U.S. Geological Survey Science for the Wyoming Landscape Conservation Initiative—2011 Annual Report

Open-File Report 2013–1033

U.S. Department of the Interior
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Foreword

The Wyoming Landscape Conservation Initiative Partnership: Five Years of Collaboration in Southwest Wyoming

In 2007, a partnership known as the Wyoming Landscape Conservation Initiative (WLCI) was formalized after a coalition of Federal, State, and local agencies recognized the need for a coordinated approach to address Southwest Wyoming's increasing development of energy and other resources, their potential effects on fish and wildlife habitat, and grazing concerns. As described in the official WLCI documentation, the WLCI is a *long-term, science-based effort to assess and enhance aquatic and terrestrial habitats at a landscape scale in Southwest Wyoming, while facilitating responsible development through local collaboration and partnerships*. The science for WLCI is conducted by a team of U.S. Geological Survey (USGS) and other scientists. Their work and associated accomplishments described in this report represent a notable 5-year milestone since the WLCI's inception.

The WLCI study area, roughly the entire southwestern quarter of Wyoming, has an abundance of renewable and non-renewable energy resources, which are important assets both to the State and to the entire Nation. Current estimates indicate that the region could supply enough natural gas to heat more than 15 million homes per year, and there are premium sites for potential wind-turbine farms that could produce billions of kilowatt hours of electricity. In addition, the region has vast quantities of mineral resources, such as trona—supplying 90 percent of the Nation's soda ash—and uranium, coal, and rare earth elements. The same landscape encompasses some of the Nation's highest-quality habitat for mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), pronghorn (*Antilocapra americana*), and greater sage-grouse (*Centrocercus urophasianus*), as well as a large variety of fish and non-game species. More than 1700 farmers and ranchers also rely on Southwest Wyoming's open spaces for cattle and sheep grazing.

In 2004, discussions were initiated among representatives of the USGS and the Wyoming State Office of the Bureau of Land Management (BLM) to explore approaches for addressing booming energy development in light of potential and known impacts to fish and wildlife habitat. In 2006, a partnership was initiated through the USGS Department of the Interior (DOI) Science on the Landscape initiative, with matching contributions from the Wyoming BLM, to conduct a sagebrush (*Artemisia* spp.) ecosystems landscape mapping activity for Wyoming. Concurrently, the Wyoming Game and Fish Department was working closely with the BLM on these same issues. These collaborations represent the first inroads leading to the broad partnership that became the WLCI.

As the WLCI partnership began to take shape, it was recognized that a sound, unbiased, science-based approach would provide the credibility necessary to make informed management decisions and that involving the public in the discussion would be crucial to the WLCI's success. As the initiative evolved, trust was built, stakeholder interests were identified, and commitment to mutual goals was achieved among all partners.

In 2007, the President's Budget requested funding for the across-Bureau initiative among the USGS, BLM, and the U.S Fish and Wildlife Service (FWS) to conduct the science necessary for assessing and enhancing aquatic and terrestrial habitats at a landscape scale in Southwest Wyoming, while facilitating responsible development through local collaboration and partnerships. This initiative provided each Bureau with the necessary funding to carry out the goals identified by WLCI partners. For the USGS, it became a unique opportunity to combine all available science discipline capabilities into a long-term, science-based program to address not only the science needs in Southwest Wyoming, but also to develop tools and models that could be transferred to other areas facing similar issues.

The WLCI partnership is formally organized through a Memorandum of Understanding (see *https://my.usgs.gov/Public/WLCI/Bibliography/MOU_July_2008.pdf*). The WLCI Executive Committee includes Regional Directors from the USGS, BLM, the National Park Service, the FWS, the U.S. Forest Service, the Wyoming Game and Fish Department, the Wyoming Department of Agriculture, and local county commissioners and conservation districts. Partners also include universities and other interested organizations, groups, and individuals. The WLCI Executive Committee meets regularly and oversees the science direction and conservation projects that account for on-the-ground, science-based management actions within the WLCI region. These projects are recommended by Local Project Development Teams (LPDTs) composed of local ranchers, land managers, and other stakeholders, submitted through a proposal process. The on-the-ground science-based projects are funded through BLM and FWS partners, and through BLM collaborations with partners, resulting in a five-fold increase in total annual project funding.

The WLCI Executive Committee relies on support from the WLCI Coordination Team and the Science and Technology Advisory Committee (STAC). The Coordination Team is composed of representatives from each of the partners and is housed in the BLM office in Rock Springs, Wyoming, serving as the liaison between the LPDTs and the Executive Committee. The STAC works closely with the Executive Committee in reviewing and recommending the WLCI science direction, in collaboration with the USGS Science Team.

One of the latest innovations of the Science Team includes an Integrated Assessment (IA) for the WLCI. In fact, the WLCI IA is highlighted in the draft USGS Energy and Minerals Science Strategy as an example of how the USGS can use integrated assessments to (1) address the scope and complexity of large-scale issues, and (2) help meet the USGS goal of better understanding the effects of energy and mineral development on natural resources. In FY2011, the first version of the IA index of landscape condition was finalized and is now being prepared for public release. The primary output of the IA is an index—a categorical (low, medium, or high) score—that scores condition for each sub-watershed unit in the WLCI area. The index is based on an analysis of baseline information that was compiled under one of the original WLCI science and technical assistance activities outlined in the WLCI science plan. Subsequently, these compiled data have been used for (1) generating products to inform the ranking and prioritization of WLCI on-the-ground conservation projects, and (2) developing simulation models of potential changes in vegetation and habitat that incorporate a set of bioclimatic variables for evaluating future ecosystem health and sustainability. The overall IA index map may be overlaid with change agents, potential future changes, land ownership, and WLCI focal ecosystems. An interactive Website developed for the IA has a downloading capacity that will allow users to access underlying data and interim products for addressing specific issues or management questions. Combined, the data, maps, and Web application provided through the IA will be invaluable resources for informing conservation and restoration planning.

USGS scientists, working collaboratively across all science disciplines and organizational units, have created a truly integrated science approach for the WLCI. The USGS Science Team has made significant progress in advancing scientific knowledge regarding sagebrush steppe ecosystems and the flora and fauna that rely on this habitat, as well as a better understanding of the impacts of energy and other development on the landscape. WLCI Federal and State land management agency partners are now applying this information to make more informed management decisions.

The value of the WLCI has been recognized beyond local stakeholders. The Department of the Interior Landscape Conservation Cooperatives have collaborated with WLCI partners, specifically on issues related to the sagebrush steppe, and parties associated with other monitoring and assessment efforts are seeking information from the WLCI studies and reports produced over the five years since the initiative's inception. The research has been extensive, and the USGS Science Team has produced multiple scientific publications and reports whose results can be applied to other areas addressing similar impacts of development.

The Science Team is to be highly commended for their continued accomplishments for the WLCI, as well for their continued leadership in promoting and practicing integrated science in meeting the needs of decisionmakers and stakeholders. It is fair to say that this successful partnership in Wyoming is well positioned to transfer knowledge, protocols, and technology for further applications in support of efforts to ensure sustainable and productive ecosystems. Please enjoy your review of the many accomplishments described in this document.

Frank D'Erchia
Science Advisor
U.S. Geological Survey, Rocky Mountain Area

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Figures

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
mile (mi)	1.609	kilometer (km)
yard (yd)	0.9144	meter (m)
	Area	
acre	0.004047	square kilometer (km^2)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
	Mass	
ounce, avoirdupois (oz)	28.35	gram (g)

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
square kilometer (km^2)	247.1	acre
square meter (m^2)	10.76	square foot (ft^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
liter (L)	0.2642	gallon (gal)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)

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

Altitude, as used in this report, refers to distance above sea level.

Acronyms Used in this Report

AOGCM	Atmosphere-ocean general circulation model
BLM	U.S. Bureau of Land Management
CART	Classification and Regression Tree
CT	Coordination Team (for the Wyoming Landscape Conservation Initiative)
DESI	Detection of Early Season Invasives (software)
DIMT	Data and Information Management Team
dNDVI	Differenced normalized difference vegetation index
EC	Executive Committee (for the Wyoming Landscape Conservation Initiative)
EM	Effectiveness monitoring
EPA	U.S. Environmental Protection Agency
FWS	U.S. Fish and Wildlife Service
GIS	Geographic information system
GNLCC	Great Northern Landscape Conservation Initiative
GPS	Global positioning system
IA	Integrated Assessment
ISR	*In-situ* recovery (in mining)
LiDAR	Light Detection and Ranging (a type of satellite imagery)
LPDT	Local Project Development Team
LTM	Long-term monitoring
MODIS	Moderate Resolution Imaging Spectroradiometer
MRDS	Mineral Resources Data System
MSW	Mechanistic studies of wildlife
MT	Monitoring Team
MXD	Mixed (a map file format that also contains layer order, symbology, toolbars, and other features associated with the map)
NAIP	National Agriculture Imagery Project
NPL	Non-pressurized Lands gas project
NRCS	Natural Resources Conservation Service
NDVI	Normalized difference vegetation index
NPS	U.S. National Park Service
NWISWeb	National Water Information System Web site
PDF	Portable document format
PMF	Published map file
RMBO	Rocky Mountain Bird Observatory
SGCN	Species of Greatest Conservation Need
SQI	Soil quality index
STAC	Science and Technical Advisory Committee
TDS	Total dissolved solids
TNC	The Nature Conservancy
TOC	Total organic carbon
TN	Total nitrogen
USGS	U.S. Geological Survey
WDA	Wyoming Department of Agriculture
WDEQ	Wyoming Department of Environmental Quality

WGFD	Wyoming Game and Fish Department
WLCI	Wyoming Landscape Conservation Initiative
WYGISC	Wyoming Geographic Information Science Center
WYNDD	Wyoming Natural Diversity Database

Acknowledgments

The authors thank the Wyoming Landscape Conservation Initiative's (WLCI) Science and Technical Advisory Committee (STAC) 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 the WLCI STAC, Greg Auble, and Sarah Hawkins for their thorough reviews, and to acknowledge the modeling groups, the Program for Climate Model Diagnosis and Intercomparison and the World Climate Research Programme's Working Group on Coupled Modelling, for their roles in making available the Coupled Model Intercomparison Project phase 3 multi-model dataset. Support of this dataset is provided by the U.S. Department of Energy's Office of Science.

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Executive Summary

This is the fourth annual report on the U.S. Geological Survey (USGS) science and technical assistance activities conducted for the Wyoming Landscape Conservation Initiative (WLCI). The WLCI is a partnership of Federal, State, and local agencies seeking to conserve the vast and nationally important natural resources of Southwest Wyoming in the face of rapid land-use changes. 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 in Southwest Wyoming, while facilitating responsible development through local collaboration and partnerships. The USGS is the WLCI partner conducting most of the science and technical assistance activities that lay a foundation for conservation and management activities, whereas the land management partners (Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service, U.S. Forest Service, Wyoming Fish and Game

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[9] U.S. Geological Survey, Crustal Geophysics and Geochemistry Science Center, Denver, Colo.
[10] U.S. Geological Survey, EROS Data Center, Sioux Falls, S.D.
[11] Wyoming Natural Diversity Database, Univ. of Wyoming, Laramie, Wyo.
[12] U.S. Geological Survey, Core Science Systems, Denver, Colo.
[13] Cherokee Services Group, contracted to Department of Interior, U.S. Geological Survey, Fort Collins Science Center, Fort Collins, Colo.
[14] U.S. Geological Survey, Geology and Environmental Change Science Center, Corvallis, Ore.
[15] U.S. Geological Survey, Central Mineral and Environmental Resources Science Center, Denver, Colo.

Department, Wyoming Department of Agriculture, and local county commissioners and conservation districts) are implementing the habitat enhancement and restoration projects, conservation actions, and best management practices. In accordance with the WLCI Memorandum of Understanding (see *https://my.usgs.gov/Public/WLCI/Bibliography/MOU_July_2008.pdf*), the science USGS is conducting for the WLCI includes evaluating the effectiveness of habitat enhancement and restoration projects, assessing current and modeling future ecosystem conditions, and studying the short- to long-term and cumulative effects of land-use changes on target species, focal habitats (sagebrush steppe, aspen, mountain shrublands, riparian, and aquatic communities), and the overall Southwest Wyoming landscape.

The USGS WLCI Science Team has included more than 50 individuals from at least seven disciplines, including biology, geology, geography, hydrology, sociology, remote sensing/geographic information systems (GIS), and data and information management. The USGS also provides a liaison to the WLCI for the crucial work of coordinating WLCI activities and facilitating the integration of science with work conducted by WLCI partners. Tasks entail informing the development of adaptive management, best management practices, and prioritization of habitat projects based on results of USGS science and other studies; integrating existing data with new knowledge and technologies; and disseminating the outcomes of our science to partners and other stakeholders. This report and the three annual reports that preceded it describe the annual accomplishments and findings for each of our current science and technical assistance activities. Here, we highlight some of the results and products of USGS work already available to, or in use by, WLCI partners.

Through its *Comprehensive Assessment* of baseline conditions in Southwest Wyoming, the USGS has developed an Integrated Assessment (IA) for the WLCI. The IA compiles, integrates, and analyzes the best available data and information amassed over the last 4–5 years to provide an index, based on watershed units, of conditions across the WLCI landscape. It is a decision support tool designed to assist the WLCI Executive Committee, the Communication Team, Local Project Development Teams (LPDTs), managers, and other decisionmakers with landscape-scale conservation planning and evaluation. It is also a data and analysis resource that partners use for addressing specific management questions. The IA index is presented in map format, which makes it easy to understand and use for addressing simple to complex "where" questions. Although enhancements to the IA will be ongoing, this online tool is now available for use and may be accessed at *http://www.wlci.gov/?q=integrated_assessment*. For further details of the IA's development, index, and how it may be used, see the section below, entitled Application of Comprehensive Assessment to Support Decisionmaking and Conservation Actions.

Another major USGS science activity is the Assessment of Wildlife Vulnerability to Energy Development (AWVED). The initial work for this activity was to develop Wyoming-specific range maps for all 152 of Wyoming's terrestrial vertebrate species of greatest conservation need (SGCN). Subsequently, distribution models for each species were developed to refine projections of where they are likely to occur in Wyoming. See pages 47–58 in the 2010 annual report (*http://pubs.usgs.gov/of/2011/1219/*) for a synopsis and graphical explanation of this foundational work. In fiscal year (FY) 2011, maps of current and potential energy development were generated for assessing where energy development overlaps SGCN ranges in Wyoming, and then the energy and species distribution maps were used to analyze the potential exposure of each SGCN to energy development (see pages 40–43 of this report for details). In FY2012, the AWVED work will wrap up with assessing the biological sensitivity of the SGCN most highly exposed to development disturbance. The products resulting from this work are in wide use by many parties. For example, the WGFD is incorporating all the AWVED maps and models into its revised State Wildlife Action Plan (see *http://wgfd.wyo.gov/web2011/Departments/Wildlife/pdfs/SWAP_2012_FULL0001898.pdf*) and the WISDOM (Wyoming Interagency Spatial Database and Online Management; see *http://wisdom.wygisc.org/*) support tool, and it is using AWVED methods and models to expand its vulnerability assessment of Wyoming's SGCN and key wildlife areas. The U.S. Fish and Wildlife Service (Cheyenne Office) is using AWVED distribution models to inform consultations and comments regarding development plans, and the Region 6 Ecological Services Office is using AWVED maps and models as a base layer in its Landscape-scale Energy Action Plan (LEAP) project. The BLM's Rawlins and Rock Springs Field Offices are using some AWVED products when drafting environmental impact statement documents and responding to siting proposals for energy infrastructure, particularly the models for Wyoming pocket gopher and pygmy rabbit. The Nature Conservancy is using AWVED methods and models (in collaboration with WGFD) to expand vulnerability assessments to include not only energy development, but also residential development, climate change, and other stressors. The Wyoming Outdoor Council also has relied heavily on AWVED products, both distribution models and exposure assessments, to inform its comments on a variety of issues, including environmental impact statement analyses, listing petitions for the U.S. Endangered Species Act, siting plans for resource extraction developments, and prioritization of their focal species. At the University of Wyoming, several graduate students have used AWVED products to inform their work. At the Wyoming Natural Diversity Database, AWVED models have been used to help stratify survey sites for a variety of taxa in the past couple years.

One of our ongoing USGS WLCI science activities, *Remote Sensing and Vegetation Inventory and Monitoring*, has already resulted in or contributed to more than five major publications and countless related products. The products describe a new, innovative method for mapping and monitoring vegetation at the landscape-scale and report initial monitoring results from using this new method. Among the products is a set of highly accurate, fine-scale GIS data layers that predict the percent cover of seven components in sagebrush habitat, including sagebrush and other shrub cover, herbaceous plants, litter, and bare ground, as well as sagebrush height, throughout Wyoming. The WGFD has already used the map to revise and refine its designated core habitat and habitat connectivity areas for greater sage-grouse within Wyoming (see *http://gf.state.wy.us/web2011/wildlife-1000382.aspx* and click on "Sage Grouse Management and Connectivity Areas Version 3"). This same product is being used in a separate USGS study to identify and model seasonal habitats needed to support all three stages of the sage-grouse's annual cycle: nesting, late summer (brood), and winter. When these seasonal habitat models are completed, BLM Field Offices of Wyoming will be incorporating the information directly into their revised environmental impact statements. Scientists outside of the USGS also are incorporating our sagebrush mapping results into their work (for example, see *http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0026273*).

Our *Effectiveness Monitoring* activities continue to provide crucial information to the BLM and other partners as to the value of certain habitat enhancement and restoration actions. For example, in FY2011, initial results of core samples taken from trees in our aspen-treatment studies (*Aspen Regeneration Associated with Mechanical Removal of Subalpine Fir*, and *Herbivory, Stand Condition, and Regeneration Rates of Aspen on Burned and Unburned Plots in the Little Mountain Ecosystem*) indicate that prior assumptions about the rate of conifers encroaching on high-elevation aspen stands in southern Wyoming may have been inappropriate. The core samples show that many of the aspen and conifers became established at the same time, indicating that, at least in southern Wyoming, aspen and conifer growing in proximity to one another in high-elevation forests may represent co-dominance instead of separate stages of succession. This information is helping us to develop map products that will assist WLCI partners with prioritizing aspen stands for treatment. We are also developing numerous map products associated with our effectiveness monitoring to provide new information about the distribution and condition of aspen and mountain shrub habitats, and the distribution of invasive species. We also have developed maps that show the boundaries of past and current treatments and the point locations of where we photographed our long-term sampling plots. Information and products associated with *Effectiveness Monitoring* activities are shared with WLCI partners to facilitate project planning and prioritization of habitat treatments.

Results and products of the four USGS *Mechanistic Research of Wildlife* studies, designed to reveal what drives the responses of target species or species assemblages to energy development, are already being used in a variety of ways. For example, occupancy surveys conducted for the *Pygmy Rabbit* (*Brachylagus idahoensis*) study has helped to refine the species' known range and habitat characteristics in Wyoming. Because this species is a candidate for listing under the Endangered Species Act, this information is invaluable to BLM and other land managers seeking to minimize negative effects of management actions and land-use changes on this species.

Phase I of the *Songbird Community* study revealed that songbird density decreases along a gradient of increasing well pad density. The publication of those findings (Gilbert and Chalfoun, 2011) generated local (Wyoming Public Radio), national (*Billings Gazette, L.A. Times, Scientific American*), and international media attention (*Reuters UK*), which helped raise public awareness about the implications of landscape-level habitat changes associated with energy development for declining populations of migratory birds. The study, now in its second phase, is investigating possible mechanisms associated with the decreased densities of songbirds—including nest predation and characteristics of nest sites. Resulting data will be used to evaluate what drives avian productivity in sagebrush habitats and how energy development may be affecting the overall population and community dynamics of sagebrush-obligate songbirds that nest in Wyoming and beyond.

From our *Sage-Grouse* (*Centrocercus urophasianus*) study, one of the recent products is a long-term dataset assembled to evaluate and model sage-grouse population trends in relation to energy development (see the section below, entitled "Sage-Grouse" under the section on Mechanistic Research of Wildlife). Already, the models are being used by the BLM Rawlins Field Office as a tool for monitoring sage-grouse at the Field Office level. Several published works on both the population trend work and work on seasonal movements and migration behavior of sage-grouse are also now available. The findings reported in Fedy and others (2012; abstract available at *http://pubs.er.usgs.gov/publication/70003817*) indicate that sage-grouse nesting habitat in Wyoming is better represented by the core regions established for sage-grouse in Wyoming than summer or winter habitats. If decisionmakers want to ensure sage-grouse conservation, then they would need to incorporate all seasonal habitat needs into their planning. As mentioned above, the BLM is already planning to incorporate these models when developing or revising its environmental impact statements.

In Phase I of the *Mule Deer* (*Odocoileus hemionus*) study, results indicated that migrating ungulates derive considerable foraging benefits from the stopover habitats along their migration routes (Sawyer and Kauffman, 2011, downloadable at *http://www.wyocoopunit.org/index.php/archives/20/sawyer-h-s-and-m-j-kauffman-2011-stopover-ecology-of-a-migratory/*). Foraging benefits derived during migration take place at the start of the annual period of fat gain, and those energy reserves are crucial to winter survival. The BLM Pinedale and Rawlins Field Offices are using the information about stopover habitat locations to guide their shrub monitoring and the determination of where to conduct habitat treatments. In addition, this work provided the analytical tools to identify stopover sites used by mule deer and pronghorn (*Antilocapra americana*), which the U.S. Forest Service is now using in their development of a supplemental environmental impact statement for a new drilling proposal in the Wyoming Range. Our synthesis of

Global Positioning System (GPS) migration data used for those analyses also assisted the Wyoming Department of Transportation with citing underpasses in the Baggs area and overpasses in the Trapper's Point area near Pinedale to facilitate migrating ungulates trying to cross major thoroughfares. In Phase II, we are evaluating whether disturbance—from energy development in particular—affects the *rate* at which ungulates migrate and the foraging benefit they receive during migration. Initial results show that across spring and fall migrations in two study areas, deer moved more quickly when migrating through disturbed habitats than they did in more pristine habitats, which suggests that human disturbance likely diminishes foraging opportunities associated with stopover sites. The mule deer work has also been used by LPDTs to identify locations for fence removals. Results of all the mechanistic wildlife studies will be used to update the Wyoming State Action Wildlife Plan and develop better monitoring and mitigation strategies for species most at risk from energy development.

The main body of this report provides the details of the highlighted projects above, plus all the work not discussed here. Additional background information for many ongoing projects may be found in prior annual reports, the hotlinks for which are provided below in our *Introduction*.

Introduction

Southwest Wyoming contains abundant wildlife, habitat, and energy resources. Human settlement in the region has been limited; thus, it is characterized by open spaces and local economies are tied to agriculture, recreation, and resource extraction. Since the late 19th century, Southwest Wyoming, including the fossil-fuel-rich Green River Basin, has been explored and developed for coal, oil, natural gas, and uranium. In the early 2000s, however, the pace of energy development increased significantly, especially development associated with natural gas and wind energy. Combined with increased residential and industrial development, energy development has led to changes in land use and socioeconomics throughout much of Southwest Wyoming. As described in Frank D'Erchia's Foreword to this document, the potential effects of these changes on wildlife and wildlife habitat prompted the Bureau of Land Management (BLM) and the Wyoming Game and Fish Department (WGFD) to take the initial steps to develop the Wyoming Landscape Conservation Initiative (WLCI) for Southwest Wyoming (fig. 1). Driven by local and regional leaders, the WLCI was officially launched in 2007 with support from the U.S. Department of the Interior. The initiative's mission is to implement a long-term, science-based program of assessing, conserving, and enhancing fish and wildlife habitats while facilitating responsible energy and other development through local collaboration and partnerships. Formal WLCI partners include the BLM, the U.S. Geological Survey (USGS), the U.S. Fish and Wildlife Service (FWS), the Wyoming Game and Fish Commission (the policy-making board for the WGFD), the Wyoming Department of Agriculture (WDA), the U.S. Forest Service, six Wyoming County Commissions, and nine of Wyoming's Conservation Districts. Additional collaborators provide support to the WLCI effort, including the National Park Service, the U.S. Natural Resources Conservation Service, the U.S. Bureau of Reclamation, the Wyoming Department of Environmental Quality (WDEQ), the Wyoming State Land Board, the Pinedale Anticline Project Office, and the Jonah Interagency Mitigation and Reclamation Office, as well as non-profit entities, industry, and landowners.

