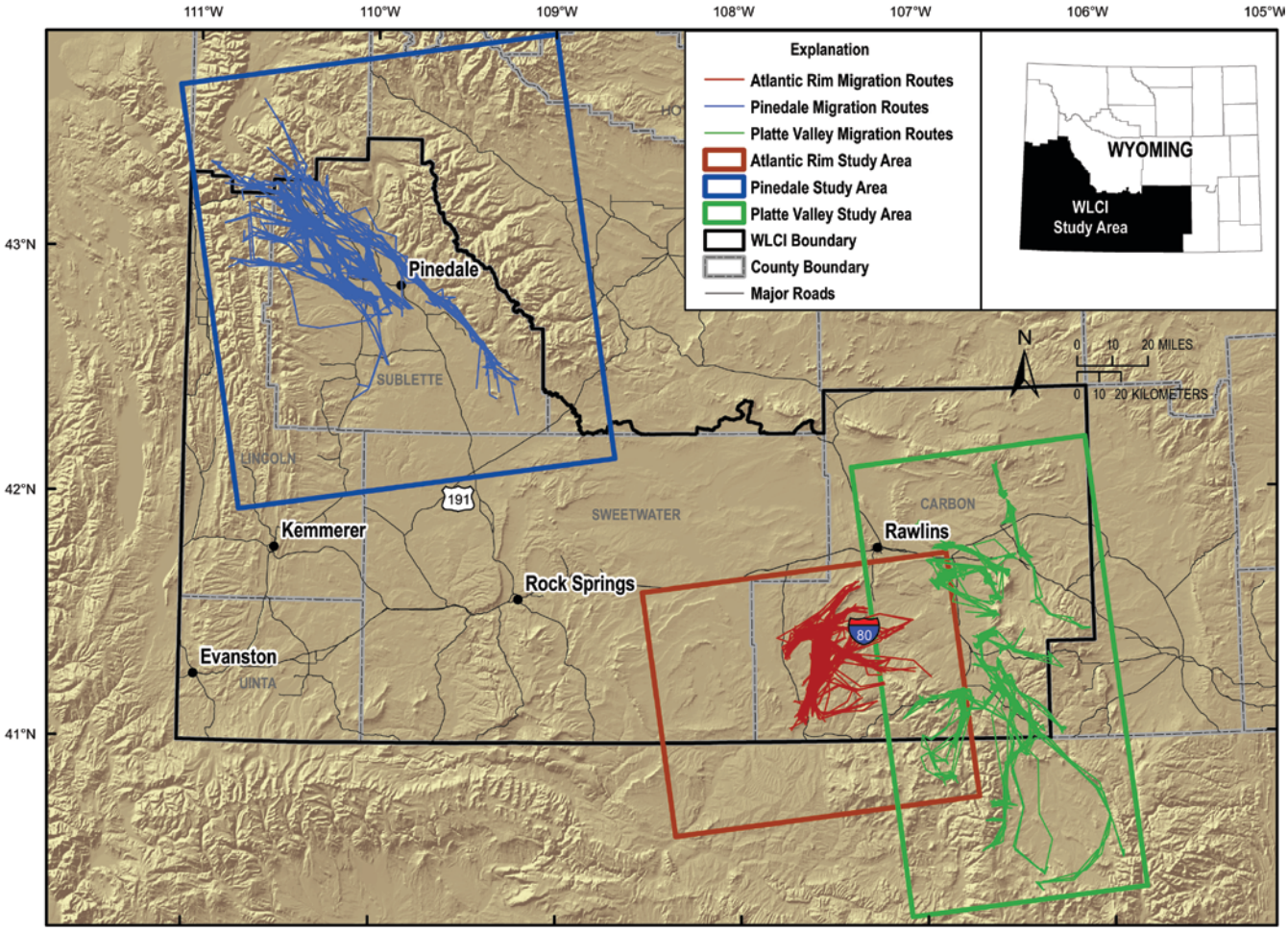


Figure 10. Mule deer migration routes used to evaluate the influence of energy and housing development on behavior.