The role of the USGS as a partner in the WLCI is to provide multidisciplinary scientific- and technical-assistance support to WLCI partners and to advance the overall scientific understanding of ecosystems in the Southwest Wyoming landscape needed to conserve the WLCI landscape. Fulfilling these roles entails evaluating the effectiveness of habitat treatments implemented by WLCI partners and collaborators, assessing the cumulative effects of energy development and other land-use changes on wildlife and habitats in the WLCI area, coordinating WLCI activities, and demonstrating how to integrate research findings into on-the-ground management actions.

The USGS WLCI Science Strategy (Bowen, Aldridge, Anderson, Chong, and others, 2009) is currently undergoing review to assess the progress that the USGS has made towards the objectives originally outlined within the Science Strategy. Meanwhile, the document continues to serve as a robust framework for conducting science and technical assistance on behalf of the WLCI effort. As implied by the strategy's framework (fig. 2), information gained through USGS activities has been and will continue to be integrated into the overall knowledge base and made available to WLCI partners for guiding and improving future habitat treatments, best management practices, and other conservation activities. Activities performed by the USGS continue to focus on addressing immediate management needs identified by WLCI members; providing assistance with identifying, implementing, and tracking habitat projects in priority areas; and conducting longer-term, priority technical assistance, research, and both long-term and effectiveness monitoring activities. Science and technical-assistance activities also continue to address questions and issues at multiple spatial scales, from individual habitat-treatment sites to the entire WLCI landscape. This approach provides information to support policy and planning decisions while meeting specific technical-assistance needs.

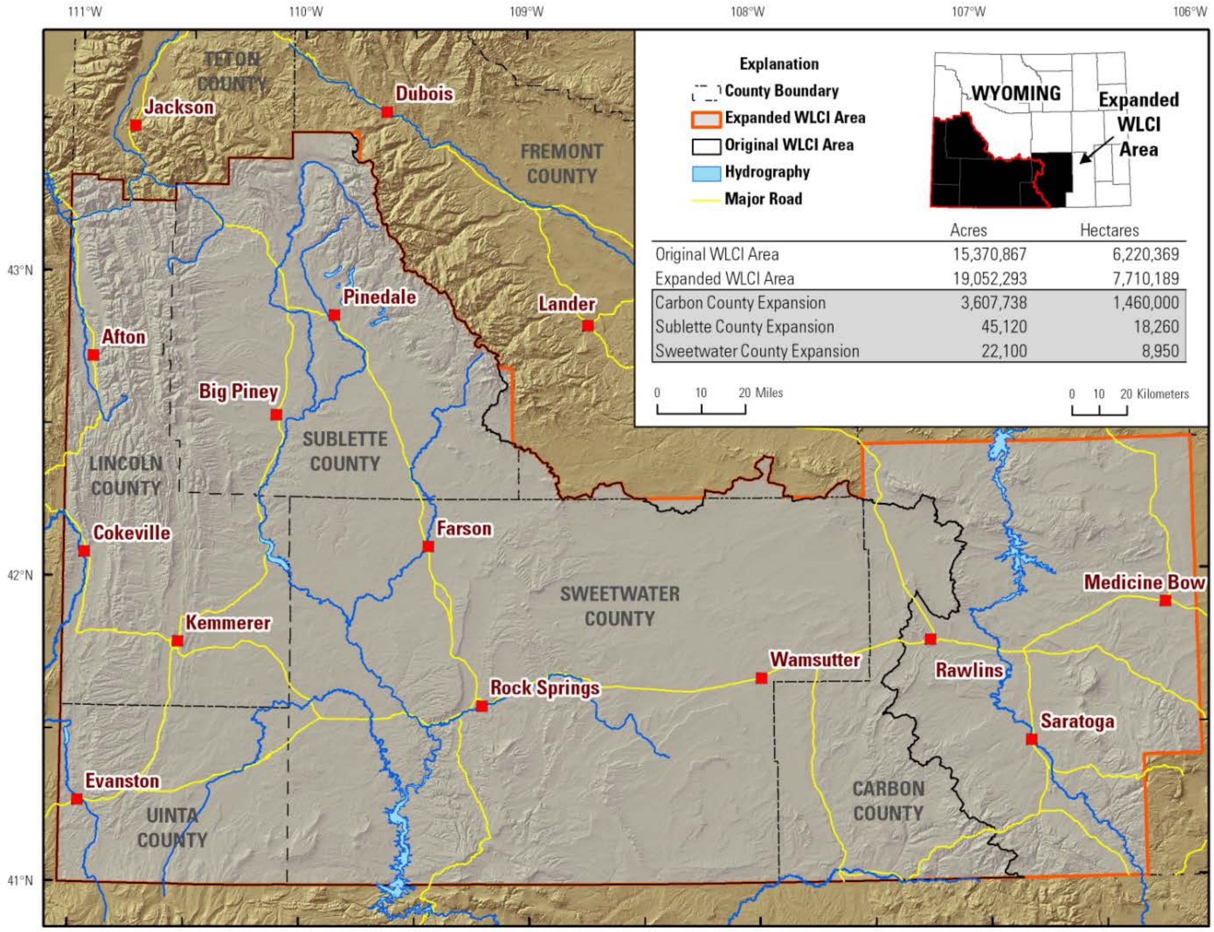

Figure 1. The Wyoming Landscape Conservation Initiative (WLCI) region, with county boundaries, major drainages, roads, and cities/towns shown. The WLCI boundary changed in 2009 to include all of Carbon, Sweetwater, and Sublette counties rather than only those portions west of the Continental Divide. This map shows both the original area (black outline) and the extended area (orange outline).

The USGS WLCI Science Strategy (Bowen, Aldridge, Anderson, Chong, and others, 2009) is currently undergoing review to assess its progress towards the objectives originally outlined within it. Meanwhile, the document continues to serve as a robust framework for conducting science and technical assistance on behalf of the WLCI effort. As implied by the strategy's framework (fig. 2), information gained through USGS activities has been and will continue to be integrated into the overall knowledge base and made available to WLCI partners for guiding and improving future habitat treatments, best management practices, and other conservation activities. Activities performed by the USGS continue to focus on addressing immediate management needs identified by WLCI members; providing assistance with identifying, implementing, and tracking habitat projects in priority areas; and conducting longer-term, priority technical assistance, research, and both long-term and effectiveness monitoring activities. Science and technical-assistance activities also continue to address questions and issues at multiple spatial scales, from individual habitat-treatment sites to the entire WLCI landscape.

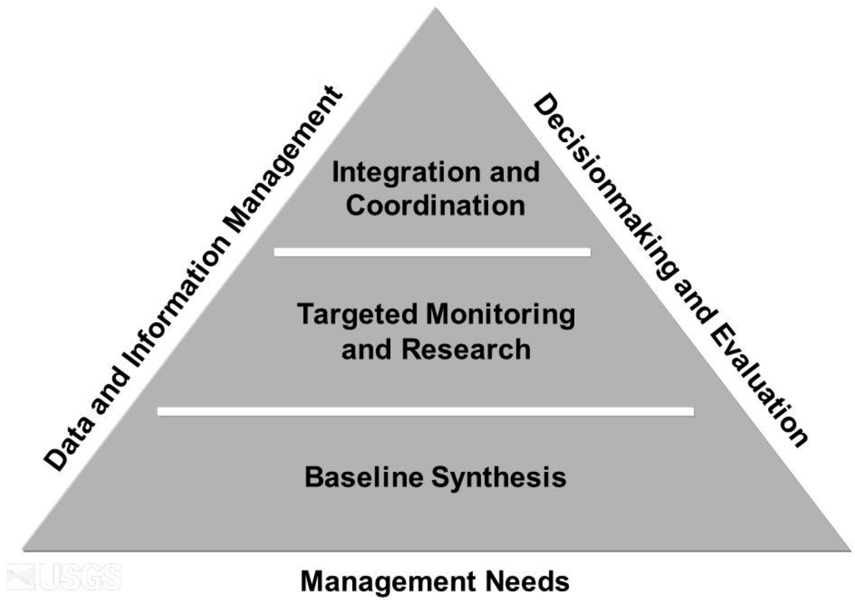

Figure 2. The U.S. Geological Survey's approach to researching and monitoring ecosystem components. The Management Needs identified by the Wyoming Landscape Conservation Initiative (WLCI) partners form the foundation of the five major USGS WLCI science activities: (1) Baseline Synthesis, (2) Targeted Monitoring and Research, (3) Data and Information Management, (4) Integration and Coordination, and (5) Decisionmaking and Evaluation. These activities represent successive stages that build on information gained from earlier stages, and at all stages, Data and Information Management ensures information and data access for use in Decisionmaking and Evaluation. The approach may be used iteratively and allows for stages to overlap.

This approach provides information to support policy and planning decisions while meeting specific technical-assistance needs.

The culmination of USGS WLCI science and technical-assistance activities to date is the Integrated Assessment (IA) of natural resource values (based on WLCI goals and priorities) for the WLCI region. The purpose of the IA is to provide a comprehensive, multiple-disciplinary assessment of the effects of energy development and other land-use changes on resource values (both natural and socioeconomic) of critical importance to WLCI partners. Primary uses of the IA will be to (1) address specific management issues; (2) answer simple to complex questions about the importance of certain areas or resources; (3) serve as a foundation for long-term and effectiveness monitoring; (4) provide a science-based framework for conservation planning and evaluation; and (5) serve as a data/analysis resource for future research projects and technical applications. Progress in FY2011 included development of the final IA landscape analysis, which yields an overall condition index score for each sub-watershed [hydrological unit code (HUC) 12/level 6) across the WLCI region. FY2011 progress also included development of an interactive Web application that provides access to the underlying IA data and interim products, as well as a visualization (mapping) tool. The index may be used to map priority resource values (for example, priority areas, water resources, special management areas), condition indices [for example, distributions of species of concern or WLCI focal habitats: sagebrush steppe, mixed mountain shrub, aspen (*Populus tremuloides*), woodland, riparian, aquatic], and agents of change (for example, energy development, road density, and climate) to generate current assessments and “what-if” scenarios for use in conservation and restoration planning. For example, one could map where in a given jurisdiction the resource values are greatest and the potential for energy development lowest to help resource managers identify locations suitable for habitat improvement, restoration projects, or conservation easements. Another example might be to overlay road density and energy-development infrastructure with WLCI focal habitat types or the predicted ranges of Wyoming Species of Greatest Conservation Need (SGCN) under a given scenario of climate change (changes in precipitation and temperature) to help decisionmakers assess resource conditions and identify where actions may be necessary to conserve species and habitats. The final IA products will include a document, associated data resources, and decision-support tool for evaluating cumulative effects of energy development and other land-use changes on wildlife and their habitats. As more information and data are generated throughout the WLCI effort, the IA will be updated accordingly.

Throughout FY2012, the USGS will continue providing technical assistance and research on behalf of the WLCI effort, including completion of the IA and meeting partner needs while also improving the overall understanding of the WLCI region ecosystems and how they are driven by and respond to change. This understanding will strengthen the basis for management decisions and advance the mission of the WLCI.

The USGS WLCI Annual Report for FY2011: Approaches and Organization

The first annual USGS WLCI report (Bowen, Aldridge, Anderson, Assal, and others, 2009, at *http://www.fort.usgs.gov/Products/Publications/pub_abstract.asp?PubID=22683*) summarized the work accomplished from FY2007 through FY2008 and established a foundation for the research approaches the USGS would use. The second and third annual reports (Bowen and others, 2010, 2011, at *http://pubs.usgs.gov/of/2010/1231/* and *http://pubs.usgs.gov/of/2011/1219/*) summarize the work conducted by the USGS Science Team and findings of that work in FY2009, FY2010, respectively. This report, which discusses accomplishments and findings from FY2011, builds on the first three annual reports, and it is structured in the same way that the 2010 report was structured. In subsequent annual reports, however, we will develop a new approach to the annual report that will result in a more efficient presentation of USGS WLCI science results, products, and their relevancy to management questions.

The main body of this report, Science and Technical Assistance Summaries, is sectioned by major USGS WLCI science and technical assistance projects: Baseline Synthesis; Targeted Monitoring and Research (further sectioned by Inventory and Long-term Monitoring, Effectiveness Monitoring, and Mechanistic Research of Wildlife); Data and Information Management; and Integration and Coordination, and Decisionmaking and Evaluation. At the beginning of each major section is a summary of activities conducted during FY2011 for that project. These summaries provide brief overviews of each major activity, including the work accomplished and findings for FY2011. Following each section summary are the detailed reports for each activity under that project. The activity reports are in a standardized format that includes the study’s scope or background and overall approaches, objectives, and a description of the study area. Each activity report also includes a map showing study sites or sampling locations (if applicable), work accomplished and findings for FY2011, products completed in FY2011, and a section on work to be conducted in FY2012. Where relevant, the study’s background and scope section generally covers the entire study to provide a broad understanding of why that work is being conducted and what it is intended to accomplish. Likewise, the methods sections are generally meant to describe general approaches for addressing the issue or question rather than protocol details. The work accomplished and findings sections provide a synopsis of FY2011 activity and (where relevant) notable results, and the products completed in FY2011 include final products, as well as interim products required for developing final products. Finally, the sections on work planned for

FY2012 provide a brief overview of anticipated activity (under anticipated funding levels). Literature and other works cited in the document are listed at the end in the References Cited section. For highly detailed background and methods information, readers may wish to refer to the appendix in the 2009 report online at *http://pubs.usgs.gov/of/2009/1201/*.

Science and Technical Assistance Summaries

Baseline Synthesis

Summary of FY2011 Activities for Baseline Synthesis

An important first step to understanding the cumulative effects of energy development and other land-use changes, climate change, and habitat treatments was to conduct an overall assessment of baseline resource conditions throughout the WLCI region. This step has entailed assembling, standardizing, and making accessible the wealth of existing and incoming information and data; assessing the vulnerabilities of species to energy development and other land-use changes; filling information gaps by conducting a variety of surveys and other assessments across the WLCI region; developing new methods for assessing resource conditions and trends; modeling the ecosystem dynamics, including major drivers of change in focal habitat types of the WLCI region; and selecting indicators that would be most useful for detecting changes in long-term monitoring of conditions across the landscape. The resulting products and tools associated with the baseline synthesis include reports, spatial (maps) and mathematical models, and protocols. To help guide and establish priorities for conservation planning and management activities across the WLCI landscape, the USGS is developing an integrated assessment (IA) that incorporates much of the baseline synthesis and other WLCI science conducted to date.

There were 13 Baseline Synthesis work activities conducted in FY2011, including the completion of 1 activity, and 1 new activity: (1) *Application of Comprehensive Assessment Data to Support WLCI Decisionmaking and Conservation Actions*; (2) *Assessing Land Use/Cover Change*; (3) *Assessing Energy Futures*; (4) *Assessing Mineral Resources*; (5) *Developing Methods for Assessing Energy Exploration/Development Impacts on Biogeochemical Cycling in the Muddy Creek Watershed* (new focus); *(6) Developing Methods for Assessing Element Mobility and Availability in Soils of the Greater Green River Basin*; (7) *Developing Remote Sensing Applications for Geologic, Vegetation, and Soil Investigations*; (8) *Developing a Soil-Quality Index;* (9) *Assessing Rancher Perceptions of Energy Development in Southwest Wyoming* (completed); (10) *Western Energy Citation Clearinghouse* (new); (11) *Assessing Wildlife Vulnerability to Energy Development;* (12) *Climate Change and Simulating Potential Future Vegetation;* and (13) *Development of Regional Curves Relating Bankfull-Channel Geometry and Discharge to Drainage Area for the Rocky Mountain Hydrologic Region in Wyoming*.

The *Application of Comprehensive Assessment Data to Support WLCI Decisionmaking and Conservation Actions* work in FY2011 entailed continued compilation and analysis of resource data from many sources to support diverse needs and efforts within the WLCI region, and to support long-term, multi-scale conservation planning. Data and information provided by LPDTs and collected as part of the Comprehensive Assessment were used to (1) prioritize habitat projects proposed for 2012; (2) refine areas of interest, conservation priorities, and issues identified by LPDTs; and (3) support the development of the WLCI 5-year Conservation Action Plan. In turn, project prioritization information was provided to the USGS Data and Information Management Team (DIMT) to update the WLCI internet-based conservation projects database and update the WLCI web page, and to support the IA. The first version of the IA was finalized, including priority resources, condition indices, agents of change, and potential for future change associated with development and climate. The IA summarizes information by sub-watershed into an overall index. In addition to supporting landscape-scale conservation planning and evaluation, the IA is a data and information resource for addressing specific agency management questions. A web application and dynamic mapping platform (*http://my-beta.usgs.gov/wlciIA/*) were developed and launched in 2011 for displaying the mapped information and accessing underlying resource values. Initial IA results were presented to the WLCI EC, members of the CT, an interdisciplinary team from the BLM Rock Springs Field Office, the FWS Great Northern Landscape Conservation Cooperative (GNLCC), the FWS Landscape Energy Assessment Project Team, members of the BLM Wyoming Basins Rapid Ecoregional Assessment Technical Team, members of USGS regional leadership, and many other audiences, including a multi-agency audience in Colorado. Feedback from these audiences has resulted in improvements to the IA and the web application.

In FY2011, work conducted for the *Assessing Land Use/Cover Change* task included simulation modeling of potential land uses with patterns of future climate to model future potential changes in vegetation and wildlife habitat. Results of these simulations can begin to identify land-management strategies that maximize long-term persistence of habitat for wildlife species and support land-management decisionmaking.

In FY2011, the work of *Assessing Mineral Resources* continued with incorporating new field observations into the USGS Mineral Resources Database System, eliminating duplicate records for the same deposit (largely an unintended consequence of merging the USGS deposit-based database with the former U.S. Bureau of Mines mine–based database several years ago), improving location descriptions, confirming the commodities of interest at the sites, and, where available, adding resource (grade and tonnage) and production information, with an emphasis on uranium, phosphate, and sand and gravel, although some work was done on other commodities as well. Numerous mineral deposits (base- and precious metals, uranium, and industrial minerals) are located within the WLCI study area, mostly within 18 mineralized areas; however, the current state of the industry is, with a few notable exceptions (trona and uranium), mostly dormant in the WLCI study area. WLCI hosts the world's largest trona (soda ash) deposit, which is being mined and processed by several companies. Successful *in-situ* recovery of uranium elsewhere in Wyoming has fueled interest in exploration and feasibility projects in the northern and central part of the study area.

As coal, wind, oil, gas, uranium and solar energy sources are developed in Southwest Wyoming, the *Assessing Energy Futures* work activity continues to focus on collecting baseline data to assess what is known about those energy resources and the ecosystems potentially affected by that development. In FY2011, we continued to focus on collecting baseline data and developing methods for archiving and disseminating this information to collaborators and the public. Specifically for WLCI, our Energy Resources Science team is assembling a comprehensive inventory of pertinent data available to the public as an online resource. Energy maps, data, documentation, and spatial data-processing capabilities will be available by media and served at the USGS website.

Muddy Creek, which is part of the Upper Colorado River watershed, is a semi-arid catchment in a sagebrush steppe ecosystem. The work activity, *Developing Methods for Assessing Energy Exploration/Development Impacts on Biogeochemical Cycling in the Muddy Creek Watershed*, has entailed conducting a synoptic watershed assessment to identify areas within the watershed that are more susceptible to mobilization of trace elements that occur in soils forming on marine shale. In FY2010, the soil, stream sediment, and water samples were collected and analyzed for major elements and a suite of trace elements. In FY2011, this work continued with sampling formation waters discharged from two wells within the watershed to evaluate their potential contribuion of organic carbon, nitrogen species, and trace elements to surface water.

Transmission lines proliferating in sagebrush habitat as wind turbines are installed. Photo credit: Anna Wilson, U.S. Geological Survey.

In FY2011, the work on *Developing Methods for Assessing Element Mobility in Soils of the Greater Green River Basin* continued with final analyses of samples and initial manuscript preparation. When completed in FY2012, the products resulting from this work will provide geochemical data regarding trona resources in the Green River basin for inclusion with the comprehensive assessment task of assessing mineral resources in the WLCI region. This work also will result in geochemical data on soils and weathering profiles of the Green River Formation. This information, which will help to define the biogeochemical controls of soils on the ecological health of Wyoming sagebrush landscapes, will be valuable information to USGS biologists working in the WLCI region.

The *Development of Remote Sensing Applications for Assessing Geology, Soils, and Vegetation* work continued in FY2011 with review of the updated mineral composite map developed in FY2009; final publication of the map is expected in early FY2012. The new work initiated in FY2010 to evaluate the use of Landsat imagery processed with USGS-developed software for detecting early season invasives (DESI) continued. Preliminary normalized difference vegetation index (NDVI) and differenced normalized difference vegetation index (dNDVI) analyses were conducted and DESI was used to produce initial maps to show the probability of cheatgrass (*Bromus tectorum*) occurrence.

The FY2011 work on *Developing a Soil-Quality Index* (SQI) was postponed to FY2012, when additional soil sampling will take place in the Muddy Creek area before concluding this task.

Progress in FY2011 on the *Assessing Rancher Perceptions of Energy Development in Southwest* Wyoming work activity included further revisions of the final report, which will be published in FY2012. Although this activity was officially completed in FY2011, work will continue in FY2012 with publication of the final report, development of a fact sheet about the project, and a manuscript detailing the project results for a peer-reviewed publication.

The *Western Energy Citation Clearinghouse* (WECC) is a new project initiated in FY2011 to develop a web-based energy-resource database comprising pertinent, foundational, up-to-date references for relevant literature and links to on-line resources and research efforts. Although there are several valuable on-line resources that provide information about energy development and associated effects, they are distributed across numerous websites and often are focused on only a few key components (for example, oil and gas literature; wind energy and wildlife). The WECC will provide USGS researchers and collaborators an efficient mechanism for accessing the latest data and research references, and it will be reviewed and updated continuously to provide the most current resources and information. In FY2011, the initial database of more than 3000 references was developed to serve as a foundation for the WECC. Website developers have created an initial wireframe for making the WECC accessible on the Web.

The work on *Assessing Wildlife Vulnerability to Energy Development* continued in FY2011 with ranking Wyoming's SGCN according to how much of their habitat is exposed to energy development. Immediate research is needed to investigate mechanisms of potential impact on highly ranked species and to help identify appropriate mitigation actions.

In FY2011, the *Climate Change and Simulating Potential Future Vegetation* work entailed simulating potential future vegetation changes for the WLCI study area and initiating analyses of the data. Self-documenting files for the climate and bioclimate data were developed for publication in FY2012.

Development of Regional Curves Relating Bankfull-Channel Geometry and Discharge to Drainage Area for the Rocky Mountain Hydrologic Region in Wyoming was initiated in FY2010 and continued in FY2011 as part of a larger effort to develop regional bankfull curves across the Rocky Mountain Hydrologic Region. Regional curves are statistical models (one-variable, ordinary least-squares regressions) for drainages that relate bankfull discharge, bankfull cross-sectional area, bankfull width**,** and bankfull mean depth to drainage area in settings that are expected to have similar runoff characteristics. The regional curves are used to evaluate the stability of stream channels (as compared to reference sites) and designs for stream restoration. In FY2011, 15 additional sites were surveyed across Wyoming (1 of which is in the WLCI area), bringing the total number of sites surveyed from FY2010–FY2011 to 40 (six of which are in the WLCI area). In FY2011, the final report was reviewed but placed on hold while the 15 additional sites were surveyed and the corresponding regional curves were developed. The final report will be published in FY2012.

These 13 Baseline Synthesis tasks are detailed in the sections that follow.

Application of Comprehensive Assessment to Support Decisionmaking and Conservation Actions

Status

Ongoing

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Scope and Approaches

The comprehensive assessment is a collaborative effort to compile and analyze resource data to support the needs and efforts of WLCI. The comprehensive assessment is divided into two focus areas. The first focus area is to direct data synthesis and assessment activities to support LPDTs. This information is helping the WLCI CT and LPDTs to conduct conservation planning which includes developing conservation priorities and strategies, identifying priority areas for future conservation actions, and supporting the evaluation and ranking of conservation projects. The second focus area is referred to as the Integrated Assessment (IA). Activities and products associated with the IA are designed to support decisionmaking at the WLCI programmatic level and conservation planning at landscape scales. Both of these assessment focus areas are described in more detail below.

Assessments for Local Project Development Teams—Data acquired or derived through the Comprehensive Assessment are being used to support the evaluation and ranking process for proposed WLCI habitat treatments. The WLCI CT uses this information to evaluate the spatial and ecological relationships between the proposed habitat projects and WLCI priorities listed below:

- conservation areas of interest and vegetation focus communities;
- priority wildlife habitats and core habitat areas that are essential to certain life stages, genetic connectivity, and maintaining populations (for example, migration corridors, crucial seasonal habitats, parturition areas);
- ecosystem components (habitat function, stability, integrity, and biodiversity);
- locations of population strongholds for greater sage-grouse and other species of concern;
- locations where abiotic and biotic conditions are favorable for maintaining or restoring ecosystem function; and
- proximity to protected areas and/or areas of development, or other past or current projects.

Integrated Assessment (IA)—The primary purpose of the IA is to inform and support landscape-scale conservation planning and resource-management decisions and actions. It also serves as a data and information resource for addressing specific agency management questions. The main feature of the IA is a multiple-disciplinary assessment of the effects of energy development and other land uses on resources important to WLCI partners. An important use of the assessment is to identify areas of high conservation and restoration value, and those with high development potential, based on the current landscape. The IA also can be used to develop potential scenarios of future development (based on data-informed assumptions of land-use and climate trends) for evaluating potential conservation and restoration areas.

Another purpose of this effort is to develop a framework for performing additional assessments by both USGS clients and WLCI partners. A variety of assumptions are inherent with the initial assessments. Although assumptions are logical and based on current knowledge, it is likely that managers will want to use local knowledge in assessments, perform finer-scale assessments in support of local management projects, or perform assessments of land-uses and resource values not considered in this initial effort. The USGS WLCI science team will periodically meet with State and Federal resource specialists and planners to discuss collaborative opportunities between the USGS and WLCI partners with regard to additional work needed, as implicated by the IA.

Objectives

The Comprehensive Assessment effort addresses the objectives as follows.

- Collect inventory data for important ecosystems and acquire information on conservation, land management, and energy-related concerns across the WLCI area.
- Develop strategies and approaches to evaluate relationships between data derived from modeling and data acquired from WLCI partners. These evaluations will inform decisionmakers, such as the WLCI CT and other WLCI committees, about risks, threats, and priorities for future conservation actions.
- Using the Integrated Assessment, provide an understanding of the relationships between ecosystem stressors and drivers of change, and their influence on important species and habitats.
- Develop a coarse screen to identify potential threats and support retrospective analyses for identifying important areas for future conservation projects.
- Assist the livestock industry with spatial representations of priority areas, such as calving or lambing areas, and areas for potential forage reserves and grass banks.
- Compile, rectify, manage, and provide data to the USGS Geographic Information Office in support of the USGS/WLCI Data Catalog.

The IA effort addresses the objectives as follows.

- Provide a synthesis of current understanding of the natural, economic, and human resources of Southwest Wyoming as a baseline reference of conditions and the state of knowledge.
- Identify the key natural resource and socioeconomic values, and change agents (human-mediated stressors) to consider in the IA. Values and change agents are based on WLCI goals and priorities.
- Develop procedures for performing assessments to delineate the biotic integrity, hydrologic function, conservation, restoration, and development potential of the landscape.
- Identify a range of plausible future projections of the change agents that may affect biotic integrity and hydrologic function of the landscape.
- Apply these procedures to the current landscape to identify areas for conservation, restoration, and development potential.
- Develop a comprehensive source of geospatial information on current conditions of multiple resource values to facilitate periodic future assessments of trends associated with resource values.

Study Area

Activities associated with this work are not specific to any one location, site, or habitat. They apply to the entire WLCI region (fig. 1).

Work Accomplished in 2011 and Findings

Assessment for Local Project Development Teams—Data and information provided by LPDTs and collected as part of the comprehensive assessment were used to prioritize habitat projects proposed for 2012. Project prioritization information was provided to the USGS DIMT to update the WLCI internet-based conservation projects database and to update the WLCI web page. Selected data obtained as part of this effort also were provided to USGS staff to support the IA. Spatial data and information about WLCI habitat treatments were acquired and work to refine areas of interest, conservation priorities, and issues identified by LPDTs were continued. The USGS WLCI coordinator, other WLCI CT and Monitoring Team (MT) members, and other WLCI partners obtained this information, and habitat project priority areas reflect where LPDTs will concentrate conservation actions during the next five years. This information was used to support the development of the WLCI 5-year Conservation Action Plan and with ranking and prioritizing future proposed conservation projects.

Integrated Assessment—In FY2011, the first version of the IA was finalized. It addresses priority resources (for example, WLCI partner priority areas, water resources, special management areas), condition (provides condition indices; for example, based on distributions of species of concern, WLCI focal habitats), agents of change (for example, energy and mineral development, roads, invasive plants, climate), and potential for future change associated with development and climate. The assessment analysis was conducted in a raster environment using a cell size of 30 m (see *http://www.wlci.gov/?q=integrated_assessment*); mean values, however, are summarized and displayed on the index map by sub-watershed unit [National Hydrography Dataset, hydrological unit code (HUC) 12/level 6). For each HUC, the summary information was used to generate an overall, categorical (low, medium, high), multi-criteria (aquatic and terrestrial considerations) index score. The IA framework was developed to be transparent and hierarchical, and the folder structure for the IA data and derived products is consistent with the hierarchical structure used to calculate index scores. This will allow users to decompose the summary scores and evaluate individual resources if they wish.

In addition to completing the first version of the IA, the USGS also launched a web application developed for the IA (*http://www.wlci.gov/?q=integrated_assessment*). The application provides an interactive environment and access to the underlying resource values that were combined to produce the final results. The web application also provides a tool for mapping the IA summary results (overall IA index scores) for individual HUCs across the WLCI area. By zooming in on the index map and double-clicking on an individual HUC, users can view a pop-up box that provides (in tabular format) the information used for each sub-score that contributed to the overall index score for that HUC. Individual tabs in the pop-up box also allow users to view the input-layer scores that form the basis of the IA score for that HUC. To better understand how HUCs may be affected by current change agents and future development, the overall index map may be overlaid with index scores for HUC-level change agents (current energy, mine, road, and urban development) or potential future change (urban, energy, or mineral development, and temperature data associated with climate change). Additional layers for displaying land ownership and WLCI focal ecosystems may be toggled on and off, and users may select either a map or satellite-image background. Finally, the web application allows users needing to address specific issues or management questions to download IA data and derived-product inputs for their use in additional analyses.

Initial results from the IA were presented to the WLCI EC, members of the CT, an interdisciplinary team from the BLM Rock Springs Field Office, the FWS Great Northern Landscape Conservation Cooperative, the FWS Landscape Energy Assessment Project Team, members of the BLM Wyoming Basins Rapid Ecoregional Assessment Technical Team, members of USGS regional leadership, and to multiple other audiences including a multi-agency audience in Colorado. Feedback from these audiences has resulted in improvements to the IA and the web application.

Products Completed in FY2011

- First version of IA analysis and product development completed.
- Web application and dynamic mapping platform (*http://www.wlci.gov/?q=integrated_assessment*) used to display the IA, and to access underlying resource scores.
- Presentation of IA results and web application to multiple audiences – see text above for details.
- GIS data and geospatial maps and posters associated with the IA and proposed and completed habitat projects. Datasets relevant to WLCI, which may be viewed by authorized users at *https://my.usgs.gov/csc/wlci*.
- Continued to update data directory and theme group descriptions of compiled and derived data associated with the comprehensive assessment and integrated assessment. This product was used to identify and transfer data to support BLM Rapid Ecoregional Assessments.
- Continued to develop limited metadata standards for data obtained from WLCI partners. This information is provided in the data directory.

Work Planned for FY2012

The USGS will continue to obtain and synthesize data relevant to conservation planning and the IA. The USGS WLCI coordinator and USGS staff associated with the acquisition of data and assessments will continue to meet with WLCI partners about data needs, acquisition of information from LPDTs, and priorities for conducting related assessments. The data directory will continue to be updated and it will be provided periodically to WLCI partners and BLM planners and the National Operations Center to facilitate sharing of data and interim products. The IA web application will be enhanced based on user feedback, and metadata for input data used in the IA will be completed. Example applications using IA data and derived products to address specific management questions will be developed based on partner input and added to the IA web application. A report on the IA will be drafted in 2012 based on work to date and the results of the initial IA. Additional presentations and workshops on the IA will be conducted with WLCI partners to demonstrate potential uses and obtain additional input on priorities for inclusion in IA enhancements to be made during 2012. Data stewards with USGS, BLM, and other WLCI partners will coordinate data and information sharing during 2012.

Assessing Land Use/Cover Change

Status

Ongoing

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Scope and Approaches

This effort evaluates the effects of future land uses on vegetation and wildlife habitat and is designed to illustrate potential management actions that may minimize land-use impacts. The entire WLCI landscape will be included in a spatially-explicit simulation framework to explore future potential land-use effects and the potential influence of future climatic conditions. Future potential energy development will be simulated along with elements of climate change from climate models to determine potential types and patterns of land cover change. Scenarios of future change will be used to determine conditions (land uses and patterns) that minimize long-term effects on vegetation conditions and wildlife resources, including migration corridors, sage-grouse core areas, and habitat. The results of this study will aid in identifying the spatial and temporal patterns of land uses that may minimize effects on wildlife habitat.

A frame-based model is a type of knowledge-based model used to illustrate system states and state changes, whereby the generalized alternative states of a system are represented as “frames” and knowledge about factors influencing a frame is used to model the temporal transition among frames. Frames consist of one or more key plant species or species groups. The simulated landscape in the modeling system is represented as a lattice of equal-sized cells called landscape elements, which are initialized with frames that represent current vegetation. Other biophysical properties are stored for each landscape element.

The WLCI conceptual models for contemporary ecosystems define all possible ecosystem states and the pathways and triggers of transition among states in response to natural disturbances and human-mediated stressors. Disturbances within the natural range of variability are modeled to mediate changes in variants of the native state. Degraded states (outside the range of native conditions) induced by stressors are explicit, and assumptions about the intensity or severity of a stressor determine the probability of transition to a degraded state. Degraded states are described by changes in species composition, and by impacted soil properties (soil erosion, reduced soil stability). These states become susceptible to conversion (subdominant replacing dominant species) or invasion (new species assemblage). Dynamic features related to degraded soil conditions, climatic conditions, and propagule abundance (which considers ‘migration’ barriers) influence the species that invade the landscape element containing the degraded state.

Objectives

- Identify land-management strategies that maximize persistence of habitat for wildlife species of special concern (for example, sagebrush obligates) under future potential land-uses and climatic conditions.

Study Area

Activities associated with this subtask are not specific to any one location or site. They apply to the entire WLCI region (fig. 1).

Work Accomplished in 2011 and Findings

A prototype of this simulation system was completed and used to estimate trends in energy-development patterns and native habitat within an energy field (64 km^2) designated as having high potential for future development. We continue to extract oil/gas pad surface disturbance from 1-m NAIP imagery; approximately13,400 pads have been extracted from the 2,255 NAIP images that cover the WLCI area.

Simulation experiments of continued development within an energy field illustrated a tipping point (exponential increase) in cheatgrass cover and loss of native habitat when surface disturbance due to energy development reached approximately 12–13 percent (proportion of the total area of the field; fig. 3). This trend was apparent for different experimental climatic conditions, which varied from least to most favorable to cheatgrass establishment. These results begin to help inform decision makers in terms of understanding possible effects of land-use patterns on native resources, and in terms of land uses that should be avoided.

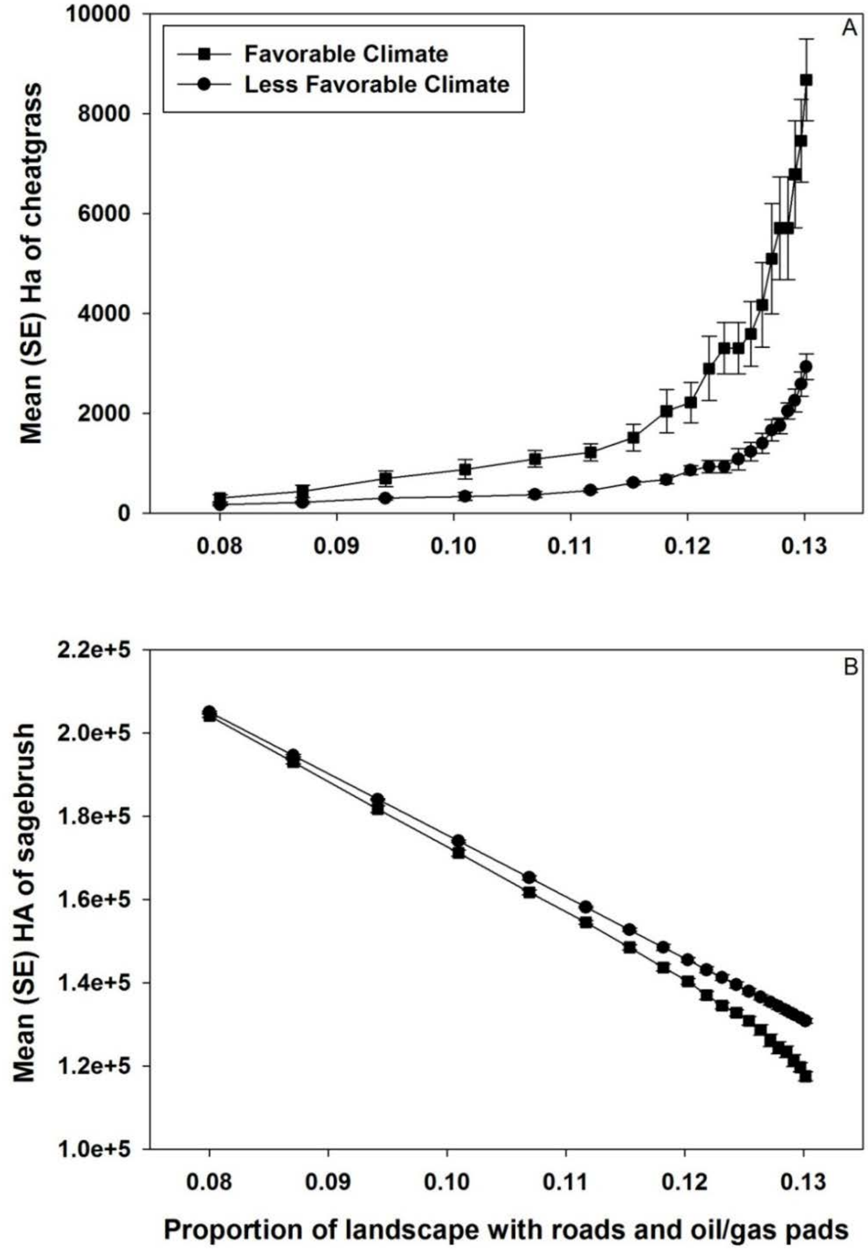

Figure 3. (A) Simulated trends in the area with cheatgrass (*Bromus tectorum*) and (B) sagebrush (*Artemisia* spp.) with increasing surface disturbance due to oil/gas pads and roads under two assumptions of climatic conditions in a 64-square kilometer energy field in Southwest Wyoming. Favorable climate conditions were emulated by using a relatively high rate of spread by cheatgrass. Less favorable climatic conditions used a spread rate that was 75 percent lower than for favorable climate. The simulation time frame was 20 years since the present.

Products Completed in FY2011

- Geospatial data layer of oil/gas pads.

Work Planned for FY2012

We will complete the extraction of oil/gas pad surface disturbances from 1-m NAIP imagery. We will continue to apply the frame-based model for energy-development and conservation scenarios over large portions (500,000 ha) of the WLCI area.

Assessing Energy Futures

Status

Ongoing

Contacts

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Scope and Approaches

The USGS has a long-standing program for assessing energy resources, including coal, gas, oil, uranium, and geothermal resources, and for assessing environmental and health impacts of energy occurrence and use. Future effects of energy development in Southwest Wyoming ecosystems are dependent on which particular energy resources are exploited. For each geologic resource, it is important to understand the geologic controls on potential exploration and production strategies. For this reason, it is important to apply a geologic understanding of emerging patterns in energy extraction when identifying the regions most likely to be developed in the future.

Studies include (1) continued development and interpretation of an extensive subsurface geologic dataset for Southwest Wyoming; (2) development of new GIS products that portray energy resource development; (3) preparation for future assessments of volumes of undiscovered natural gas; and (4) continued evaluation of existing (non-USGS) forecasts of future energy resource development footprints.

In FY2010, the GIS database of oil and gas drilling activity throughout Wyoming was developed. This was compiled for the WLCI region and complements the 2009 USGS publication on oil and gas development in Southwest Wyoming (*http://pubs.usgs.gov/ds/437/*) by approximating (based on database attributes) both beginning and ending dates of drilling activity for the entire state of Wyoming. Each well is assigned not only a start year, but also a stop year. These data originated from the Wyoming Oil and Gas Conservation Commission, have been processed by the USGS, and will become available as online resources in the form of GIS data (geodatabase and shapefile), a published map file (PMF) and a PowerPoint slideshow. In addition, an assessment of in-place oil shale resources in the Greater Green River Basin of Wyoming was completed (Johnson and others, 2011).

In FY2010, compilation of a new, detailed subsurface database continued for the Southwest Wyoming region. The database incorporates all available oil and gas well data, including standard suites of downhole geophysical logs, and a regional seismic reflection profile purchased with funds leveraged from the USGS Energy Resources Program. The assembly of these data will provide opportunities for developing enhanced interpretations of subsurface geology related to the evolution of the sedimentary basin and for emerging petroleum exploration concepts.

In FY 2010, existing models and forecasts of future energy production in Southwest Wyoming were examined. The BLM approach was found to be sound, though considerable uncertainty remains with respect to specific sites of future energy development (U.S. Bureau of Land Management, 2006). The Nature Conservancy (TNC) approach is conceptual and not based on geologically-relevant inputs (Copeland and others, 2009).

The Energy Map of Southwest Wyoming is currently being developed by using GIS techniques and expertise. It is a compilation of both published and previously unpublished energy resources data. The data are provided in a geodatabase, published map file (PMF), ArcMap document (MXD), and an Adobe Acrobat PDF map. Once published, energy maps, data, documentation and spatial data processing capabilities will be available on CD-ROM and at the USGS Energy Resources Program Web site *(http://energy.cr.usgs.gov/regional_studies/wlci/).*

The subsurface geology of southwest Wyoming is compiled in a Geographix® database that allows correlation of multiple well logs, construction of geologic cross sections, and integration with seismic reflection data to provide new interpretations of sedimentary facies architecture and basin structure. These new interpretations, in turn, will provide insight into the potential for undiscovered natural gas resources.

Objectives

- Build upon previous work to further document the temporal evolution of energy resource production in the Southwest Wyoming Province. Previous work (Biewick, 2009) examined oil and gas production in the context of assessment units defined in the 2004 USGS assessment of undiscovered oil and gas resources in southwestern Wyoming (Kirschbaum and others, 2004; U.S. Geological Survey Southwestern Wyoming Province Assessment Team, 2005). Present work (“Energy Map of Southwestern Wyoming”) incorporates coal, including coalbed methane, and wind energy development in the area within the WLCI. These data represent decades of research by the USGS, Wyoming State Geological Survey, the BLM, and industry, and they will facilitate a landscape-level approach to integrated science assessments, science based resource management, and science based decisionmaking.
- Enhance what is understood about subsurface geology of the Southwest Wyoming Province for use in updating perspectives on the potential impact of future energy development on critical ecosystems.
- Evaluate existing models and forecasts of future energy production in Southwest Wyoming, and work to enhance these if possible.

Study Area

Activities associated with this subtask are not specific to any one location or site. They apply to the entire WLCI region (fig. 1).

Work Accomplished in 2011 and Findings

A GIS database of oil and gas drilling activity throughout Wyoming was published (fig. 4). This historical perspective was compiled by approximating (based on database attributes) both beginning and ending dates of drilling activity for the entire state of Wyoming. Each well is assigned not only a start year, (spud or completion date), but also a stop year (shut in, permanently abandoned, and so on). These data originated from the Wyoming Oil and Gas Conservation Commission, have been processed by the USGS, and are available as an online resource in the form of GIS data (geodatabase and shapefile), an interactive published map file (ArcReader PMF) and a PowerPoint slideshow.

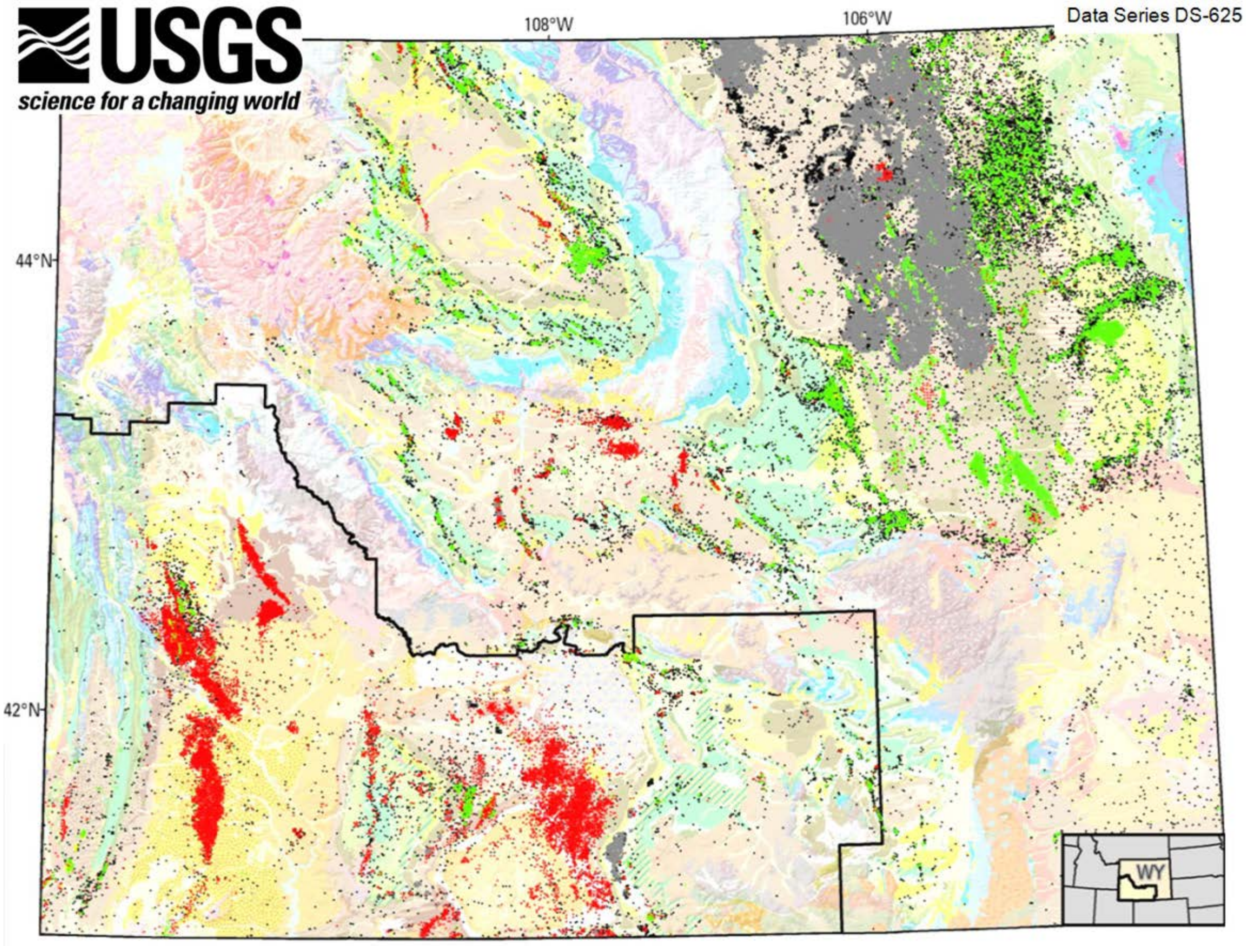

Figure 4. Historical oil and gas drilling activity in Wyoming. Red dots represent wells that are either producing gas or have produced gas in the past. Green dots show where oil is or has been produced from wells. Coalbed gas production is shown as grey dots. The black dots represent wells that are either dry or the production status is unknown. The colors shown in the background represent the surface geology.