Influence of Energy Development on Native Fish Communities (new in FY2013)

The rapid expansion of natural gas development has raised concerns about potential effects of energy development for fish and wildlife. Southwest Wyoming is one of the top energy producers in the nation, with a long history of coal, oil, and natural gas development and many proposed developments of natural gas fields. Research on how energy development can affect aquatic ecosystems is limited. An understanding of how energy development can affect aquatic habitat and fish will help land managers determine appropriate development levels and prioritize species or areas where monitoring and protection measures might be appropriate.

The aim of this project is to determine the habitat and water-quality characteristics that influence the presence and abundance of fish, and to evaluate how the presence and intensity of energy development influence habitat and water-quality characteristics. The project addresses the management needs to identify the condition and distribution of key wildlife species/habitats and species' habitat requirements, and to evaluate wildlife and livestock responses to development. Specifically we are identifying the vulnerability/ sensitivity of aquatic stream habitat to energy development. We are also relating habitat characteristics to fish distribution and population dynamics to assess effects of key drivers of change on aquatic habitats. Lastly, we are evaluating direct and indirect effects of energy development on native fish communities. This work will provide data on fish communities and riparian ecosystem health that could be incorporated into the integrated assessment.

Study site near the confluence of Fogarty and Dry Piney creek in the energy development-affected area. Photo by Carlin Girard, University of Wyoming.

Objectives

- Evaluate the influence of energy development on habitat quality, water quality, and fish communities in the Upper Green watershed.
- Determine which habitat factors are driving the presence and abundance of fish species.
- Determine which fish species are most sensitive to energy development.
- Explore potential mechanisms driving species' responses to energy development.

Methods

The project is a comparative study examining sub-watersheds with differing levels of energy development. We are using aerial imagery to quantify the total footprint of energy development in each watershed; metrics include length of roads per square mile, road-stream crossing per river mile, and pipelines crossing streams per river mile. We are also collecting fish and habitat data at 90 sites (fig. 11) along the study streams. We collected fish using backpack electrofishing and identified and measured all collected fish. We collected habitat data on riparian, geomorphic, and in-stream characteristics.

Examples of characteristics examined include percent shrub cover, maximum pool depth, stream incision, stream width, substrate classification, and bank trampling. We used continuous data loggers to measure temperature at 12 sites, discharge at 6 sites, and conductivity continuously at 3 sites. In the summer of 2013, we also used semi-permeable membrane devices to monitor potential hydrocarbon infiltration to surface waters. We are collaborating with scientists at the USGS Columbia Environmental Research Center for the water-quality component of this project.

Study Area

We are conducting a comparative study in the Dry Piney drainage (which has high levels of energy development) and South Beaver drainage (which has less energy development) in the Green River drainage, just west of Big Piney (fig. 11). The streams are similar in slope, morphology, and catchment size and offer good comparative strength, but the Dry Piney Creek drainage is highly affected by the La Barge Oil and Gas Field, which includes both natural gas and oil development. Our focus is aquatic and riparian systems, and fish in particular. Our three focal fish species are all native: mountain sucker, mottled sculpin, and Colorado River cutthroat trout.