Both coal and wind are among the energy resources being developed in Southwest Wyoming. Part A of the "Energy Map of Southwestern Wyoming," which primarily focuses on the electrical power sources of coal and wind, is in press (fig. 5).

Products Completed in FY2011

- Biewick, L.R.H., 2011, Geodatabase of Wyoming statewide oil and gas drilling activity to 2010: U.S. Geological Survey Data Series 625, *http://pubs.usgs.gov/ds/625/*.

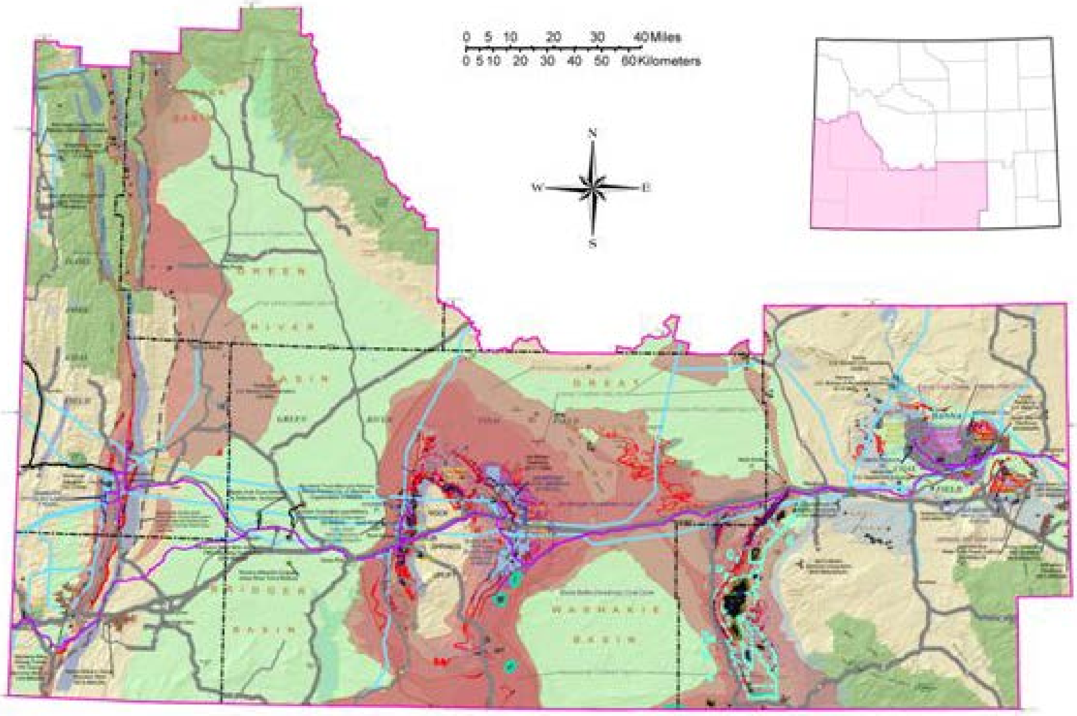

Figure 5. Generalized graphic of the U.S. Geological Survey "Energy Map of Southwestern Wyoming, Part A—Coal and Wind." Surface coal mines are shown as light blue polygons near Kemmerer in southern Lincoln County, on the east side of the Rock Springs Uplift in central Sweetwater County, and in the Elk Mountain Mining District, southwest of the town of Medicine Bow, in Carbon County. Some surface coal mines are no longer active and have been abandoned or reclaimed (as shown by the cross-hatch pattern). Underground coal mines are present in all three of the coal fields, but the only active underground coal mine is currently the Jim Bridger longwall operation on the eastern flank of the Rock Springs Uplift. Some coals contain enough gas to be potentially economic. Coalbed natural gas activity as of 2009 in the area southwest of Rawlins is shown as small black well symbols in the Atlantic Rim area (zoom to view at 500–800 percent to see the symbols). The large polygons shown in various shades of maroon represent seven coalbed gas assessment units that the USGS defined and assessed. The purple polygons represent selected coals in rocks of Tertiary age that were assessed during the 1999 USGS coal assessment of the Northern Rocky Mountains and Great Plains region. Two of the areas are within the Wyoming Landscape Conservation Initiative region and include the Greater Green River Basin and the Hanna-Carbon Basin.

Work Planned for FY2012

In FY2012, the USGS will continue compilation of oil (including oil shale), gas, solar and uranium geologic data and related features for the Southwest Wyoming region. The assembly of these data will provide opportunities for developing enhanced interdisciplinary understandings of the geological resources, and also the biological, hydrological, and landscape consequences associated with energy resource development. The USGS and partners will be poised to contribute to informed dialog about natural resource security for the future, environmental health, economic vitality, and management of Federal lands. With the addition of a new staff geologist assigned to subsurface interpretations in

Rocky Mountain basins, the USGS Central Energy Resources Science Center will develop enhanced interpretations of subsurface geology related to the evolution of the sedimentary basin and for emerging petroleum exploration concepts.

The products listed below will be published in FY2012.

- Biewick, Laura R.H., and Jones, Nick R., 2012, Energy Map of Southwestern Wyoming, Part A: Coal and Wind, U.S. Geological Survey Data Series DS (fig. 5).
- Biewick, Laura R.H., Wilson, Anna B., and others, 2012, Energy Map of Southwestern Wyoming, Part B: Oil, Gas, Solar and Uranium, U.S. Geological Survey Data Series DS (fig. 6).

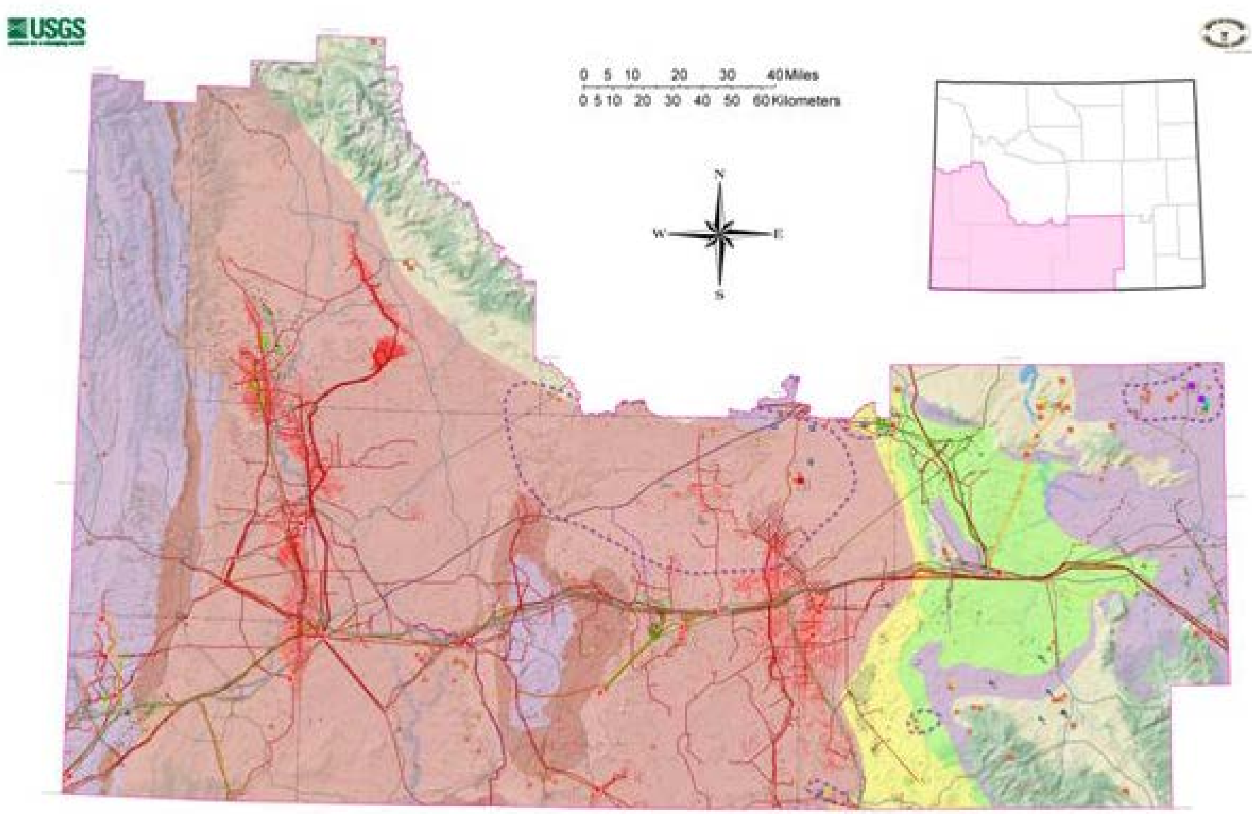

Figure 6. Generalized graphic of the U.S. Geological Survey Energy Map of Southwestern Wyoming, Part B: Oil, gas, uranium and solar. The large polygons shown in gold, green, purple and shades of red, represent oil and gas assessment units that the USGS has defined and assessed. The lighter red color shows areas of unconventional gas. In the darker red areas, the unconventional gas is restricted to coalbed gas. Gold is used to show areas of both unconventional oil and gas. Areas of unconventional oil are shown in green. The purple area defines where conventional oil and gas occurs. Conventional oil and gas underlies the entire area of the unconventional resources, as well. Oil and gas wells are shown as red, green, gold, gray or black dots. The areas outlined in dashed purple lines define uranium districts. The colored circles, squares and triangles represent areas of uranium production, deposits, or occurrences. The locations of pipelines, refineries, and gas processing plants as defined by the Wyoming State Geological Survey are also displayed on this map graphic.

Assessing Mineral Resources

Status

Ongoing

Contact

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Scope and Approaches

This is a multi-year study to understand the current extent of mineralization and mining activity (excluding coal and other energy minerals, with the exception of uranium), and the likelihood of continued or future mining development in the WLCI region. Numerous mineral deposits are located within the WLCI study area, mostly within 19 mineralized areas (fig. 7), and it was important that the WLCI Comprehensive Assessment include mineral deposits and mining activities because they have potential consequences for ecosystems.

The first step in the study was to visit as many of the sites recorded in the USGS Mineral Resources Database System (MRDS) as feasible to determine the types of mineral properties, whether or not they are active, and verify the location and other basic information contained in the record. Three field seasons (2008–2010, approximately 10–12 days each field season), allowed us (the author, accompanied by William D. Heran, USGS) to visit each of the mining districts and many of the sites within them. Based on the new field observations, the database was improved by merging or deleting duplicate records, creating new records for mines not previously accounted for, adding additional information, and making corrections. With accurate locations, it was then possible to plot the sites on geologic maps and outline districts with similar geology and deposit types. Mine samples were taken at several sites to confirm the type or intensity of mineralization if there was not sufficient information in the literature to ascertain the commodity(ies) of interest.

Objectives

- Provide an overview of known mineralized areas in WLCI
- Update the status and location of historic mines and prospects in WLCI
- Revise the USGS MRDS based on current information.
- Extrapolate potential for mineralization to areas that could be of economic interest in the future.

Study Area

This work was conducted throughout the WLCI study area (fig. 1), but observations were concentrated in the 18 mineralized areas as outlined on the map in Figure 7. Base- and precious-metal districts include Lake Alice, Seminoe, Encampment, Big Creek, Cooper Hill, Gold Hill, Herman, an area with the Iron Formation in the western part of the Seminoe area, and the extreme western part of the Keystone area. Wherever Permian Phosphoria Formation is at or near the surface in the western part of the study area, it has been added to the map (represented by pale blue lines in Figure 7 in the northwestern portion of the WLCI region). The largest trona deposit in the world covers almost 3,600 square kilometers (km^2) in the area west of Green River. Uranium is concentrated in the Ketchum Buttes, Poison Basin, Crooks Gap/Green Mountain, and Shirley Basin areas. Renewed interest for *in-situ*-recovery (ISR) methods for uranium has widely expanded the area in which uranium is sought.

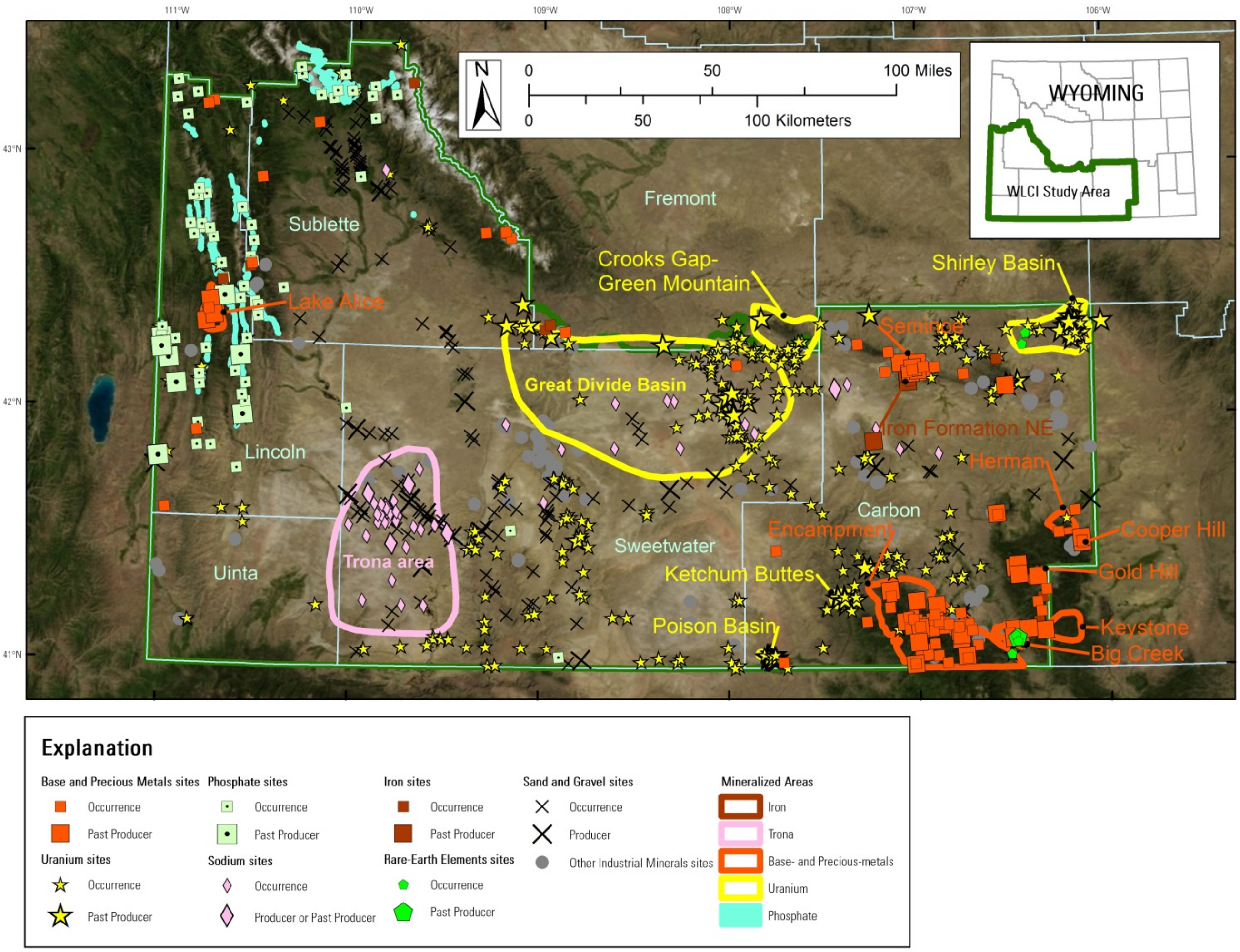

Figure 7. Locations of mineralized areas in and immediately adjacent to the Wyoming Landscape Conservation Initiative's (WLCI) expanded study area (see fig. 1 for locations context). Areas primarily containing base- and precious-metals are shown in red, uranium in yellow, trona in pink, phosphate in blue. Base- and precious-metals (red diamonds), uranium (yellow diamonds), and sodium (pink diamonds), phosphate (blue diamonds) deposits occur throughout the study area and are not restricted to these areas. Other commodities are not shown in this figure.

There are recent reports of new uranium ISR development in the Great Divide basin, roughly 20 kilometers (km) south of the Crooks Gap/Green Mountain area.

Work Accomplished in 2011 and Findings

In FY2011, work entailed incorporating new field observations into the MRDS database, eliminating duplicate records for the same deposit (largely an unintended consequence of merging the USGS deposit-based database with the former U.S. Bureau of Mines mine-based database several years ago), improving location descriptions, confirming the commodities of interest at the sites, and, where available, adding resource (grade and tonnage) and production information. In the first years of the project, the emphasis was on base and precious metals and trona. In FY2011, emphasis was on uranium, phosphate, and sand and gravel, although some work was done on other commodities as well.

Although Wyoming has had a rich mining history, the current state of the industry is, with a few notable exceptions, nearly extinct in the WLCI study area. While there are hundreds of open claims and leases, there are only a handful of active exploration projects, and even fewer active mining operations. 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 just to the west in Idaho there is some activity. (The largest former phosphate mines in southwest Wyoming, at Leefe and South Mountain, have been reclaimed; see photographs of these mines on pages 27−28 in the 2010 WlCI annual report at *http://www.fort.usgs.gov/Products/ProdPointer.asp?AltID=1665*).

Uranium companies are exploring and developing some “hot” areas in the WLCI area, 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 projects. Currently, there is no active mining or extraction of uranium in the study area, but several operations are proposed for the northern and eastern parts of the Great Divide Basin and another in the Ketchum Buttes area (Gregory and others, 2010). Trona mining is the only currently viable mining operation of any note. It occurs in the center of the Green River basin where it is underlain by the Wilkins Peak member of the Eocene-age Green River Formation. Several large companies west of Green River are mining trona underground and processing it to make soda ash.

In the updated MRDS database, there are 928 records for locations within the WLCI boundary. Of these, 380 are primarily uranium sites, 142 are sand and gravel, 73 are phosphate, and 54 are sodium (including trona and sodium salts). The remaining records (the number of which will exceed 928 because many sites have more than one primary commodity) include other metals (gold, silver, copper, lead, zinc, aluminum, tin, tungsten, iron, manganese, molybdenum, rare-earth elements and heavy metals such as titanium), barite, bentonite (and other clays), gypsum (and anhydrite), kyanite, stone (crushed and dimension), mica, rare earth elements, potassium, pumice, silica, talc, titanium, corundum, gemstones, abrasives, vermiculite, asbestos, and zeolites.

Products Completed in FY2011

- Corrections and updates to 951 records in the USGS public access MRDS database (U.S. Geological Survey, 2011a) at database, *http://mrdata.usgs.gov/mrds/*. Countless duplicate records were consolidated and deleted. For easy retrieval, all current WLCI records have the group code “WLCI."
- Uranium resources map (draft stage in collaboration with Laura Biewick, USGS Energy Resources Program).
- Mineral resources of WLCI Fact Sheet (draft stage).
- Mineral resources of WLCI poster or talk for May WLCI workshop (draft stage).
- Aggregate (sand and gravel) assessment of WLCI (draft stage).

Work Planned for FY2012

In 2012, the final set of maps will be completed and released as a USGS online-only publication, either as an open-file report or a data series. The mine and prospect data will be included in a USGS data series publication, in collaboration with Laura Biewick and others (Energy Map of Southwestern Wyoming, Part B; see above under Energy Futures). Our work also will be presented at the WLCI Workshop in Rock Springs, Wyo., in late May, 2012.

Developing Methods for Assessing Energy Exploration/Development Impacts on Biogeochemical Cycling in the Muddy Creek Watershed

Status

Ongoing. This project's focus shifted in FY2010 from a regional evaluation of soil organic matter and mercury (see page 22 of the 2009 annual report at *http://pubs.usgs.gov/of/2010/1231/pdf/OF10-1231.pdf*) to a more localized assessment of trace elements in the Muddy Creek Subbasin. This shift in emphasis and location was an adaptive research response to the results of two other USGS WLCI projects: (1) the long-term monitoring work on soil geochemistry (see page 49 of the 2009 annual report at *http://pubs.usgs.gov/of/2010/1231/pdf/OF10-1231.pdf*), and (2) the effectiveness monitoring work for assessing effects of energy development on soil and water salinity in the Muddy Creek Subbasin (see page 79 of the 2009 annual report). Results of both studies indicated that selenium and arsenic occur in the Muddy Creek Subbasin, pointing out the need for deeper investigations.

Wil Sadler, JoAnn Holloway, and Melanie Clark, U.S. Geological Survey, observe a continuously flowing well in the eastern part of the Muddy Creek drainage basin near Dad, Wyoming. Photo credit: Robert McDougal, U.S. Geological Survey.

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Scope and Approaches

Energy exploration and development has progressed steadily over the past few years in the Muddy Creek Subbasin, Carbon County, Wyo. The area includes the Atlantic Rim and Creston energy fields. Gravel roads, drill pads, pipelines, buried powerlines, and both production and injection wells have been constructed in the watershed and more are being considered for permitting. Trace elements, such as selenium, arsenic, and copper, are known to occur in soils and water in the watershed, and in some areas these elements occur at elevated levels. It is important to understand the geologic roles in the source, transport, and fate of these elements so that informed decisions can be made on how and where energy development and/or mitigation should occur. Sampling rocks, soils, stream sediments, and water can help identify source areas of metals that have negative impacts on ecological health due to their toxic effects and/or strong potential for bioaccumulation. Sampling and analyzing aquatic and terrestrial invertebrates likewise helps determine whether and to what extent detected trace elements are accumulating in the food web and, ultimately, how that may affect ecosystem health.

Eleven sites throughout the watershed were sampled, including the uplands, tributaries, and mainstem of Muddy Creek. Basin components that were sampled included source rocks and soils, alluvial soils, streambed sediments, aquatic and terrestrial invertebrates, water quality and streamflow, and sagebrush. Samples are being analyzed with mass spectrometry for major constituents and trace elements.

Objectives

- Assess the potential impacts of oil and gas development in the Muddy Creek watershed.
- Determine the bioaccumulation of trace elements in terrestrial and aquatic invertebrates.
- Determine the geologic controls on source, transport, and fate of trace elements.
- Determine the concentrations of trace elements, such as selenium, in upland, alluvial, and streambed soils.

Study Area

Muddy Creek is located in south-central Wyoming, north of Baggs, Wyoming, and south of the Atlantic Rim. The watershed, which is dominated by alluvial soils, drains the western slope of the Sierra Madre (fig. 8).

Work Accomplished in 2011 and Findings

Soil, rock, and water samples were collect from sites used in 2010, with the addition of two sites in the watershed. All samples are in analysis currently. Soil nutrients were present in low concentrations throughout the watershed, with the exception of the headwater sampling site. Muddy Creek sediments were also nutrient-poor, with low concentrations of organic carbon (less than 0.05 to 1.4 percent C) and no detectable concentrations of nitrogen. Selenium (Se), which was primarily derived from the weathering of exposed shale, increased in concentration with organic carbon in stream sediments and in alluvial soils. This correlation is consistent with the binding of Se to organic matter. Soils that formed directly from Se-bearing shales did not exhibit this relationship between Se and organic carbon. In surface waters, concentrations of dissolved organic carbon (DOC) were 280–840 micrometers (µM) C, and of total dissolved nitrogen (TDN) concentrations were 12-40 µM N. Groundwater collected from two wells did not have unusually elevated Se or DOC concentrations, but did have elevated inorganic nitrogen concentrations (60 µM N-NH_4^+ in Well 1, 13 µM N-NO_3^- in Well 2) relative to stream concentrations ([N-NH_4^+ + N-NO_3^-] less than 4 µM N). The introduction of groundwater with DOC:TDN ratios 0.8 to 1.5, where N is dominantly inorganic, to streams with DOC:TN greater than 20 where N is dominantly organic, can potentially result in the shift of stream ecosystems and the type of organic matter present.

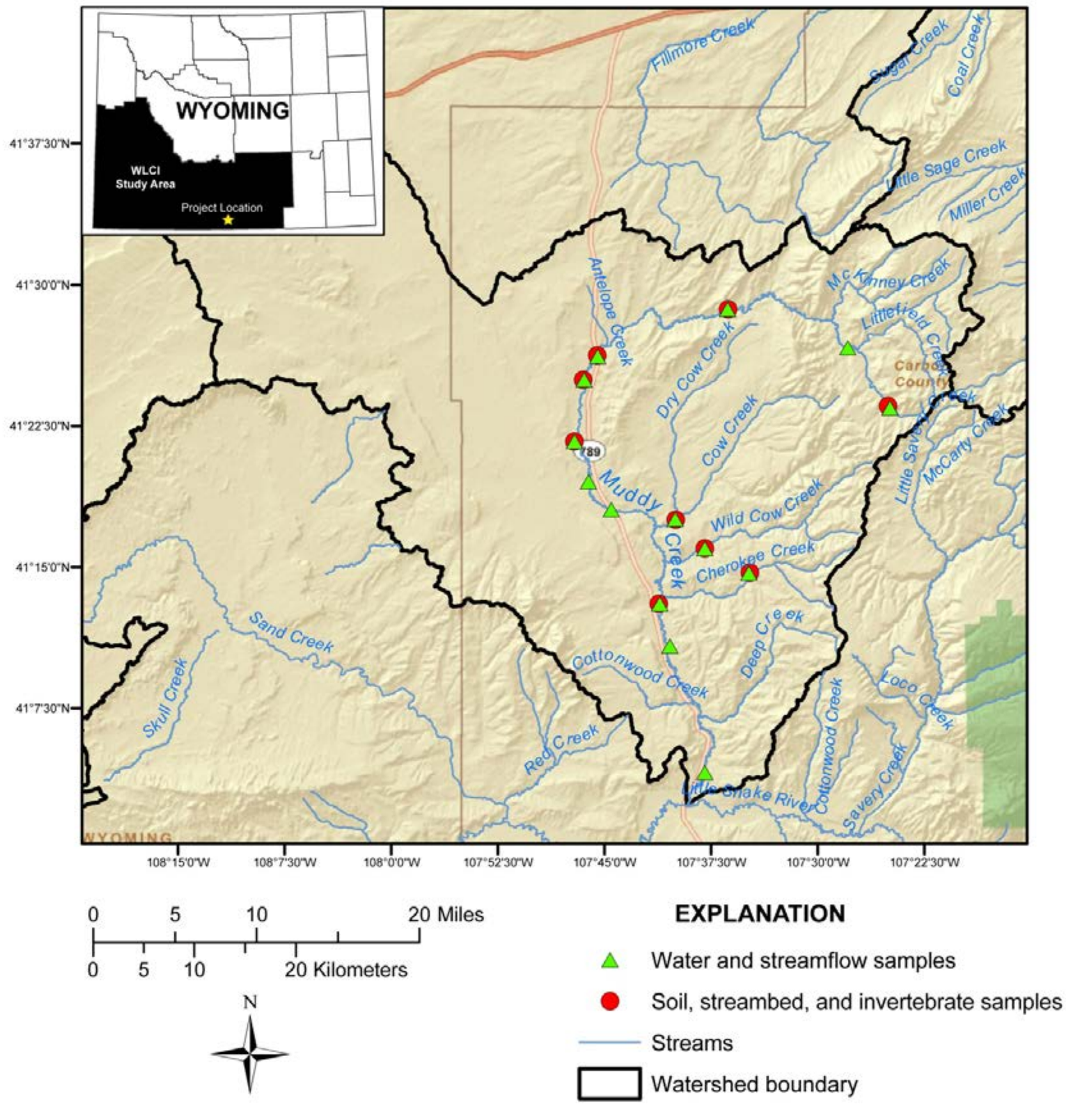

Figure 8. Locations of Muddy Creek watershed sampling sites, Carbon County, Wyoming. The town of Baggs, Wyo., is situated at the southern apex of the Muddy Creek watershed (outlined in black), just south of the southern-most green triangle.

Products Completed in FY2011

- Holloway, J.M., Bern, C., Schmidt, T.S., McDougal, R. R., Clark, M. L. Stricker, C. A., Wolf, R. E., 2011, Evaluating natural gas development impacts on stream ecosystems in an Upper Colorado River watershed, Eos Transactions, American Geophysical Union 92, Fall Meeting Supplement, Abstract H31A-1124.

Work Planned for FY2012

We will complete analysis of soil, water and rock samples and prepare a manuscript of results to be published in a peer reviewed journal. We also will present our FY2011 findings at the May 2012 WLCI Science Workshop to be held in Rock Springs, Wyoming.

Developing Methods for Assessing Element Mobility in Soils of the Greater Green River Basin

Status

Ongoing

Contacts

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Scope and Approaches

The Green River Formation that characterizes much of the Green River Basin hosts thick sequences of organic carbon-rich shale (oil shale), extractable pockets of natural gas, and bedded trona ($Na_3[CO_3][HCO_3] \times 2H_2O$), the extraction or mining of which can mobilize elements that could potentially affect the function and health of ecosystems in the basin. In an ongoing effort to develop methods for assessing element mobility in the basin, the USGS has sampled soils from the three main members of the Green River Formation (Laney Shale, Wilkins Peak, and Tipton Shale), and contracted with XRAL Laboratory, Canada, to conduct mass spectrometry analyses of the soils for bulk and trace elements. Soils were extracted by using a method that best simulates the type of weathering that occurs in a semi-arid climate characteristic of the study area.

Objectives

- Provide geochemical data to the Mineral Resources Environmental Assessment on trona resources in the Green River Basin.

- Provide valuable geochemical data on soils and weathering profiles of Green River Formation to USGS biologists working in the WLCI (this task is being partially supported by Energy Resource’s Oil Shale Assessment Project).

Study Area

This study is taking place in the greater Green River Basin near the Rock Springs/White Mountain area in southwestern Wyo. (fig. 9).

Work Accomplished in 2011 and Findings

Work on sample analyses of the chemical composition of soils and rocks in the Green River Formation were completed, and findings will be reported in 2012.

Products Completed in FY2011

- A final report was outlined and will be completed in FY2012.

Work Planned for FY2012

The work activity will be completed in FY2012 with development of a manuscript to report results of chemical composition of soils and rocks of the Green River Formation.

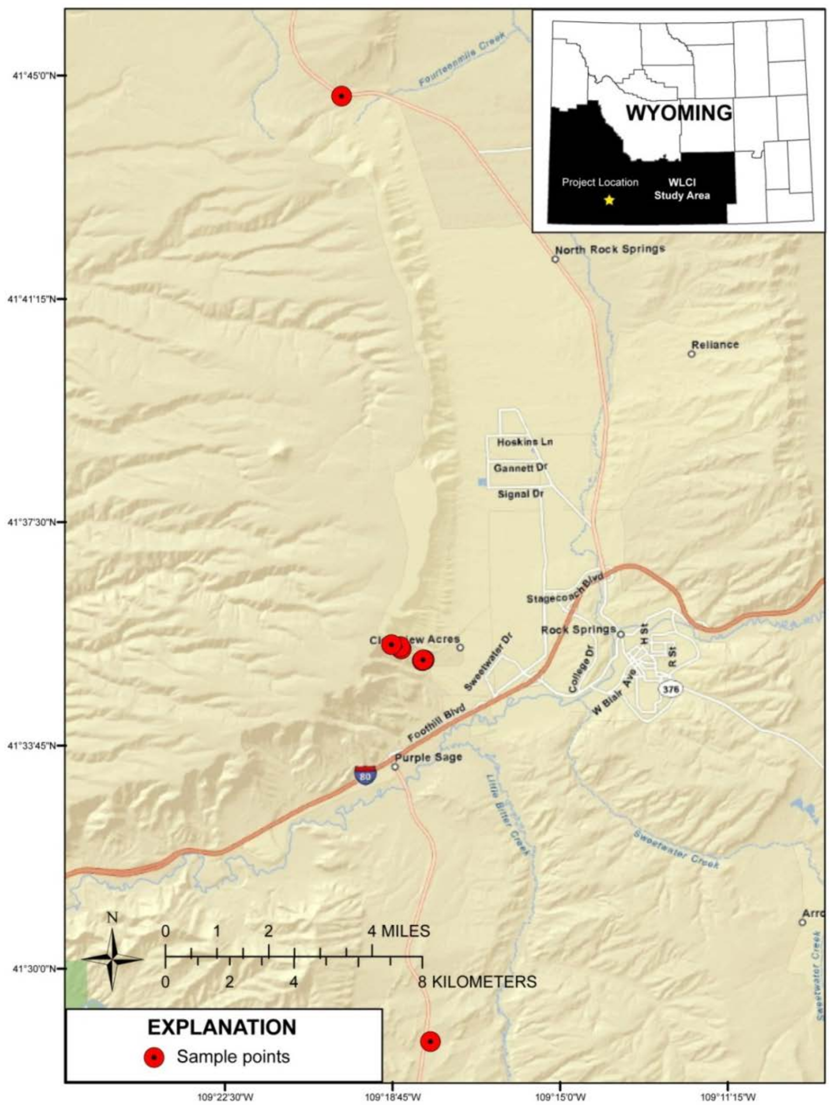

Figure 9. Locations of sampling sites (red circles) for assessing soil profiles and rocks in the three members of the Green River Formation (Laney Shale, Wilkins Peak, and Tipton Shale).

Developing Remote Sensing Applications for Geologic, Vegetation, and Soil Investigations

Status

Ongoing

Contact

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Scope and Approaches

Regional-scale studies, such as those being conducted for the WLCI, are well suited for the use of remote-sensing techniques. Products derived from remote-sensing instruments, such as Landsat images, have been used successfully for decades in studies of geology, vegetation, environmental change, and many other types of scientific research. Landsat data provide continuous records of coverage since 1972, making it possible to establish baseline conditions in areas affected by renewable and nonrenewable energy development. In this study, various Landsat datasets are being used to map current and pre-development conditions in the WLCI study area.

In FY2009, Landsat scenes were mosaicked (for producing one seamless image) and used to produce a mineral composite map for the WLCI region (see fig. 10 on page 27 in the 2009 WLCI annual report at *http://pubs.usgs.gov/of/2010/1231/pdf/OF10-1231.pdf*). The map uses different colors to show the distributions of (1) clays, carbonates, sulfates, and micas; (2) ferric iron minerals; and (3) ferrous iron minerals, bare rock, and soil. In FY2010, the USGS began evaluating the USGS-developed software, DESI[1] (Kokaly, 2011), for mapping the distribution of cheatgrass. The technique entails first obtaining Landsat imagery to produce NDVI/ dNDVI[2] maps. DESI was used to convert raw Landsat data to use in mapping probable cheatgrass occurrence. Landsat imagery for one scene from April and June of 2009 was obtained to produce NDVI and dNDVI maps to demonstrate the effectiveness of DESI.

Objectives

- Develop a composite surficial mineral map, showing ferric iron, ferrous iron, clays and carbonates.
- Derive an NDVI, showing therCelative condition of vegetation.
- Derive a dNDVI, showing the occurrence of cheatgrass in the WLCI study area.

Study Area

The extent of the study area covers the entire WLCI study area including the expansion in 2009 into Carbon County, Wyo. (fig. 1).

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[1] DESI (Detection of Early Season Invasives) software (*http://pubs.usgs.gov/of/2010/1302/*) is comprised of programs written in Interactive Data Language (IDL) that run within the ENVI (ENvironment for Visualizing Images) image-processing system (ITT Visual Information Solutions, 2009).

[2] An NDVI (normalized difference vegetation index) indicates whether or not an observed target contains live green vegetation. A differenced NDVI (dNDVI) is the "difference" between NDVIs produced from imagery obtained on different dates. Because cheatgrass in southwestern Wyoming is among the first plants to green up in spring and among the first to senesce (by mid-summer), using DESI to compare NDVIs for early spring and mid-summer produces a map of probable cheatgrass occurrence.

Work Accomplished in 2011 and Findings

Preliminary NDVI and dNDVI analyses were conducted and initial maps were produced showing the probability of the occurrence of cheatgrass. Maps were field checked for occurrence of cheatgrass and the maps were refined for accuracy, and it was found that original map products showing cheatgrass underestimated its occurrence. The algorithm parameters were subsequently adjusted to increase accuracy of the maps.

Products Completed in FY2011

- McDougal, R., Holloway, J., Schmidt, T., Stillings, L., Tuttle, M., and Blecker, S., 2011, Development of Assessment Methods in Support of U.S. Geological Survey Integrated Science—Wyoming Landscape Conservation Initiative: Cheyenne, Wyo., presented to the WCLI Executive Committee [presented by R. McDougal].

Work Planned for FY2012

Work in FY2012 will entail completing the Landsat-derived maps of vegetation and mineralogy.

Developing a Soil-Quality Index

Status

Ongoing

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Scope and Approaches

The severe disturbance that surface mining often causes has the potential to drastically alter a soil's physical, chemical, and biological properties (Insam and Domsch, 1988). In particular, metals associated with mining deposits present obstacles to ecosystem recovery (Nielsen and Winding, 2002), as their residence time in soils can be quite extensive (Brookes, 1995). Quantifying soil quality can be useful for evaluating the impact of such disturbances and can improve the understanding of the mechanisms behind ecosystem processes. Definitions of soil quality generally involve soil function [for example, a soil's ability to support vegetative diversity and biomass or to sustain itself through nutrient cycling (Doran and Parkin, 1994)]. SQIs are generally composed of biological (and sometimes physicochemical) parameters that reduce a system's complexity to a metric that indicates the soil's ability to carry out one or more functions (Papendick and Parr, 1992; Halvorson and others, 1996).

Simple ratios, such as the metabolic quotient, qCO_2 (quantity of mineralized substrate/unit of microbial biomass carbon/unit of time) and enzyme activity/total carbon, are generally too simplistic and often difficult to interpret (Gil-Sotres and others, 2005); thus, many SQIs combine these parameters with other microbial indicators, such as organic matter (TOC and TN) and microbial activity. Specifically, estimates of carbon and nitrogen mineralization, respiration, and enzyme activity (assays of enzymes, such as arylsulfatase and phosphatase, are recommended in other papers on soil quality indicators) can be very useful in evaluating soil recovery in surface-mining situations (Insam and Domsch, 1988; Mummey and others, 2002). Identifying sensitive soil-quality indicators in mineralized terrane (terrain), therefore, and incorporating them into an SQI, could aid long-term monitoring of reclamation efforts in areas impacted by surface mining.

The work of this task is to extend ongoing efforts to develop an SQI that represents a soil ecosystem's ability to incorporate organic carbon and nitrogen, as many SQIs combine many different data types, including TN and TOC, into one metric. Methods include sampling field sites of varying climate, vegetation, and trace metal chemistry that have been impacted by mining (Blecker and others, 2010). The first step entails identifying the microbial indicator variables that correlate with soil organic carbon and nitrogen for a variety of ecosystems and types of geological mineralization. Soil samples were collected at a few WLCI sites during spring 2010. Meanwhile, work to develop an SQI from existing chemical data (without microbial indicator variables) continued; the SQI will be a cumulative metric representing diverse indicator data such as pH, salt content, nutrient content, and concentration of metals. Although this number will demonstrate the data variability across the WLCI region, it will not provide any information on soil or ecosystem function. The addition of the microbial indicator variables to the SQI calculation will greatly improve the utility of the SQI and help to integrate scientific and management objectives.

Objective

- Produce an SQI for the WLCI study area by using indicators—such as mineralization, disturbance, climate differences, geology, topography, and ecologic region—that distinguish various parts of the landscape.

Study Area

Activities associated with this work are located across the WLCI region; Figure 10 indicates where sampling occurred in FY2010.

Work Accomplished in 2011 and Findings

Field work planned for FY2011 was postponed due to scheduling conflicts. Additional soil sampling will be completed in FY 2012.

Products Completed in FY2011

- Products will be forthcoming in FY2012.

Work Planned for FY2012

In FY2012, we will draft a final report containing a soil sample database, interpretation of the soil analyses, and a soil-quality index map. This will be published as either a USGS Open-File Report or Scientific Investigations Report.

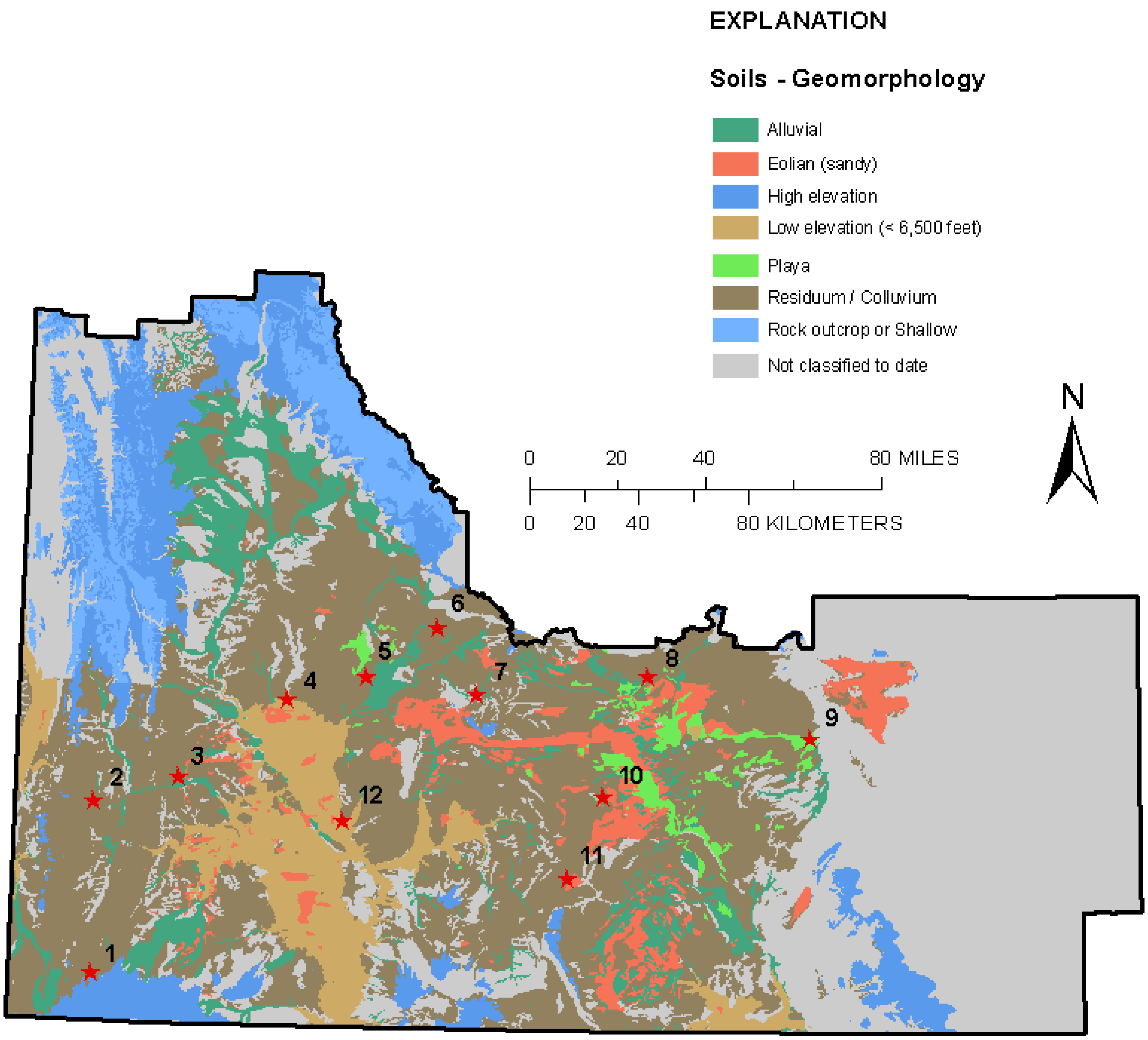

Figure 10. Locations (red stars) where soil and vegetation samples were collected in FY2010.

Assessing Rancher Perceptions of Energy Development in Southwest Wyoming

Status

Completed

Contact

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Scope and Approaches

Energy and other forms of development can have significant effects on ranching and farming communities. Jobes (1987) characterizes these communities as small, isolated, stable, interdependent, and independent of outsiders, and argues that energy development can devastate such communities because the informal institutions that hold them together (for example, community meetings) are disrupted and replaced by formal institutions. Many people may begin to feel like outsiders in their own communities as the population grows and changes rapidly. This causes some people to feel less satisfaction with their lives and move away. The lack of current research on how energy development affects ranching communities provides an opportunity for further study. This WLCI study evaluates perceptions about these and other issues facing ranchers to get a more complete picture of how ranchers perceive the effects of energy development.

Through an agreement between the WDA and the USGS, a study evaluating ranchers' perceptions of energy development has been initiated. This entails a WDA survey with the USGS serving as consultant in survey design and construction based on the needs and issues provided by the WDA. Following the standard survey methodology set forth by Salant and Dillman (1994), surveys were mailed to randomly selected ranchers operating in counties encompassed by the WLCI area (Lincoln, Sublette, Uinta, Sweetwater, and Carbon Counties) and the portion of Fremont County that lies within the WLCI boundary (see fig. 1).

Objectives

- Develop an understanding of how ranchers view the underlying issues and conflicts related to energy development. Address whether or not the issues and conflicts vary with different energy types.
- Develop an understanding of how ranchers view their social well-being in the midst of energy development, including what they believe they have gained or lost.
- Identify how ranchers frame issues/impacts on federal lands differently than on private lands.
- Identify ranchers' perceptions toward policy-making, both at a local and national level, including how ranchers perceive the science on which policies are based.

Study Area

The survey was designed to provide adequate representation of ranchers throughout the entire WLCI region (fig. 1).

Work Accomplished in 2011 and Findings

The report was reviewed and revisions are nearly completed.

Products Completed in FY2011

- Lyon, K., and Montag, J.M, 2012, in review, Ranching community perceptions toward energy development in Southwest Wyoming: U.S. Geological Survey, Open-File Report.

Work Planned for FY2012

Although this work activity officially ended in FY2011, in FY2012 the final report will be published, a fact sheet about the project will be developed, and a paper on the results will be prepared for publication in a peer-reviewed journal.

Western Energy Citation Clearinghouse

Status

New in FY2011

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Scope and Approaches

Addressing concerns regarding the types and development of energy, and a secure energy future, are high priorities for the current administration, particularly the DOI. The BLM and other land management agencies within the DOI are charged with balancing energy development with other land uses and values. Such decisions are often controversial and complex, necessitating easy access to useful data, literature, and other informative resources that facilitate better understanding of the effects of energy development.

Although there are several valuable on-line resources that provide information about energy development and associated effects, they are distributed across numerous websites and often focused on only a few key components (for example, oil and gas literature; wind energy and wildlife). Development of a web-based energy-resource database comprising pertinent, foundational, up-to-date references for relevant literature and links to on-line resources and research efforts would provide USGS researchers and collaborators an efficient mechanism for accessing the latest data and research references.

To address this need, the USGS has developed the Western Energy Citation Clearinghouse (WECC). The approach has been to make this a “living” database in that it will be reviewed and updated continuously to provide the most current resources and information. Through extensive collaboration across disciplines and thorough literature searches, fundamental and current literature is identified for inclusion in the WECC. This effort will not duplicate existing on-line resources, such as the Wind Energy and Wildlife literature database developed at Colorado State University’s Natural Resources Ecology Laboratory. Rather, the WECC is a complementary reference clearinghouse that facilitates efficient access to such on-line resources and additional literature references.