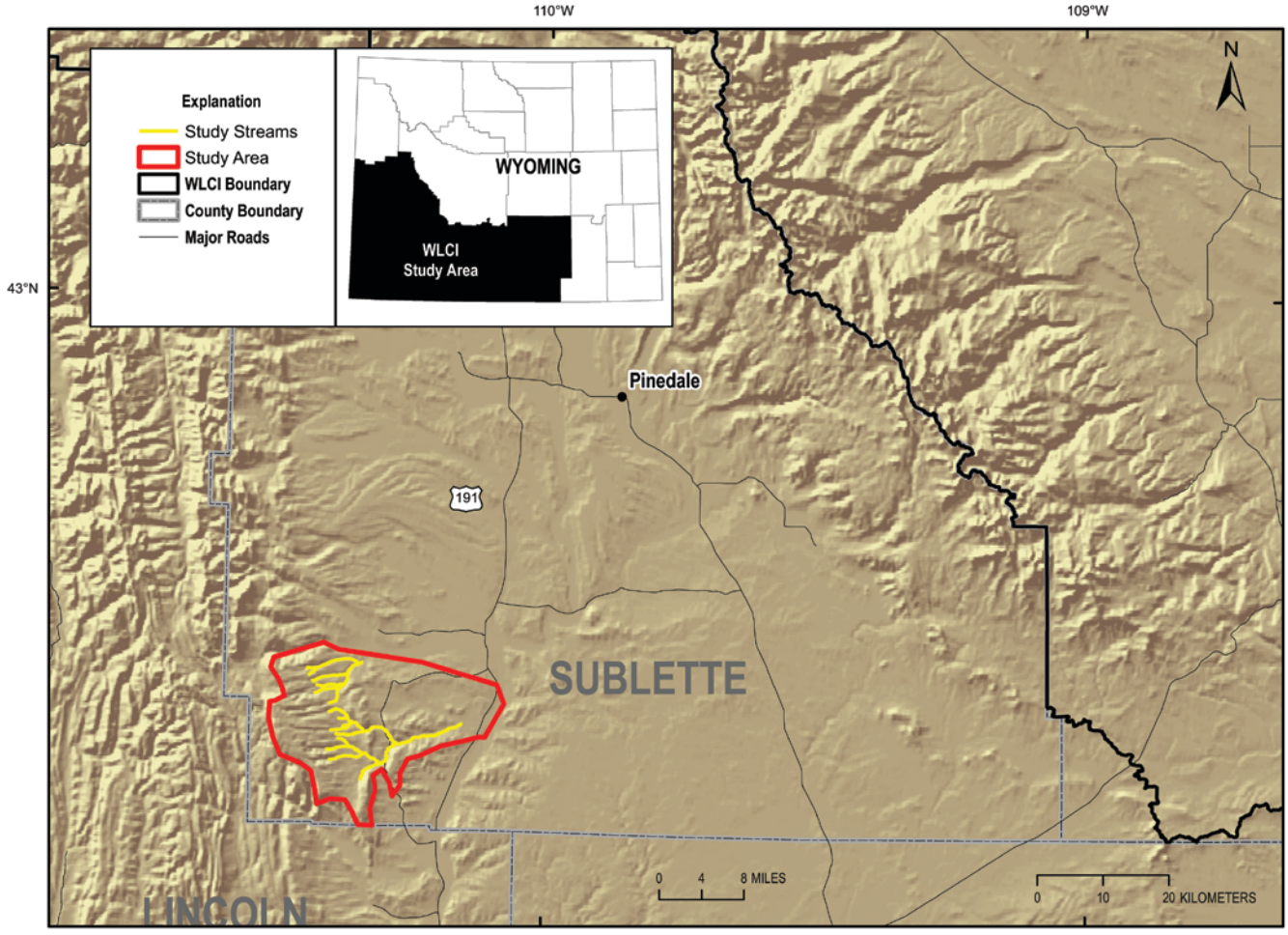


Figure 11. Study area and study streams for evaluating the influence of energy development on native fish communities. South Beaver drainage is to the north and Dry Piney drainage is to the south. Map by Carlin Girard, University of Wyoming Wyoming Landscape Conservation Initiative (WLCI).

Work Accomplished in FY2013 and Implications of Initial Findings

We collected field data on habitat availability and quality, water quality, and fish communities. Preliminary examination of the data shows that, in areas with high energy development, streams had reduced shrub cover and increased levels of suspended sediments. We also found that fish species varied in their sensitivity to energy development; abundances of cutthroat trout and mottled sculpin were lower in affected streams, but mountain suckers maintained similar population sizes across streams.

Products Completed in FY2013

Mountain sucker populations are robust throughout the Dry Piney and South Beaver drainages in the Green River drainage. Photo by Carlin Girard, University of Wyoming.