Using a variety of applicable terms and term combinations (table 1), building the database has entailed searching citation databases, specifically CSA Illumina, GeoRef, GeoScienceWorld, GreenFILE, Groundwater & Soil Contamination Database, ScienceDirect, Scopus, Web of Knowledge, and Water Resources Abstracts. Through the USGS library’s “search the literature” system, numerous other resources also have been searched (table 2). Various online resources also have been searched, including

- the Energy Citation Database (http://www.osti.gov/energycitations/index.jsp);

- the Wyoming Energy Resources Information Clearinghouse (http://www.weric.info/documents.htm);
- Energy Science and Technology Virtual Library (http://www.osti.gov/energyfiles/about.html);
- International Energy Agency publications (http://www.iea.org/publications/index.asp);
- Knowledge Management Database Portal (http://www.netl.doe.gov/KMD/);
- Intermountain Oil and Gas BMP Project (http://www.oilandgasbmps.org/bibliosearch.php); and
- Wind-Wildlife Impacts Literature Database (WILD) (http://www.nrel.gov/wind/wild.html).

Table 1. List of search terms used when searching resources for research publications on energy development.

Search terms used		
Attitudes	Groundwater contamination	Petroleum development
Biomass	Hydroelectric	Policy
Coal	Hydropower	Renewable energy
Coal production	Impacts	Social impacts
Community effects	Landscape	Solar energy
Ecological impacts	Mining	Trona
Economic impacts	Natural gas	Uranium
Ecosystem	Natural gas development	Uranium production
Energy	Nuclear energy	Water and groundwater
Energy development	Oil	Wildlife
Environmental impacts	Oil development	Wind
Geothermal	Petroleum	Wind power

Finally, specific journal websites believed to publish applicable literature also have been searched. Literature searches will be ongoing to find new citations and add them to the WECC.

Objectives

- Develop a Web-based database of key literature and on-line resources relevant to energy, energy development, and associated effects on the landscape, which can be queried easily and serve as a "clearinghouse" to facilitate land managers, decisionmakers, scientists, and others who need ready access to such resources.

Study Area

There is no real spatial component to this work, thus a study map is not applicable. The WECC, however, will emphasize references relevant to energy, energy development, and the effects of energy development in the West.

Work Accomplished in 2011 and Findings

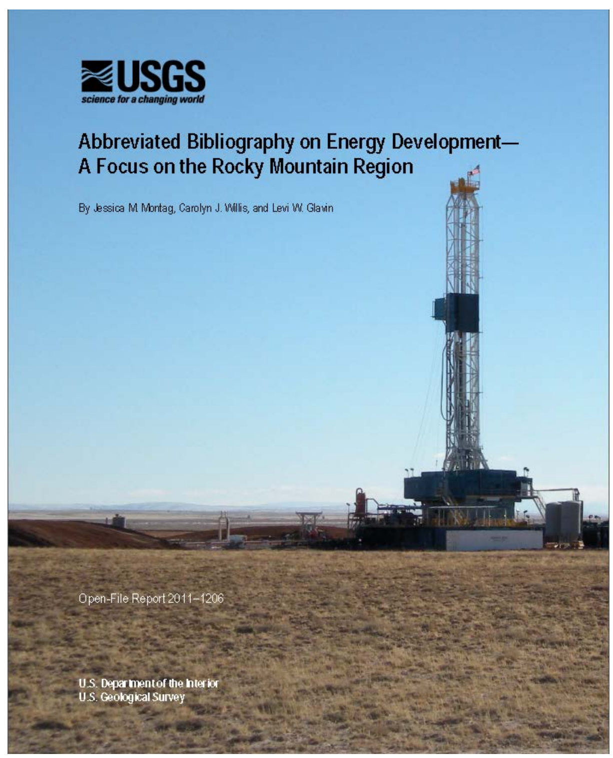
In FY2011, the initial database of more than 3000 references was developed to serve as a foundation for the WECC. Website developers have created an initial wireframe for making the WECC accessible on the Web.

Table 2. Resources searched with search terms listed in Table 1.

Resources searched	
Academic Search Premier	JSTOR Biological Sciences Collection
Access Science	JSTOR Ecology and Botany Collection
American Chemical Society Web Edition	JSTOR Health and General Science Collection
American Fisheries Society	JSTOR Life Sciences Collection
American Institute of Physics Publications	Lyell Collection
American Statistical Association Publication	MasterFile Premier
Aqualine	Mining Communications Online Journals
ArticleFirst	Nature Journals Online
ASCE Research Library	NetLibrary eBooks
ASTM Journals	Open J-Gate
BioOne Abstracts and Indexes	Oxford Journals
BioOne	PION Journals
Birds of North America Online	Royal Society Publications
Cambridge Journals Online	SAGE Premier 2007
Columbia Gazetteer of the World	Science and Technology
CSIRO Publishing Journals	Science Magazine
Current Contents Connect	SEG Research Collection
Directory of Open Access Journals	SpringerLink Contemporary (1997–Present)
Electronic Books	University of Chicago Press Journals
Electronic Collections Online	USGS Online Catalog
Environment Complete	Wiley-Blackwell Full Collection
GeoRef in Process	WorldCat (OCLC Online Union Catalog)
GeoScienceWorld	WorldCat Dissertations and Theses
Inter-Research	

Products Completed in FY2011

- Montag, J.M., Willis, C.J., and Glavin, L.W., 2011, Abbreviated bibliography on energy development—A focus on the Rocky Mountain Region: U.S. Geological Survey Open-File Report 2011–1206, 316 p. (Cover page shown to the right.)



Work Planned for FY2012

In FY2012, we will develop the Web-program component of the WECC, including getting it running and online.

Assessing Wildlife Vulnerability to Energy Development

Status

Ongoing

Contacts

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Scope and Approaches

The Assessing Wildlife Vulnerability to Energy Development research task was established to help prioritize the management, monitoring, and research needs of Wyoming's SGCN, which are listed in Wyoming's Comprehensive Wildlife Conservation Strategy (Wyoming Game and Fish Department, 2010). The primary goal is to focus conservation attention on the most vulnerable species—before they become imperiled—by assessing relative risks from energy development-related disturbances, based on geospatial estimates of exposure and evaluation of biological sensitivities. The first step in this multi-year process was to develop a Wyoming-specific range map for terrestrial vertebrate SGCN, which was completed in FY2009. The second step, completed in FY2010, was to develop detailed distribution models for all species that refine where they are most likely to occur within their range. The next step (currently ongoing) is to develop maps of current and potential future energy development and assess how that development coincides with the predicted distribution for each species.

Background on data collection and distribution model preparation can be found in the 2011 WLCI annual report (Bowen, Aldridge, Anderson, Assal, and others, 2011). To estimate spatially-explicit oil and gas development potential across Wyoming, we refined a previously published forecast for the intermountain west (Copeland and others, 2009) by incorporating detailed maps of current development from the Wyoming Oil and Gas Conservation Commission (2010) and higher-resolution data on bedrock geology and distance from geologic faults from the Wyoming State Geological Survey (Love and others, 2010). We 'built out' the Wyoming landscape by seeding it with oil and gas wells according to the underlying oil and gas potential and 20-year Reasonable and Foreseeable Development Scenarios (RFDS) from resource management plans of BLM field offices (for example, Stilwell and Crockett 2004), placing wells preferentially in areas with high potential values and minimum restrictions, up to the densities allowed by current stipulations. We forecasted the potential for wind energy development developing a predictive model using Maximum Entropy methods (Phillips and others, 2006) with existing wind turbines as the response variable and wind power class, slope, and topographic position as the predictor variables. The resulting map of wind resource potential was then adjusted to reflect expected short-term development and legal or operational constraints, such as development limitations on protected lands.

The built-out maps were used to generate energy footprints for Wyoming, wherein maximal disturbance occurred at well and turbine sites and decayed to a negligible amount with increasing distance. We chose 1 km as a reasonable effect distance (Benitez-Lopez and others, 2010) and created an exposure function that logarithmically decayed to 1 percent of maximal exposure at that distance. Applying this function to well locations in our build-out maps resulted in a continuous, statewide surface with values ranging from 1 (complete exposure at a well or turbine location) to 0 (negligible exposure when far from the nearest well or turbine). To calculate an index of exposure for each species, we took the product of this exposure surface and habitat suitability from species distribution models and summed the resulting values across Wyoming. This yielded a weighted average of the species habitat suitability, where a logarithmic distance to development is the weighting factor. Thus, as the exposure index for a species approaches the theoretical limit of 1.0, an increasingly larger proportion of suitable habitat for that species *s* occurs proximate to development.

Objectives

- Develop range maps and distribution models for Wyoming's terrestrial vertebrate SGCN.
- Develop maps of current and potential future energy development (that is, oil, gas and wind-power development) across Wyoming.
- Assess the potential exposure of each Wyoming's terrestrial vertebrate SGCN to energy development.
- Assess the biological sensitivity to disturbance of highly exposed terrestrial vertebrate SGCN.

Study Area

Activities associated with this work apply to all of Wyoming, encompassing the entire WLCI region (fig. 1).

Work Accomplished in 2011 and Findings

In FY2011, we completed mapping the energy footprints, and we conducted an analysis for assessing the degree to which habitat for each terrestrial vertebrate SGCN was exposed to energy development. Petroleum and wind footprints are largely non-overlapping, resulting in spatially extensive disturbance. Current and expected future exposure due to wind power turbines was generally far smaller than exposure due to petroleum infrastructure. However, for 14 species, wind power represented more than half the calculated exposure to energy development.

Species varied greatly in their total exposure to development, ranging from the montane obligate brown-capped rosy finch (*Leucosticte australis;* Exposure Index (*EI*) less than 0.001) and fisher (*Martes pennanti*; *EI* less than 0.001) to the great plains toad (*Anaxyrus cognatus; EI* = 0.278) inhabiting prairies and shrublands in northeastern Wyoming. Among the most exposed species (fig. 11) are pygmy rabbit (*Brachylagus idahoensis*), Wyoming pocket gopher (*Thomomys clusius*), and black-footed ferret (*Mustela nigripes*) because they are restricted in distribution, their exposure is high, and future development is likely to result in large increases in their exposure. Great plains toad, Rocky Mountain toad (*Anaxyrus woodhousii woodhousii*), and black-tailed prairie dog (*Cynomys ludovicianus*) are also of high concern given relatively large exposure values. All of these species are substantially more exposed to development than greater sage grouse, which was the 17th most exposed species and whose populations have been demonstrably impacted by energy development.

A benefit of our comprehensive approach to examining exposure is a more definitive assessment of information gaps. As a result of our modeling, we identified 23 species that had relatively low validation statistics and/or high variability in their Exposure Index. Assessment of exposure for these species would benefit greatly from additional data to inform distribution models, including collection of additional occurrence data and/or development of improved environmental layers targeted toward species-specific biological constraints. Of these 'data deficient' species, additional information is most important for those that have potentially high exposure, such as silky pocket mouse (*Perognathus flavus*) and black-footed ferret, which were among the top ten most exposed species in our analysis.

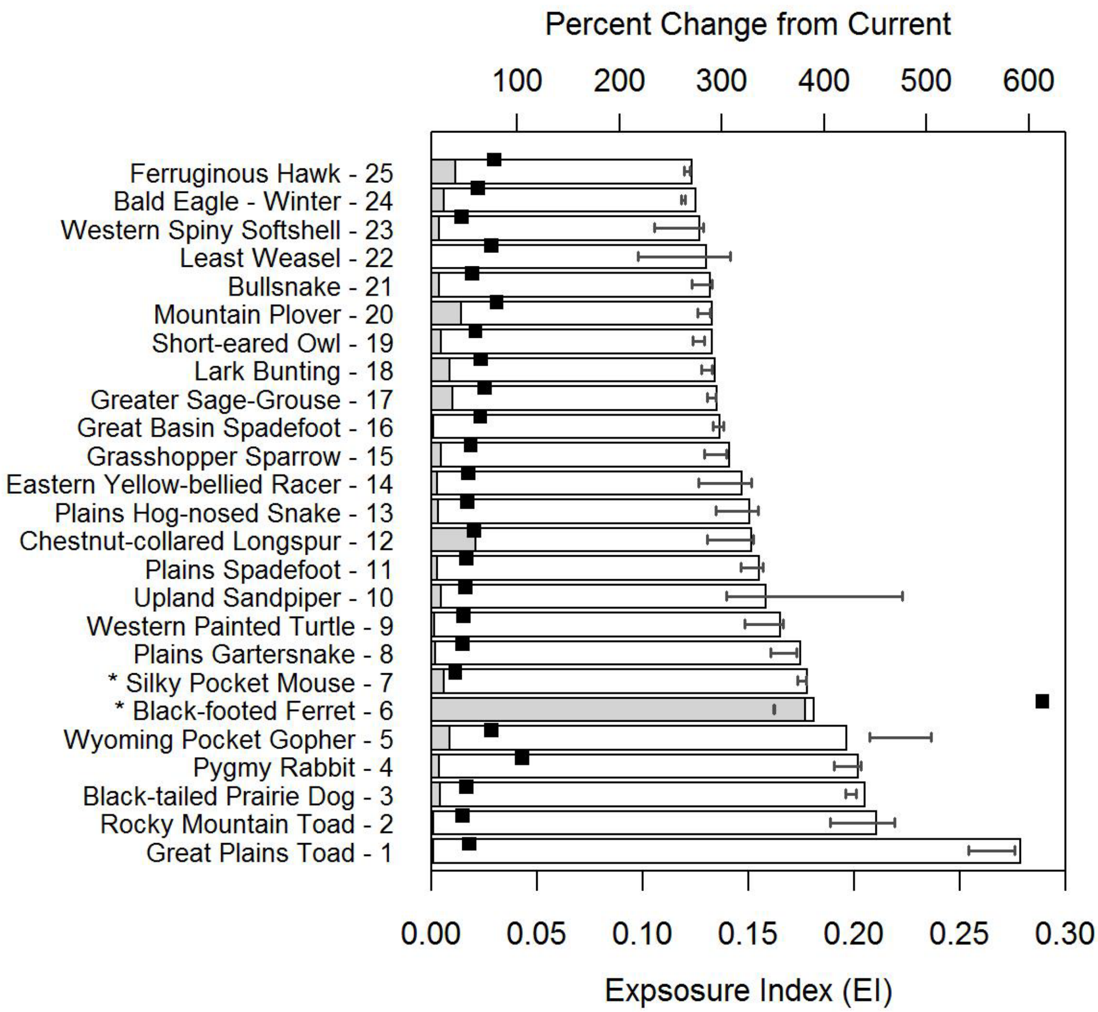

Figure 11. Exposure indices and fractional increase in exposure from current levels for the 25 most exposed species of greatest conservation need. Gray bars indicate the proportion of exposure due to wind-power development and hollow bars indicated the proportion due to oil and gas development. Error bars represent the range of total exposure obtained based on cross validated distribution models. Asterisks identify species with poor validation statistics.

Products Completed in FY2011

- Keinath, D., Copeland, H., Posewizc, A., Kauffman, M., Doak, D., and Andersen, M., 2011, Assessing the relative exposure to development for Wyoming's species of greatest conservation need: Jackson Hole, Wyoming, the Annual Conference of the Wyoming Chapter of The Wildlife Society, December 6–9, 2011. [Presentation]
- Keinath, D., Copeland, H., Posewizc, A., Kauffman, M., Doak, D., and Andersen, M., 2011, Assessing the relative exposure to development for Wyoming's species of greatest conservation need: Laramie, Wyoming, University of Wyoming, Department of Zoology and Physiology, January 30, 2012. [Presentation]

- Keinath, D., Copeland, H., Posewizc, A., Kauffman, M., Doak, D., and Andersen, M., (in prep.) Assessing landscape-scale exposure of wildlife resources to domestic energy activities: Ecological Applications.

Work Planned for FY2012

In FY2012, the results of the exposure analysis summarized in this report will be published. Subsequently, a biological sensitivity analysis will be conducted to help inform which of the most highly exposed species (for example, those in Figure 11) are likely to be impacted by development.

Climate Change and Simulating Potential Future Vegetation

Status

Ongoing

Contact

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Scope and Approaches

Projected future climate changes are predicted to affect the wildlife and habitats of southwestern Wyoming. Understanding these potential effects and how they may interact with future land-use changes is important for anticipating the impacts of climate change on the region's ecosystems. Potential future climate change simulations have been downscaled for the WLCI study area. These climate data are being used as input data for other modeling efforts, such as simulating future vegetation changes for the region, and will help to identify the potential effects of future climate change on the species and landscapes of southwestern Wyoming. The simulated climate and vegetation data produced by this research also will contribute to projecting the cumulative effects of land uses (for example, energy development and livestock grazing) and climate change on the region's species and landscapes.

Future climate simulations from five coupled atmosphere-ocean general circulation models (AOGCMs) produced under two different future greenhouse gas emissions scenarios have been downscaled to a 30-arc-second (approximately 1 km^2) grid of the study area. The AOGCM simulations were produced as part of the World Climate Research Programme's Coupled Model Intercomparison Project phase 3 multi-model dataset (Meehl and others, 2007). These simulations were used in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Solomon and others, 2007). By using climate data from multiple AOGCMs simulated under multiple emissions scenarios, a range of projected future climate changes will be captured for the WLCI region.

As part of this work, the downscaled climate data are being used to simulate potential future vegetation changes for southwestern Wyoming using Lund-Potsdam-Jena LPJ), a dynamic global vegetation model (Sitch and others, 2003). These vegetation simulations will provide a first approximation of potential future habitat changes across the WLCI region.

Objectives

- Downscale potential future climate change simulations for the WLCI study area.
- Use the downscaled climate data to model the potential impacts of climate change on WLCI species and habitats.

- Evaluate potential future changes in climate, vegetation, and habitats within the WLCI study area.

Study Area

The study area, which extends beyond the WLCI region to encompass all of Wyoming and portions of surrounding states (fig. 12), was chosen for the climate and vegetation analyses because potential future changes in climate and vegetation across this larger area may have significant implications for species and landscapes within the WLCI study area.

Work Accomplished in 2011 and Findings

The downscaled projected future bioclimate data for the study area (for example, growing degree days, seasonal moisture indices) were completed in FY2011 and self-documenting data files were developed for publication of the climate and bioclimate data. Simulations of potential future vegetation changes for the study area and initial analyses of these data also were completed.

Mean annual temperatures are projected to increase across the WLCI study area for 2070–2099 (30-year mean) under all ten simulations of future climate examined in this study as compared to a 1961-1990 (30-year mean) base period. Growing degree days are also simulated to increase by 2070–2099 (30-year mean), indicating that the annual growing season for the WLCI study area would be longer under the projected climate changes we examined.

Projected mean annual precipitation changes for the study area are more variable. Some climate models simulate increases in annual precipitation for 2070–2099 (30-year mean) while other models simulate decreases for the same time period. Analyses examining the seasonal changes in precipitation are currently underway to better estimate the potential effects of potential future precipitation changes on WLCI ecosystems.

Products Completed in FY2011

- Shafer, S., Projected future vegetation changes for the WLCI study area: Data and documentation (draft).

Work Planned for FY2012

Publication of datasets containing the simulated climate, bioclimate, and vegetation changes for the study area will be released along with documentation describing the data and analyses.

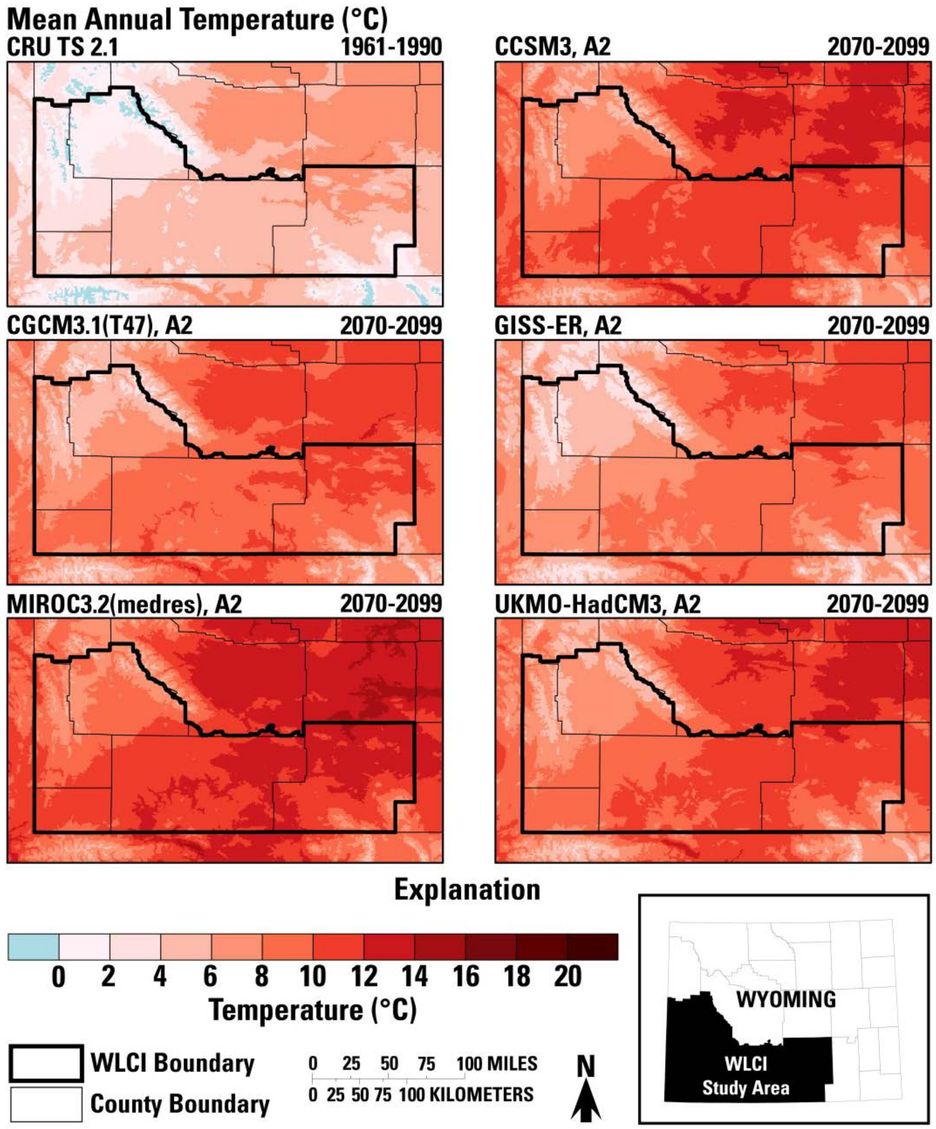

Figure 12. Mean annual temperature in degrees Celcius (°C) for 1961–1990 (30-year mean) calculated from the University of East Anglia's Climatic Research Unit (CRU) TS 2.1 dataset (Mitchell and Jones, 2005) and 2070–2099 (30-year mean) calculated from data simulated by CCSM3 (Collins and others, 2006), CGCM3.1(T47) (Scinocca and others, 2008), GISS-ER (Schmidt and others, 2006), MIROC3.2 (medres) (K-1 Developers, 2004), and UKMO-HadCM3 (Gordon and others, 2000) coupled atmosphere-ocean general circulation models, using the A2 greenhouse gases emissions scenario (Nakicenovic and others, 2000). The CRU TS 2.1 data were downscaled to a 30-arc-second grid of the study area using an interpolation method developed by P.J. Bartlein (Dept. of Geography, University of Oregon, written commun., 2009).

Developing Regional Curves Relating Bankfull-Channel Geometry and Discharge to Drainage Area for the Rocky Mountain Hydrologic Region in Wyoming

Status

Ongoing; in past years, this study was line-itemed separately in the WLCI budget, but for FY2011 it was combined with other long-term monitoring studies. For continuity, however, we retain the original position of this work under the Baseline Assessment.

Contact

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Scope and Approaches

This entails developing regional curves that relate bankfull channel geometry and river discharge to drainage area, which is important for assessing baseline run-off conditions and the extent to which energy development alters these variables in the WLCI region. The term, bankfull, references the stage of streamflow during which a given stream completely fills its channel. Regional curves are statistical models (one-variable, ordinary least-squares regressions) that relate bankfull discharge, bankfull cross-sectional area, bankfull width, and bankfull mean depth to drainage area in settings that are expected to have similar runoff characteristics. Equations describing the regional curves can be used to estimate the discharge and dimensions of the bankfull channel when drainage area of the watershed is known. These equations are useful for supporting the identification of bankfull channels in areas with similar runoff characteristics. Regional curves are also used to determine channel departure from reference conditions and stream restoration using Natural Channel Design techniques (Rosgen, 2006).