- Database of fish presence and abundance at 90 sites and associated habitat characteristics (percent shrub cover, maximum pool depth, stream incision, stream width, substrate classification, temperature, dissolved oxygen levels, and the presence of beaver dams).
- Continuous water temperature, discharge, and conductivity data for summer months.
- Walters, A., 2013, Energy development, habitat quality, and native fish communities in southwestern Wyoming, presented (invited) at American Fisheries Society annual meeting, September 8−12, 2013, Little Rock, Ark.
- Walters, A., 2013, The effects of energy development on habitat quality and fish communities in southwestern Wyoming, presented (invited) at Society of Freshwater Science Annual Meeting, May 19−23, 2013, Jacksonville, Fla.
- Walters, A., 2013, What are the effects of energy development for native fish communities?, presented at University of Nebraska, March 2013, Lincoln, Neb.
- Girard, C., 2013, The Wyoming Range fish project—The influence of energy development on native fish, poster presented at Colorado-Wyoming American Fisheries Society
- meeting, February 2013, Fort Collins, Colo.

Contact: Annika Walters, 307-766-5473, *annika.walters@uwyo.edu*

Individual Reports: Data and Information Management Activities

Data Management Framework and Clearinghouse

Providing, managing, analyzing, and using information assembled or generated for the WLCI is essential for supporting WLCI goals. The WLCI Data Management Framework and Clearinghouse (hereafter, "Clearinghouse") were developed to meet data management needs by providing a Web-based platform for (1) discovering and using existing data and information; (2) cataloging, preserving, and archiving data and information; and (3) making data and information resources available online to the public and to WLCI researchers and decision-makers. The Clearinghouse (accessible at *www.wlci.gov*) is continuously developed to meet user needs and evolving technological innovations, and is maintained to ensure that information resources are current and relevant.

The Clearinghouse includes information about and access to data sets, projects, publications, and Web sites relevant to the WLCI. Data sources are routinely sought and added to the Clearinghouse. Once identified, data and(or) metadata that we host on USGS systems are harvested and made available in the Clearinghouse. Harvesting methods are developed to catalog and document resources made available by external data providers. We periodically harvest data from provider systems to ensure that the most up-to-date resources are made available in the Clearinghouse. Using Web services to deliver cataloged information from the Clearinghouse to the WLCI Web site allows us to store information products in one locale (the Clearinghouse) and use the information in various applications.

The ScienceBase infrastructure, including the Clearinghouse, is being refined continuously to better manage and advance information resources produced through science projects. Activities and studies conducted by the Science Team and agency partners are evaluated for understanding the capabilities that WLCI partners need from our data management tools. The Science Team is contributing information resources to guide development of data-integration tools for delivering data and information to other applications, including GIS software and Web sites. The myUSGS system, an additional suite of online tools within our Data Management Framework, serves the internal WLCI community by providing an online platform for document management and methods for organizing content, conducting/recording discussions, managing community access, and organizing events (such as WLCI Science Workshops).

During FY2013, we continued to improve the Clearinghouse for enabling access to and use of WLCI data and products (for example, maps, study locations, information about science and habitat conservation projects, key results, and summaries). Information about WLCI projects and new publications were cataloged in the Clearinghouse and delivered to the WLCI Web site by using Web servicing techniques. Using Web services to display information in the WLCI Web site required preparation of metadata in the Clearinghouse to improve their completeness and uniformity.

Products Completed in FY2013

- The WLCI Data Clearinghouse was advanced and maintained; data-management tools and capabilities were advanced to enable efficiency and progression of WLCI efforts.
- Updated and refined metadata records for display in WLCI Web site via Web services.
- Web services were enhanced to efficiently serve data and information from the WLCI Data Clearinghouse to the WLCI Web site.

Contact: Natalie Latysh, 303-202-4637, *nlatysh@usgs.gov*

Partial snapshots from the USGS ScienceBase Catalog, including descrptions of habitat and science projects provided by the project tracker, and a listing of datasets stored in the catalog. These and other resources are accessible through the WLCI Web site at ***www.wlci.gov***. Users may search for specific types of information by using the hotlinks provided in the Filters textbox to the left, or they may specify what they are looking for by using the Advanced Search function provided above.

Science and Conservation Projects Database

Partners and stakeholders of the WLCI have expressed the need to access descriptive information and locations of (1) "on-the-ground" habitat conservation projects managed by the WLCI CT and (2) science projects being conducted by USGS and other science-agency partners. In response to this need, WLCI project information is documented in the Clearinghouse and available on the WLCI Web site (*www.wlci.gov*). The Clearinghouse provides an interactive map environment enabling users to click on geospatially referenced points, view project information, link to additional resources (including data), and use search and filter capabilities to constrain the information returned. Project information is entered into the Clearinghouse, which is part of the ScienceBase data management system and delivered by Web services to the WLCI Web site.