Numerous state agencies (WDEQ, WGFD, and Wyoming Department of Transportation) have expressed needs for regional curves related to bankfull flows for a number of applications, such as structure design and placement; flow regulation; habitat monitoring and assessment; and designing restoration or habitat-enhancement projects. In FY2010, the WDEQ funded the development of regional curves for a few selected watersheds in Wyoming. Although some work already has been completed on the upper Green River (Leopold, 1994) and the Upper Little Snake River (D.L. Rosgen, Ph.D., Principal Hydrologist, Wildland Hydrology, Inc., Fort Collins, Colorado, unpubl. channel geometry data for miscellaneous sites in the Upper Little Snake River, 2009), there are watersheds in the Atlantic Rim area and in the majority of the Green River Basin for which regional curves have not been developed and where they are needed due to the imminent development of wind and other energy resources. Additional funding for this work would allow the USGS to develop bankfull curves for the eastern WLCI region in a timeframe that is critical to WLCI partners, and it would provide a broader body of work for a larger portion of Wyoming. The BLM and the WGFD implemented stream assessments in 2010 that will benefit from this stream classification and regional curve development.

General guidelines and recommendations for conducting field reconnaissance and surveys at streamflow-gaging stations are described in several sources (Harrelson and others, 1994; Leopold, 1994; U.S. Department of Agriculture, 1995; McCandless and Everett, 2002; Powell and others, 2003; Rosgen 2006). Field-survey procedures to be completed at each streamflow-gaging station are described as follows:

- survey longitudinal profile;
- survey at least two representative riffle cross-sections; and

- conduct bed-material (pebble) counts for the reach and at one of the representative riffle cross-sections in accordance with the methodology described by Rosgen (1996) and Harrelson and others (1994); each pebble count should consist of at least 100 particles.

The RiverMorph (version 4.3.0, RiverMorph LLC, 2001–07) stream morphology computer program was used to compile and summarize survey data.

Objectives

- The overall objective of this work is to develop regional curves relating bankfull-channel geometry and discharge to drainage area for the state of Wyoming; the WLCI-specific objective is to develop regional curves for the WLCI region.

Study Area

The Rocky Mountain Hydrologic Region encompasses most of the mountainous areas of Wyoming, including all of the ranges in northwestern Wyoming, the Bighorn Mountains, the northern Laramie Mountains, and the Uinta Mountains, as well as those encompassed by the WLCI region: the Wind River Range, the Sierra Madre, the Medicine Bow Mountains, and the Wyoming Range. These medium- to high-elevation ranges are mostly forested, although there are some alpine areas and open woodlands. Most of the precipitation in these ranges occurs as snow from Pacific storm fronts during the winter months. Generally, annual peak flows are caused by winter snow accumulations melting in late spring and early summer. Figure 13 shows the survey sites associated with this work that fall within the WLCI area.

Work Accomplished in 2011 and Findings

Within hydrologic regions identified by Miller (2003), active and discontinued streamflow-gaging stations covering a range of drainage area sizes were selected from a list of candidate streamflow-gaging stations that satisfy initial filtering criteria. Filtering criteria are described as follows:

- each gaging station had to have at least 10 years of streamflow record, and if the record is discontinuous, whether or not to use data collected at a station was made on a case-by-case basis;
- no more than 20 percent of the upstream watershed area is classified as urban land use (municipal, industrial and residential uses combined);
- no more than 20 percent of the streamflow at the station is subjected to regulation or diversion;
- the river or stream is wadeable; and
- a suitable length of stream reach is available to complete the field survey.

For all USGS streamflow-gaging stations identified above, data acquisition and preliminary analysis were completed as follows.

- We obtained the most recent rating table (stage-discharge relationship), and compiled corresponding 9-207 forms (Discharge Summary Notes) that include moderate to high flows.
- We tabulated (1) the station name and the USGS station number (note if active or discontinued); (2) station location (latitude-longitude, legal description); (3) years of flow record; (4) land status (if private, provide landowner name and contact number, with proper handling of Personally Identifiable Information); (5) hydrophysiographic province or region; (6) drainage area (square miles); (7) land-use category (percent urban/residential/industrial or rural); (8) estimated percentage of streamflow that is regulated; (9) average annual precipitation

(in); (10) current meter measurement locations; and (11) hydraulic slope (ft/ft; from map, and if available, field measure).

- For each gaging station, we (1) provided a brief description of site location (directions to access site, landmarks), including flood history and location and elevation of reference bench mark; (2) developed a relation of hydraulic geometry (width, mean depth, and cross-sectional area) and mean velocity versus discharge from the Form 9-207 data; (3) obtained or developed the most recent annual flood-frequency curve (Log-Pearson Type III plots) following guidelines from the "Interagency Advisory Committee on Water Data, 1982"; (4) identified the discharge for the 1.5-year recurrence interval (approximate or average return period for bankfull discharge, identified as Q1.5) and 2.3-year recurrence interval (mean annual flood, identified as Q2.3); and (5) identified width, depth, cross-sectional area and velocity associated with Q1.5 and Q2.3.

Field surveys were completed for 15 more streamflow-gaging sites throughout Wyoming, one of which (Jack Creek) was in the WLCI study area, for a total of 40 Wyoming sites (25 surveyed in FY2010, 4 of which were in the WLCI area, and 15 surveyed in FY2011, one of which was in the WLCI area; fig. 13). The report drafted in FY2010 was peer reviewed; however, since it was decided that additional sites were needed in the Sierra Madre/Medicine Bow, Absoroka, and Big Horn mountain provinces, the report was put on hold and data were collected at the additional sites. The report was updated and will be peer reviewed again in early FY2012.

Products Completed in FY2011

- Preliminary regional curves for 40 sites located throughout Wyoming (6 of which are in the WLCI area)
- Foster, K., DRAFT: Development of regional curves relating bankfull-channel geometry and discharge to drainage area for the Rocky Mountain Hydrologic Region in Wyoming: A report to the Sublette County Conservation District, Wyoming.

Work Planned for FY2012

In FY2012, the final project report will be completed.

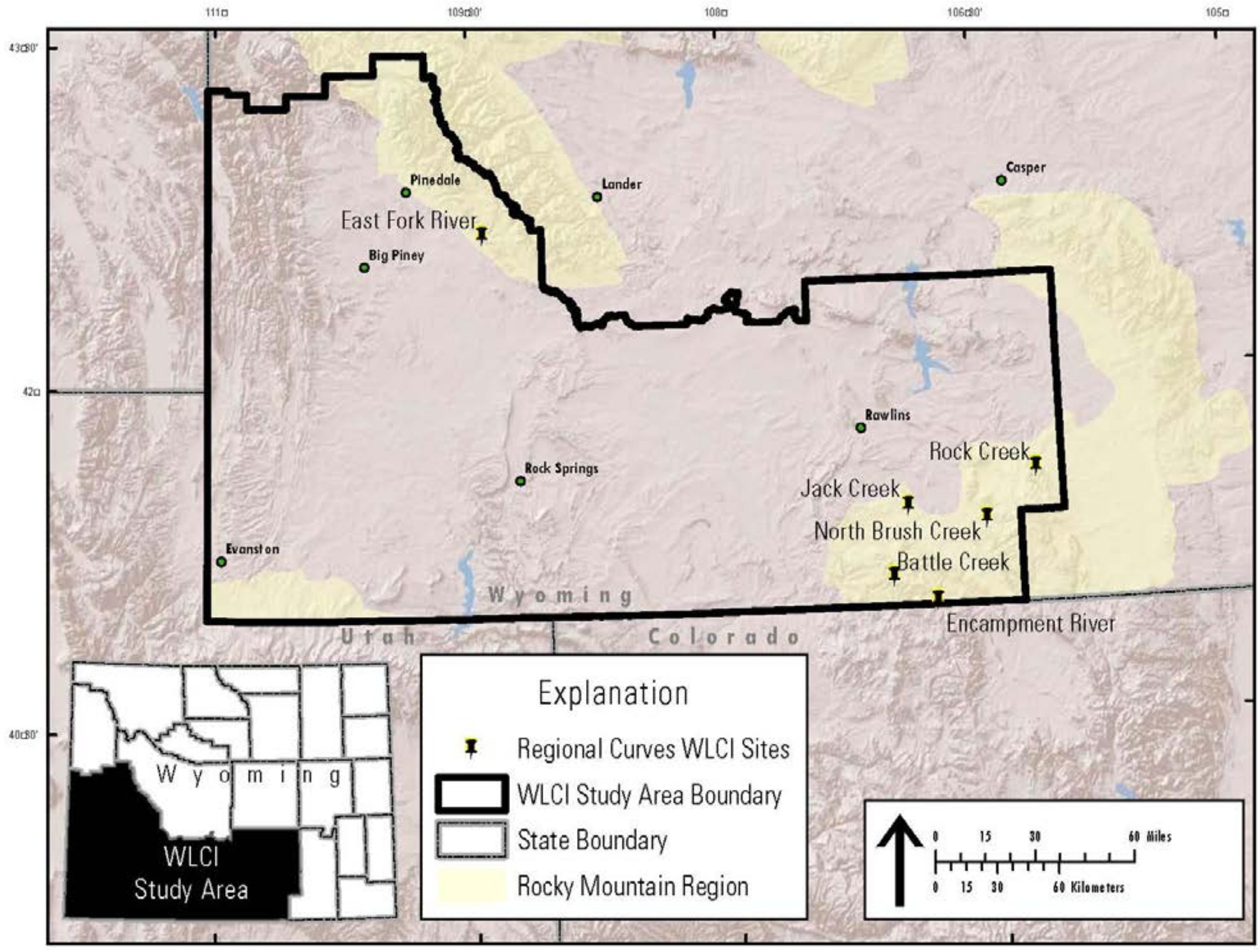

Figure 13. Locations surveyed within the Wyoming Landscape Conservation Initiative (WLCI) study area in fiscal year (FY) 2010 and FY2011 for developing regional bankfull curves.

Targeted Monitoring and Research

Three major work activities continue to comprise Targeted Monitoring and Research for the WLCI: Long-Term Monitoring, Effectiveness Monitoring, and Mechanistic Research of Wildlife. The long-term monitoring work continues to entail not only conducting long-term measurements of change, but also designing the framework (process, sampling design) and using the indicators selected for detecting changes across a large landscape characterized by significant heterogeneity. Foci for long-term monitoring studies include vegetation, birds, soil geochemistry, and water resources. The work associated with effectiveness monitoring is an outcome of the fact that Federal, State, industry, and nongovernmental organizations have been funding habitat-improvement treatments across southwest Wyoming without enough information on treatment effectiveness. A primary goal of the WLCI effort, therefore, is to assess the effectiveness of habitat treatments at individual sites and to evaluate their effectiveness in meeting landscape-level conservation goals, such as reconnecting fragmented habitats, restoring native vegetation, and controlling the spread of nonnative species. Understanding the effects of habitat treatments on wildlife use is an essential measure of individual and cumulative habitat treatments. This work is intended to help guide the design and development of future habitat treatments conducted by WLCI partners and to improve their ability to meet the objectives for WLCI landscape conservation. It also entails developing new methods for fine-scale mapping of aspen distribution associated with habitat treatments. Finally, for effective conservation planning and land management, it is not enough to simply know that a given species' population is declining, increasing, or stable; it is essential also to understand why species respond as they do. To that end, the mechanistic studies of wildlife are designed to elucidate the underlying mechanisms behind wildlife responses to habitat changes, changes in land use and climate, and mitigation and restoration projects.

Summary of FY2011 Activities for Inventory and Long-Term Monitoring

There were six Inventory and Long-term Monitoring work activities conducted in FY2011, including one new activity: (1) *Framework and Indicators for Long-Term Monitoring*; (2) *Remote Sensing for Vegetation Inventory and Monitoring*; (3) *Long-Term Monitoring of Soil Geochemistry*; (4) *Long-Term Monitoring of Surface Water and Groundwater*; (5) *Wyoming Groundwater-Quality Monitoring Network*; and (6) *New Fork River Periphyton and Bed Sediment Analysis* (new).

To date, work on the *Framework and Indicators for Long-Term Monitoring* has entailed developing and implementing long-term habitat distribution monitoring by using a protocol based on multi-scale field sampling and remote sensing. Ongoing development entails refining estimates and improving detection of changes in resource values. Focused research on wildlife distributions and wildlife responses to development informs perspectives provided by habitat maps. A compiled, interagency monitoring database is expected to help link ongoing monitoring of resources and coordinate methods, as well as house select resource condition data for collective analysis. This work provides important information required for regional planning and adaptive management. Overall, this and related projects provide the crucial data and techniques required for monitoring habitat and wildlife conditions across vast landscapes at multiple scales.

In FY2011, the work associated with *Remote Sensing for Vegetation Inventory and Monitoring* entailed using remote sensing to analyze vegetative change from 2006–2010 across the entire WLCI area. Results indicate that bare ground decreased by a total area of almost 53 km^2, herbaceous cover decreased by 63 km^2, big sagebrush (*Artemisia tridentata*) decreased by approximately 11 km^2, and Wyoming big sagebrush (*A. t. wyomingensis*) decreased by approximately 19 km^2. On the other hand, litter increased by almost 64 km^2, shrubland (including many species other than sagebrush) increased by approximately 52 km^2, and all species of sagebrush increased by approximately 9 km^2. Changes were further stratified by three potential drivers of change: approximately 6 percent of the change was due to fire, 4 percent was due to human disturbance, and 90 percent due to other effects, such as climate. The increasing trend in precipitation over the four-year period likely resulted in the bulk of measured change occurring in the other effects category, reflecting the increased greening of the area over this time frame.

Work conducted in FY2011 *Long-Term Monitoring of Soil Geochemistry* involved completing chemical analyses for the soil samples collected in 2010. The USGS laboratories analyzed the samples for aluminum (Al), calcium (Ca), iron (Fe), potassium (K), magnesium (Mg), sodium (Na), sulfur (S), titanium (Ti), silver (Ag), arsenic (As), barium (Ba), beryllium (Be), bismuth (Bi), cadmium (Cd), cerium (Ce), cobalt (Co), chromium (Cr), cesium (Cs), copper (Cu), gallium (Ga), mercury (Hg), indium (In), lanthanum (La), lithium (Li), manganese (Mn), molybdenum (Mo), niobium (Nb), nickel (Ni), phosphorus (P), lead (Pb), rubidium (Rb), antimony (Sb), scandium (Sc), selenium (Se), tin (Sn), strontium (Sr), tellurium (Te), thorium (Th), thallium (Tl), uranium (U), vanadium (V), tungsten (W), yttrium (Y), zinc (Zn), and total carbon. Colorado State University's Soil–Water–Plant Testing Laboratory analyzed the total nitrogen (N), soil pH, electrical conductivity, and sodium adsorption ratio.

A statistical summary table was prepared and exploratory data analysis was conducted, including preparation of histograms, Tukey boxplots, plots of empirical cumulative distribution function, and quantile-quantile plots.

As in FY2009 and FY2010, FY2011 work on the *Long-Term Monitoring of Surface Water and Groundwater Hydrology* project in Wyoming continued with sampling surface-water quality at three sites and groundwater levels at one site, then publishing the data online. In FY2011, surface-water quality monitoring was initiated at a fourth site, as well. All data were published on the USGS National Water Information System Website.

The FY2011 work associated with the *Wyoming Groundwater-Quality Monitoring Network* involved collecting groundwater samples from five wells (160–500 ft deep) in the Green River watershed, bringing the number of wells sampled in the WLCI region to nine over FY2010–FY2011. Groundwater samples were analyzed for a variety of natural and man-made compounds, and results were reported on the USGS water-quality Web site (*http://waterdata.usgs.gov/wy/nwis/qw/*) in real time. Overall, drinking water standards were exceeded for iron (2 samples), manganese (2 samples), total dissolved solids (2 samples), sulfate (1 sample), and aluminum (1 sample). Methane was detected in all five samples. Gasoline-range organics were detected in one sample. Diesel-range organics were not detected in any samples.

The New Fork River drainage basin is an area of active energy exploration and development in the northeastern part of the WLCI study area. To address potential effects of energy development on the basin's ecology and water quality, we initiated the new task, *New Fork River Periphyton and Bed Sediment Analysis*. This is a synoptic study of periphyton (algae), bed sediment, and water-quality that was conducted during September, 2011, in the Pinedale Anticline Project Area to characterize biological conditions in the New Fork River drainage basin. Sampling was conducted at five new sites and an existing USGS streamgage (09205000 New Fork River, near Big Piney, Wyoming). Work was conducted in cooperation with the Sublette County Conservation District and will help support their findings in the Pinedale Anticline Project area.

Details of the Inventory and Long-Term Monitoring work are provided below in the six sections that follow.

Framework and Indicators for Long-Term Monitoring

Status

Ongoing

Contacts

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Scope and Approaches

For the past several years, USGS has taken a multi-faceted approach to investigating the condition and trends in sagebrush steppe ecosystems. The report on Framework and Indicators for Long-Term Monitoring describes this multi-faceted approach. The subsequent report (Remote Sensing and Vegetation Inventory and Monitoring) describes in greater detail a major effort to develop remote-sensing protocols to monitor landscapes, specifically sagebrush habitats. These efforts build upon decades of work in semi-arid ecosystems providing focus on the cumulative impacts of expanding human activities across these landscapes. There are two main applied science goals underlying our approach, (1) understand the distribution and dynamics of habitat conditions across the landscape, and (2) understand the relationship between habitat conditions and dynamics of wildlife populations. Current efforts are focused on change detection using a remote sensing approach, and compiling an integrated, multi-agency resource monitoring database to integrate data and support coordinated analyses and future monitoring. Several parallel projects contribute to the combined effort including mapping and monitoring the cover and distribution of sagebrush and shrub steppe communities, monitoring the effects of habitat treatments on the ecosystem, and assessing the relationships between land-use and native and invasive species. To identify wildlife responses to habitat changes, several projects investigate distributions and dynamics of wildlife populations related to local and regional environmental patterns, including greater sage-grouse, songbirds, pygmy rabbits, and ungulates. Dispersed field sampling coupled with statistical modeling was used to generate projections of the distribution of common invasive plant species, including cheatgrass (figs. 14 and 15). Our research is focused on the northern sagebrush steppe in Wyoming, but mapping of species and communities often extends into Montana, Colorado, Utah and/or Idaho. The study area crosses important environmental gradients within the semi-arid basin and includes several sagebrush types and other semi-arid shrubland types (for example, *Sarcobatus* and *Atriplex* species), which have been variously impacted by industrial energy activities and resulting in a revealing multiple-variable analysis. We use a combination of remote sensing, Geographic Information Systems (GIS), and field-based, replicated sampling to generate multiple scales of data representing the distribution of shrub communities for the habitat inventory.

The USGS has designed and tested a variety of potential approaches, and current efforts are focused on coordinating designs and methods with existing efforts. Regional designs and perspectives are necessary to insure that sampling protocols and objectives provide a comprehensive, representative picture of the current status and, if continued through time, an accurate perspective on ongoing changes in the WLCI area. Current implementation by the USGS incorporates the use of multi-scale sampling by linking field measurements of vegetation to remotely sensed data (QuickBird, Landsat, and Advanced Wide Field Sensor) at several scales of resolution and extent. Ongoing work is directed at maximizing change-detection accuracy while minimizing the costs of repeated sampling across the region. The resulting maps facilitate analyses of land use and habitat changes at multiple scales, including current implementations by federal and state agencies to represent sage-grouse habitats and evaluating cumulative impacts and planning alternatives. Details of this effort are described in the following section.

Additional, ongoing efforts by the collaborative, interagency Monitoring Team, led by USGS scientists, have entailed developing database records [acquired from participating agencies, including, BLM, WGFD, WDEQ, FWS, USGS, National Park Service (NPS), WDA] that represent monitoring programs and projects, and/or former research projects, and could be implemented as monitoring frameworks. This information, and subsequent participant effort, is expected to help develop efficiency and consistency among formerly independent and therefore less effective, efforts. Implementation of selected monitoring programs is contingent upon the availability of funding.

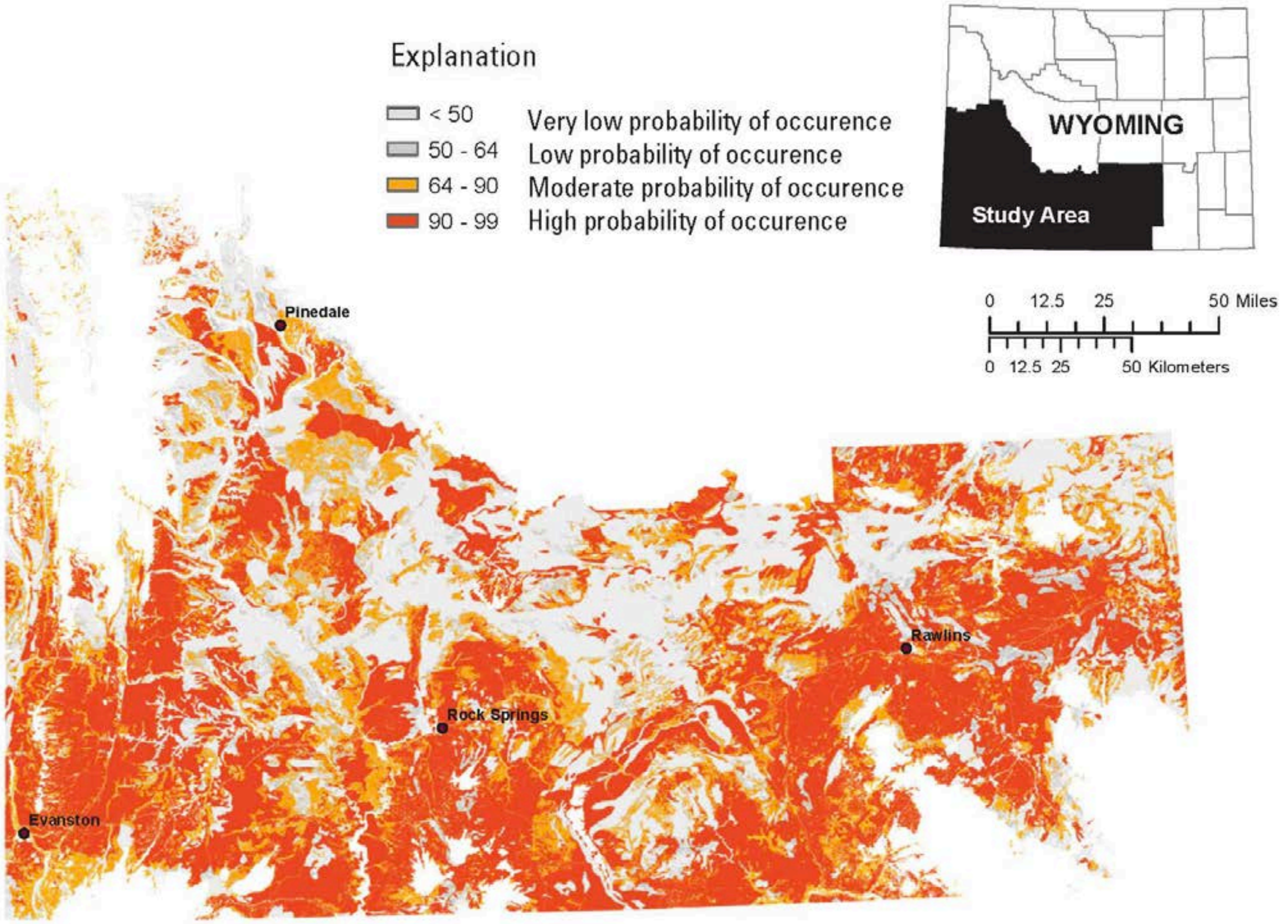

Figure 14. Example of a boosted regression tree model of the *potential distribution* of cheatgrass (*Bromus tectorum*) across the 15 million acres of southwestern Wyoming that represent the Wyoming Landscape Conservation Initiative study area. Pale gray to dark orange colors represent a range of very low to high (respectively) modeled probabilities of cheatgrass occurrence.