The CT is using the myUSGS system (a virtual collaboration site) for storing, organizing, and tracking information for annually proposed and funded habitat conservation projects. Annually, the USGS Science Team provides information about WLCI Science projects for publications listed as USGS Science for WLCI. The USGS DIMT members tasked with developing and maintaining data-management capabilities for the WLCI routinely update science project information obtained from published reports, habitat conservation project information, myUSGS, and the Clearinghouse. WLCI data personnel routinely communicate with the WLCI CT, Monitoring Team, and Science Team members to identify data-management needs for project tracking and management.

During FY2013, WLCI project descriptions cataloged in the Clearinghouse were maintained and updated with information about new projects, and additional information regarding status and progress was provided for ongoing projects. WLCI science and habitat projects were refined in the Clearinghouse for display in the WLCI Web site by using Web services. We maintained and updated the information in myUSGS, our virtual collaboration space used to help the CT organize, track, and store information for annually proposed and funded conservation projects. In myUSGS, the project information is organized by year and includes associated project artifacts, such as presentations, proposals, and photographs. Additionally, the information for funded projects is cataloged in the Clearinghouse and made available on the WLCI Web site.

Products Completed in FY2013

- Posted new and updated USGS Science and Partner Habitat Conservation Project information to WLCI Data Clearinghouse.
- Advanced Web servicing capabilities allowing dynamic use of cataloged information items, such as project information and citations, in WLCI Web site.

Contact: Natalie Latysh, 303-202-4637, *nlatysh@usgs.gov*

Outreach and Graphic Products

A project as large as the WLCI and with as many partners requires excellent intra- and interagency communication, as well as the dissemination of products and other information to users interested in learning about the WLCI and tracking its progress. To meet that need, we developed a usable and content-rich Web site for the WLCI. The WLCI Web site (*www.wlci.gov*) provides information about ongoing activities and facilitates discovery of additional resources, including workshops, publications, reports, newsletters, data products, and habitat conservation and science projects. The WLCI CT and Communication Team manage content for the WLCI Web site, with aid from USGS data managers.

The USGS Data and Information Management Team (DIMT) routinely communicates with the WLCI CT and Communication Team to identify modifications for the WLCI Web site. Authorized WLCI CT and Communication Team members maintain current information on the WLCI Web site by routinely adding and updating information, including projects, photographs, press releases, and meeting notes and agendas. The USGS data representatives routinely attend meetings conducted by the WLCI Executive Committee, the CT, and others, to be informed of WLCI activities, coordinate with team members to identify outreach needs, and ensure that information about the WLCI is being adequately advertised and promulgated. The USGS data representatives routinely participate on ad-hoc committees to manage and coordinate information regarding special events and activities.

The USGS DIMT also identifies effective methods for managing and disseminating information. These methods are articulated in information articles and publications and are shared with and used for other scientific projects. Ongoing advancements in information technology and technical infrastructure result in improving methods used to manage and deliver WLCI data. The WLCI Web site requires regular maintenance and refinement, and both it and the Clearinghouse are continually being improved through implementation of innovative and cutting-edge techniques.

In FY2013, we maintained and refined the WLCI Web site and supported CT and Communication Team members by providing current information and resolving issues. To promote dissemination of current and representative information, the WLCI bibliography and project information cataloged in the Clearinghouse were updated and improved for display in the WLCI Web site.

Products Completed in FY2013

- Refinement of and support for WLCI Web site, using Web services to dynamically display cataloged information in the WLCI Data Clearinghouse.
- Improved data and information records cataloged in WLCI Data Clearinghouse for display in WLCI Web site.

Contact: Natalie Latysh, 303-202-4637, *nlatysh@usgs.gov*

References Cited

Bowen, Z.H., Aldridge, C.L., Anderson, P.J., Assal, T.J., Baer, L.A., Bristol, Sky, Carr, N.B., Chong, G.W. Diffendorfer, J.E., Fedy, B.C., Homer, S.L., Manier, D., Kauffman, M.J., Latysh, N., Melcher, C.P., Miller, K.A., Montag, J., and others, 2009, U.S. Geological Survey science for the Wyoming Landscape Conservation Initiative—2008 annual report: U.S. Geological Survey Open-File Report 2009–1201, 83 p., at *http://pubs.usgs.gov/of/2009/1201/*.

Bowen, Z.H., Aldridge, C.L., Anderson, P.J., Assal, T.J., Biewick, L.R.H., Blecker, S.W., Bristol, S., Carr, N.B., Chalfoun, A.D., Chong, G.W., Diffendorfer, J.E., Fedy, B.C., Garman, S.L., Germaine, S., Grauch, R.I., Holloway, J., Homer, C., Kauffman, M.J., Keinath, D., Latysh, N., Manier, D., McDougal, R.R., Melcher, C.P., Miller, K.A., Montag, J., Nutt, C.J., Potter, C.J., Sawyer, H., Schell, S., Shafer, S.L., Smith, D.B., Stillings, L.L., Tuttle, M., and Wilson, A.B., 2010, U.S. Geological Survey Science for the Wyoming Landscape Conservation Initiative—2009 Annual Report: U.S. Geological Survey Open-File Report 2010–1231, 106 p., at *http://pubs.usgs.gov/of/2010/1231/pdf/OF10-1231*.

Bowen, Z.H., Aldridge, C.L., Anderson, P.J., Assal, T.J., Biewick, L.R.H., Blecker, S.W., Boughton, G.K., Bristol, S., Carr, N.B., Chalfoun, A.D., Chong, G.W., Clark, M.L., Diffendorfer, J.E., Fedy, B.C., Foster, K., Garman, S.L., Germaine, S., Holloway, J., Homer, C., Kauffman, M.J., Keinath, D., Latysh, N., Manier, D., McDougal, R.R., Melcher, C.P., Miller, K.A., Montag, J., Nutt, C.J., Potter, C.J., Schell, S., Shafer, S.L., Smith, D.B., Stillings, L.L., Tuttle, M., and Wilson, A.B., 2011, U.S. Geological Survey Science for the Wyoming Landscape Conservation Initiative—2010 Annual Report: U.S. Geological Survey Open-File Report 2011–1219, 146 p., at *http://pubs.usgs.gov/of/2011/1219/*.

Bowen, Z.H., Aldridge, C.L., Anderson, P.J., Assal, T.J., Biewick, L.R.H., Blecker, S.W., Boughton, G.K., Bristol, S., Carr, N.B., Chalfoun, A.D., Chong, G.W., Clark, M.L., Diffendorfer, J.E., Fedy, B.C., Foster, K., Garman, S.L., Germaine, S., Hethcoat, M.G., Holloway, J., Homer, C., Kauffman, M.J., Keinath, D., Latysh, N., Manier, D., McDougal, R.R., Melcher, C.P., Miller, K.A., Montag, J., Olexa, E.M., Potter, C.J., Schell, S., Shafer, S.L., Smith, D.B., Stillings, L.L., Sweat, M.J., Tuttle, M., and Wilson, A.B., 2013, U.S. Geological Survey science for the Wyoming Landscape Conservation Initiative—2011 annual report: U.S. Geological Survey Open-File Report 2013–1033, 145 p., at *http://pubs.usgs.gov/of/2013/1033/OF13-1033_508*.

Bowen, Z.H., Aldridge, C.L., Anderson, P.J., Assal, T.J., Bern, C.R., Biewick, L.R.H., Boughton, G.K., Carr, N.B., Chalfoun, A.D., Chong, G.W., Clark, M.L., Fedy, B.C., Foster, Katharine, Garman, S.L., Germaine, Stephen, Hethcoat, M.G., Homer, Collin, Kauffman, M.J., Keinath, Douglas, Latysh, Natalie, Manier, Daniel, McDougal, R.R., Melcher, C.P., Miller, K.A., Montag, Jessica, Potter, C.J., Schell, Spencer, Shafer, S.L., Smith, D.B., Sweat, M.J., and Wilson, A.B., 2014, U.S. Geological Survey science for the Wyoming Landscape Conservation Initiative—2012 annual report: U.S. Geological Survey Open-File Report 2014–1093, 71 p, at *http://pubs.usgs.gov/of/2014/1093/*.

Bowen, Z.H., Aldridge, C.L., Anderson, P.J., Chong, G.W., Drummond, M.A., Homer, C., Johnson, R.C., Kauffman, M.J., Knick, S.T., Kosovich, J.J., Miller, K.A., Owens, T., Shafer, S., and Sweat, M.J., 2009, U.S. Geological Survey science strategy for the Wyoming Landscape Conservation Initiative: U.S. Geological Survey Scientific Investigations Report 2008–5195, 26 p., at *http://pubs.usgs.gov/sir/2008/5195/*.

Cunningham, W.L., and Schalk, C.W., comps., 2011, Groundwater technical procedures of the U.S. Geological Survey: U.S. Geological Survey Techniques and Methods 1–A1, 151 p., at *http://pubs.usgs.gov/tm/1a1/*.

Damm, P., and Randall, J., 2012, Wyoming range mule deer habitat management plan: Big Piney-LaBarge area: Pinedale, Wyo., Wyoming Game and Fish Department, Pinedale Regional Office, 71 p.
D'Erchia, Frank, 2008, Wyoming Landscape Conservation Initiative Science Workshop Proceedings, May 15−17, 2007: U.S. Geological Survey Scientific Investigations Report 2008-5073, 96 p.
Homer, C.G., Aldridge, C.L., Meyer, D.K., Coan, M.J., and Bowen, Z.H., 2009, Multiscale sagebrush rangeland habitat modeling in Southwest Wyoming: U.S. Geological Survey Open-File Report 2008-1027, 14 p., at *http://pubs.usgs.gov/of/2008/1027*.
Homer, C.G., Meyer, D.K., Aldridge, C.A., and S. Schell, 2013, Detecting annual and seasonal changes in a sagebrush ecosystem with remote sensing derived continuous fields: Journal of Applied Remote Sensing, v. 7, no. 1.
Intergovernmental Panel on Climate Change, 2007, Intergovernmental Panel on Climate Change Fourth Assessment Report: Geneva, Switzerland, Intergovernmental Panel on Climate Change.
Kenney, T.A., 2010, Levels at gaging stations: U.S. Geological Survey Techniques and Methods 3-A19, 60 p., at *http://pubs.usgs.gov/tm/tm3A19/*.
Sauer, V.B., and Turnipseed, D.P., 2010, Stage measurement at gaging stations: U.S. Geological Survey Techniques and Methods book 3, chap. A7, 45 p. (Also available at *http://pubs.usgs.gov/tm/tm3-a7/*.)
Sawyer, Hall, Kauffman, M.J., Middleton, A.D., Morrison, T.A., Nielson, R.M., and Wyckoff, T.B., 2013, A framework for understanding semi-permeable barrier effects on migratory ungulates: Journal of Applied Ecology, v. 50, p. 68–78.
Turnipseed, D.P., and Sauer, V.B., 2010, Discharge measurements at gaging stations: U.S. Geological Survey Techniques and Methods book 3, chap. A8, 87 p., at *http://pubs.usgs.gov/tm/tm3-a8/*.
U.S. Geological Survey, variously dated, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps., A1-A9, unpaged, at *http://pubs.water.usgs.gov/twri9A*.
Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1-D3, 51 p. and 8 attachments, at *http://pubs.water.usgs.gov/tm1d3*.
Wyoming Game and Fish Department, 2010, Wyoming State wildlife action plan: Cheyenne, Wyo., Wyoming Game and Fish Department, unpaged.

ISSN 2331-1258 (online)
http://dx.doi.org/10.3133/ofr20141213

Publishing support provided by:
Denver Publishing Service Center

For more information concerning this publication, contact:
Center Director, USGS Fort Collins Science Center
2150 Centre Ave., Bldg. C
Fort Collins, CO 80526-8118
(970)226-9398

Or visit the Fort Collins Science Center Web site at:
http://www.fort.usgs.gov/