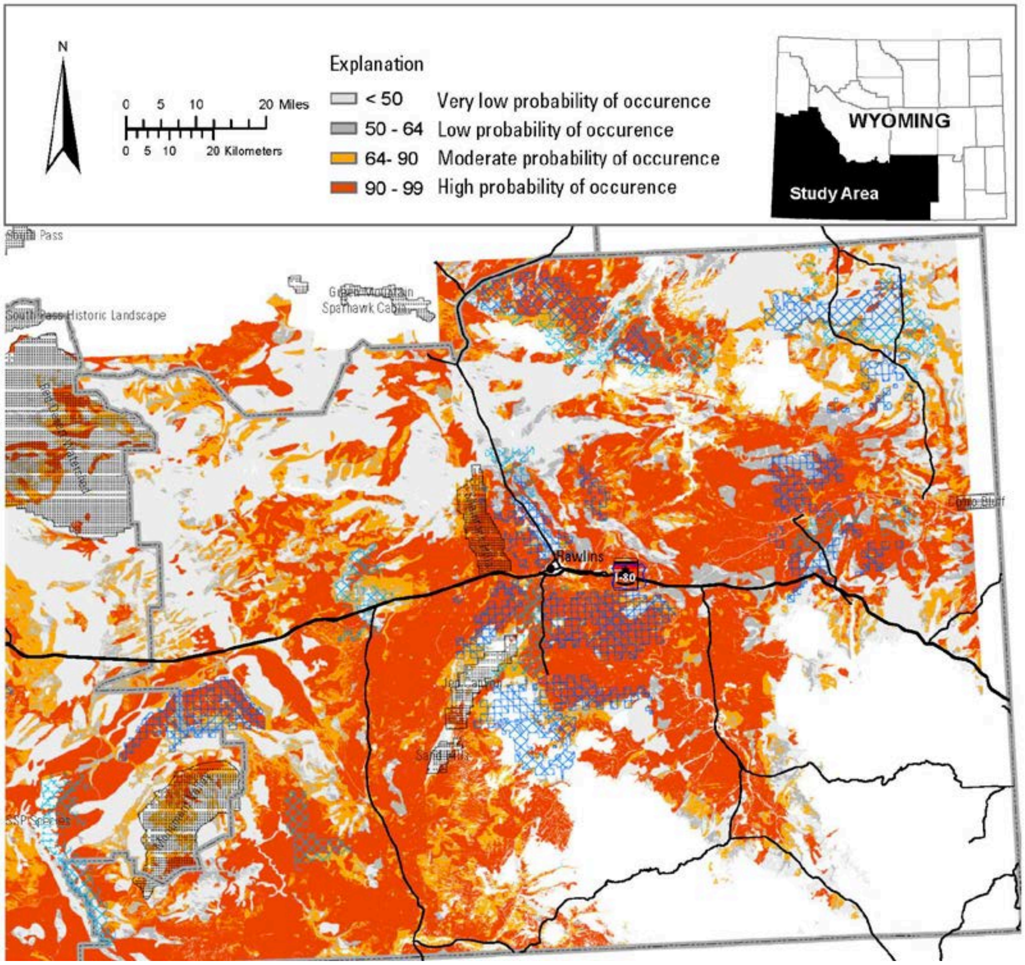

Figure 15. Closer view of the regression tree model shown in Figure 14, which shows the probability of cheatgrass invasion centered on Rawlins, Wyoming. Gray stipples delineate protected areas and blue cross-hatch identifies proposed wind-farm facilities.

Objectives

- Evaluate the success of the baseline and pilot monitoring efforts developed in prior years, analyze the sensitivity of remote sensing datasets in monitoring on-the-ground change, and analyze variability and estimate potential power for trend and status estimation in vegetation and avian data.
- Support and maintain framework of information, communication, and collaboration to support and inform measurement and monitoring of natural resources and natural diversity across the region.
- Create and compare monitoring designs based on stakeholder objectives, power analysis of pilot and ancillary data, and fiscal and time constraints. Present the alternative monitoring plans

to WLCI cooperators to obtain feedback, then refine and recommend suitable monitoring designs.
- Document approach, process, and alternatives for designs and implementation options.

Study Area

Monitoring, research, and program development associated with long-term monitoring takes place across the entire WLCI area (fig. 1). Currently only "potential sites" and "potential cooperator sites" (for example, those sampled by the Rocky Mountain Bird Observatory) have been identified as part of a common, comprehensive design. We also established several long-term monitoring sites based on four QuickBird images (scenes) as part of the USGS effort to develop remotely sensed maps for monitoring vegetation and sagebrush habitat conditions in the WLCI region (see section below on "Remote Sensing for Vegetation Inventory and Monitoring"). Additional locations and targets (for example, species of concern) are being compiled and reviewed by the interagency Monitoring Team.

Work Accomplished in 2011 and Findings

In FY2011, considerable progress was made in developing and populating the Monitoring Database. Content has been compiled from multiple cooperators, including the BLM, WGFD, WDEQ, FWS, USGS, NPS, and WDA. Based on cooperator and other stakeholder comments and input, the USGS WLCI Science Team elected to selectively expand the scope of this database to include data in addition to protocols.

Products Completed in FY2011

- Species distribution models for the ten most abundant invasive plant species occurring in a sample of 123 transects distributed across the WLCI area; maps (figs. 14 and 15) and analytical results will be prepared for publication in 2012.
- Manier, D.J., Aldridge, C.L., Anderson, P.J., Chong, G., Homer, C.G., O'Donnell, M., and Schell, S.J., 2011, Land use and habitat conditions across the southwestern Wyoming sagebrush steppe: Development impacts, management effectiveness, and the distribution of invasive plants: Natural Resources and Environmental Issues, v. 17, no. 1., article 4, at *http://digitalcommons.usu.edu/nrei/vol17/iss1/4*.

Work Planned for FY2012

In FY2012, rather than publish the fact sheet originally planned for FY2011, USGS will develop and publish a more comprehensive USGS Circular, which will discuss long-term monitoring of species and natural resource conditions in the WLCI region. We also plan to publish the invasive species distribution models. Finally, the second phase of monitoring database development will be completed, and phase three will be initiated with expanding the development of data records for regional analyses.

Remote Sensing and Vegetation Inventory and Monitoring

Status

Ongoing

Contacts

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Scope and Approaches

The focus of this work is to develop remote sensing-based protocols that allow affordable, repeatable monitoring (through spatial projections) of sagebrush habitat (Homer and others, 2009; Homer and others, 2012) of the entire WLCI region. This project (and associated remote sensing based mapping products) anchors the USGS long-term monitoring data collection and approach as described in the previous section. Based on samples collected both in the field and from remotely sensed imagery, our protocols predict the percent cover for big sagebrush, Wyoming big sagebrush, all sagebrush species, all shrubs combined, herbaceous vegetation, litter, and bare ground, as well as shrub height, across the entire WLI landscape. With repeated predictions over time, the USGS can evaluate and quantify the amount and distribution of change in the eight sagebrush habitat features. This information is critical for understanding current and future distribution and characteristics of sagebrush habitats, as well as the locations and rates of change.

Baseline predictions for the seven cover components (bare ground, herbaceous, litter, shrub, sagebrush, big sagebrush, and Wyoming big sagebrush) in the WLCI region were estimated with regression tree (RT) models that incorporated field measurements, QuickBird 2.4-m imagery, and Landsat 30-m imagery (for details, see Homer and others, 2012). The 2006 baseline predictions for the WLCI region were released as part of a statewide product. USGS used Landsat imagery from three dates (spring, summer, and fall) to perform the 2006 and 2010 change-detection analysis. The new predictions for 2010 were then compared to those predicted for 2006 to calculate the overall values in change.

Objectives

- Collect data from permanently marked QuickBird vegetation sampling sites to understand ground-based changes in vegetation patterns over time.
- Acquire and process the 2010 QuickBird and Landsat imagery required to support the large-area analysis of changes in vegetation patterns across the WLCI region.
- Publish a paper that describes the remote-sensing protocol being used for WLCI monitoring, and outline future monitoring goals.
- Publish a paper that describes the analyses of long-term trends in components of sagebrush habitat in Southwest Wyoming.
- Complete the initial analysis to quantify the 2006–2010 change in cover for bare ground, herbaceous vegetation, litter, shrub, sagebrush, big sagebrush, and Wyoming big sagebrush in the WLCI region.

Study Area

This is a nested study, with the coarse level encompassing the entire WLCI study area (fig. 1), and the secondary level (permanent vegetation-sampling plots) encompassing the extent of eight QuickBird images located primarily in sagebrush steppe habitats.

Work Accomplished in 2011 and Findings

The 2011 field sampling effort consisted of vegetation composition measurements at over 500 marked transects divided among four QuickBird footprints within WLCI (fig. 16). Spatial models were developed for trend analyses of eight sagebrush components across two QuickBird scenes for high-resolution analysis of component change between 2006–2010, and for historical change across five primary sagebrush components based on Landsat path 37/row 31 (southwestern Wyoming) for every other year from 1985–2010. Work was also completed using Landsat change vector analysis for the entire WLCI region to evaluate the amount of change for seven sagebrush habitat components between 2006 and 2010. Finally, several papers pertaining to this research and long-term monitoring of vegetation and remote sensing within the WLCI area were published, including the overall description of the methodology for these monitoring approaches (Homer and others, 2012) and the initial results of the historical monitoring of long-term vegetative change (Xian and others, 2011). An additional manuscript that characterizes potential drivers of long-term vegetative change was published (Xian and others, 2012).

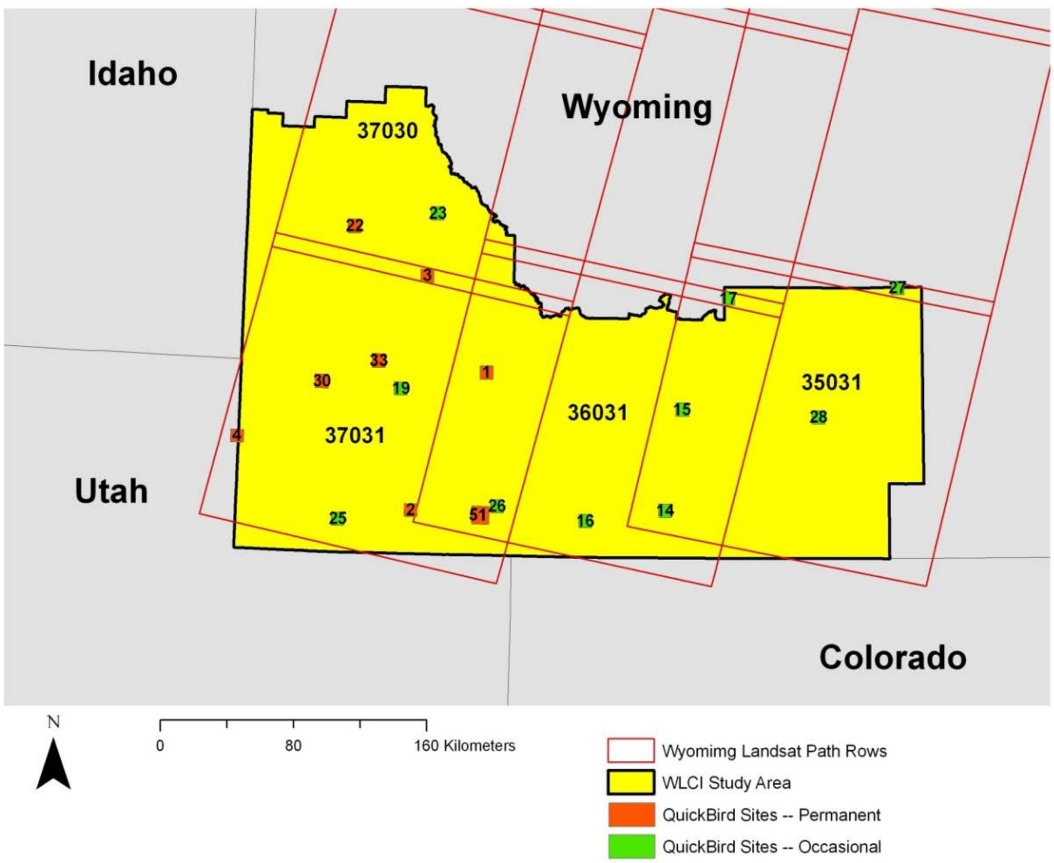

Figure 16. Footprints of Landsat and QuickBird imagery used for remotely sensed monitoring within the Wyoming Landscape Conservation Initiative (WLCI) region.

The entire WLCI area was analyzed for vegetative change using remote sensing between two time periods, 2006 and 2010. Since we calculate the proportion of each cell covered by each target component, we totaled the area covered by each component in all cells to calculate the total WLCI area covered by each component for both 2006 and 2010. The amount of area change by component from 2006−2010 is summarized in Table 3. Results are also available as a spatial file for each component showing the location, direction and magnitude of change—such as this example for bare ground (fig. 17). Results indicate bare ground decreased by total area of almost 53 km² from 2006, herbaceous cover decreased by 63 km², big sagebrush decreased by approximately 11 km², and Wyoming big sagebrush decreased by approximately 19 km². On the other hand, litter increased by almost 64 km², shrubland (including many species other than sagebrush) increased by approximately 52 km² and all other species of sagebrush increased by approximately 9 km². Changes were further stratified into three potential change drivers including fire, human induced disturbance, and all other change (typically climate variation). Approximately 6 percent of the change was due to fire, 4 percent was due to human disturbance, and 90 percent was due to other effects such as climate, for which we have previously illustrated such correlative relationships (Xian and others, 2012). The increasing precipitation trend of the last four years likely resulted in the bulk of measured change occurring in the "other" category.

Table 3. Total change in area, by habitat component, from 2006–2010 for the Wyoming Landscape Conservation Initiative region (km^2 = square kilometers)

Component	Area in 2006 (km^2)	Area in 2010 (km^2)	Change in area (km^2)	Rate of change (percent)
Bare Ground	35,200.42	35,147.56	-52.86	-0.15
Herbaceous	6,698.92	6,635.64	-63.28	-0.94
Litter	8,309.40	8,373.17	63.77	0.77
Shrub	6,060.45	6,112.81	52.36	0.86
All sagebrush	4,900.82	4,910.25	9.43	0.19
Big sagebrush	4,288.37	4,277.31	-11.06	-0.26
Wyoming sagebrush	3,267.41	3,248.18	-19.23	-0.59

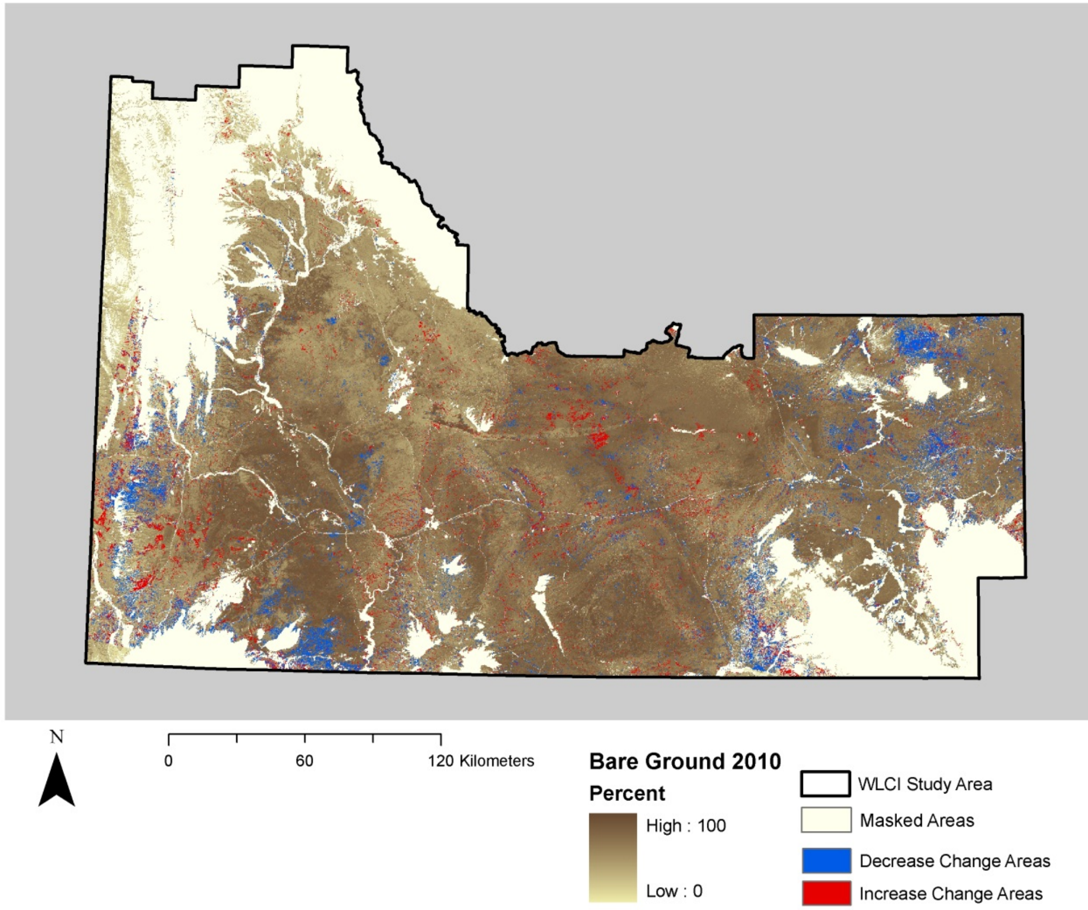

Figure 17. The spatial distribution of change in bare ground between 2006 and 2010. Red represents areas where bare ground has increased, and blue represents areas where bare ground has decreased. Map credit: Debbie Meyer, U.S. Geological Survey Earth Resources Observation and Science Center.

Products Completed in FY2010

- Resampled (field observations) of permanent monitoring plots at 260 locations distributed across four QuickBird scenes.
- Trend analysis to detect change in sagebrush components across five years of sampling in permanent plots; trend analysis incorporated field-plot data, QuickBird imagery, and Landsat imagery.
- Further development of eight spatial models based on two QuickBird scenes for the five primary sagebrush components based on Landsat path 37/row 31 (southwestern Wyoming) for every other year, beginning with 2008 back to 1985, for use in trend analyses.
- Landsat change-vector analysis for the entire WLCI region to evaluate the amount of change in seven components of sagebrush habitat between 2006 and 2010.
- Homer, C.G., Aldridge, C.L., Meyer, D.K., and Schell, S.J., 2012, Multi-scale remote sensing sagebrush characterization with regression trees over Wyoming, USA—Laying a foundation for

monitoring: International Journal of Applied Earth Observation and GeoInformation, v. 14, p. 233–244, at *http://www.sciencedirect.com/science/article/pii/S0303243411001358*.

- Xian, G., Homer, C.G., and Aldridge, C.L., 2011, Assessing long-term variations in sagebrush habitat—Characterization of spatial extents and distribution patterns using multi-temporal satellite remote sensing data: International Journal of Remote Sensing, v. 33, no. 7, p. 2034–2058.
- Xian, G., Homer, C.G., and Aldridge, C.L., 2012, Effects of land cover and regional climate variations on long-term spatiotemporal changes in sagebrush ecosystems: GIScience & Remote Sensing, v. 49, no. 3, p. 378–396, at *http://bellwether.metapress.com/content/t524kr02k7u17550/*.

Work Planned for FY2012

Field plots within long-term monitoring sites will be sampled for three QuickBird sites (8 × 8 km) to sustain the ground-monitoring effort. Landsat regression-tree models developed in 2006 and 2010 for the WLCI study area will be updated for 2011 by using change-vector analysis if sufficient Landsat imagery is available. Additional trend analysis on changes in vegetation from 2006–2011 will be completed and published. Work will continue on implementing and integrating these methods for monitoring trends in resource conditions across the WLCI region.

Long-Term Monitoring of Soil Geochemistry

Status

Ongoing

Contact

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Scope and Approaches

Establishing a geochemical baseline for soils is essential for recognizing and quantifying changes caused by either anthropogenic activities or natural processes. Having soil geochemical data generated by standardized sampling and analytical protocols across the entire WLCI study area will assist stakeholders in determining whether activities such as energy development and urbanization are releasing contaminants, particularly metals, into soils. In addition, the data can be compared to soil screening levels established by the U.S. Environmental Protection Agency (EPA) for four ecological receptors (plants, soil invertebrates, birds, and mammals) and for humans to identify portions of the study area where elevated concentrations of potentially toxic elements in soil might pose an ecological or human-health risk. To meet these needs, soil samples were collected in 2008 from 139 sites in the original WLCI study area (prior to the study area expansion in 2009) and in 2010 from an additional 36 sites in the portion of Carbon County that was added to the original study area. The 175 sites were chosen by a generalized random tessellation stratified design and represent a density of approximately one sample site per 440 km^2. This sampling scheme represents the same approach used in a continental-scale soil geochemistry program being conducted by the USGS in collaboration with the Mexican Geological Survey (Servicio Geológico Mexicano) (Smith and others, 2009, 2011).

Surface soil is considered the material with which humans and most animals come into contact most often. Geochemical information for this layer is critical for evaluating soil pathways through which potentially toxic elements may enter the bodies of both humans and animals. It is also considered to be the portion of the soil most likely to indicate the influence of human activities, such as energy development or industrialization. For these reasons, the primary sample medium for this investigation was soil sampled at a depth of 0–5 cm. At 39 of the sites sampled in 2008, additional samples were collected to represent the soil A horizon (the uppermost mineral soil) and the soil C horizon (generally the partially weathered parent material for the surface soil). The samples were analyzed in the USGS laboratories (in order of prevalence) for aluminum (Al), calcium (Ca), iron (Fe), potassium (K), magnesium (Mg), sodium (Na), sulfur (S), titanium (Ti), silver (Ag), arsenic (As), barium (Ba), beryllium (Be), bismuth (Bi), cadmium (Cd), cerium (Ce), cobalt (Co), chromium (Cr), cesium (Cs), copper (Cu), gallium (Ga), mercury (Hg), indium (In), lanthanum (La), lithium (Li), manganese (Mn), molybdenum (Mo), niobium (Nb), nickel (Ni), phosphorus (P), lead (Pb), rubidium (Rb), antimony (Sb), scandium (Sc), selenium (Se), tin (Sn), strontium (Sr), tellurium (Te), thorium (Th), thallium (Tl), uranium (U), vanadium (V), tungsten (W), yttrium (Y), zinc (Zn), total carbon, and carbonate carbon. Samples were also submitted to Colorado State University's Soil, Water, Plant Testing Laboratory for the determination of total nitrogen (N), soil pH, electrical conductivity, and sodium adsorption ratio. The complete sampling and analytical protocols, along with the dataset for the samples collected in 2008, were published by Smith and Ellefsen (2010). Data for the samples collected in 2010 were added to this report in 2011.

Objectives

- Define the natural variation of Al, Ca, Fe, K, Mg, Na, S, Ti, Ag, As, Ba, Be, Bi, Cd, Ce, Co, Cr, Cs, Cu, Ga, Hg, In, La, Li, Mn, Mo, Nb, Ni, P, Pb, Rb, Sb, Sc, Se, Sn, Sr, Te, Th, Tl, U, V, W, Y, Zn, organic carbon, N, soil pH, electrical conductivity, and sodium adsorption ratio in the WLCI study area.
- Determine the spatial distribution of the above elements and chemical parameters in the WLCI study area, based on a sampling density of one site per 440 km^2.
- Compare soil concentration values to established EPA ecological or human health soil screening levels for Sb, As, Ba, Be, Cd, Cr, Co, Cu, Pb, Mn, Ni, Se, Ag, V, and Zn and generate maps showing where within the WLCI study area these values are exceeded.

Study Area

This soil geochemical investigation involved the entire WLCI study area with sampling sites selected using a generalized random tessellation stratified design (fig. 18).

Work Accomplished in 2011 and Findings

In 2011, the samples collected in 2010 were analyzed in the USGS laboratories for all elements listed above in the Scope and Approaches section, as well as total carbon and carbonate carbon. Colorado State University's Soil–Water–Plant Testing Laboratory analyzed splits of these same samples for total nitrogen (N), soil pH, electrical conductivity, and sodium adsorption ratio. Rigorous quality-control protocols were used throughout the analytical process.

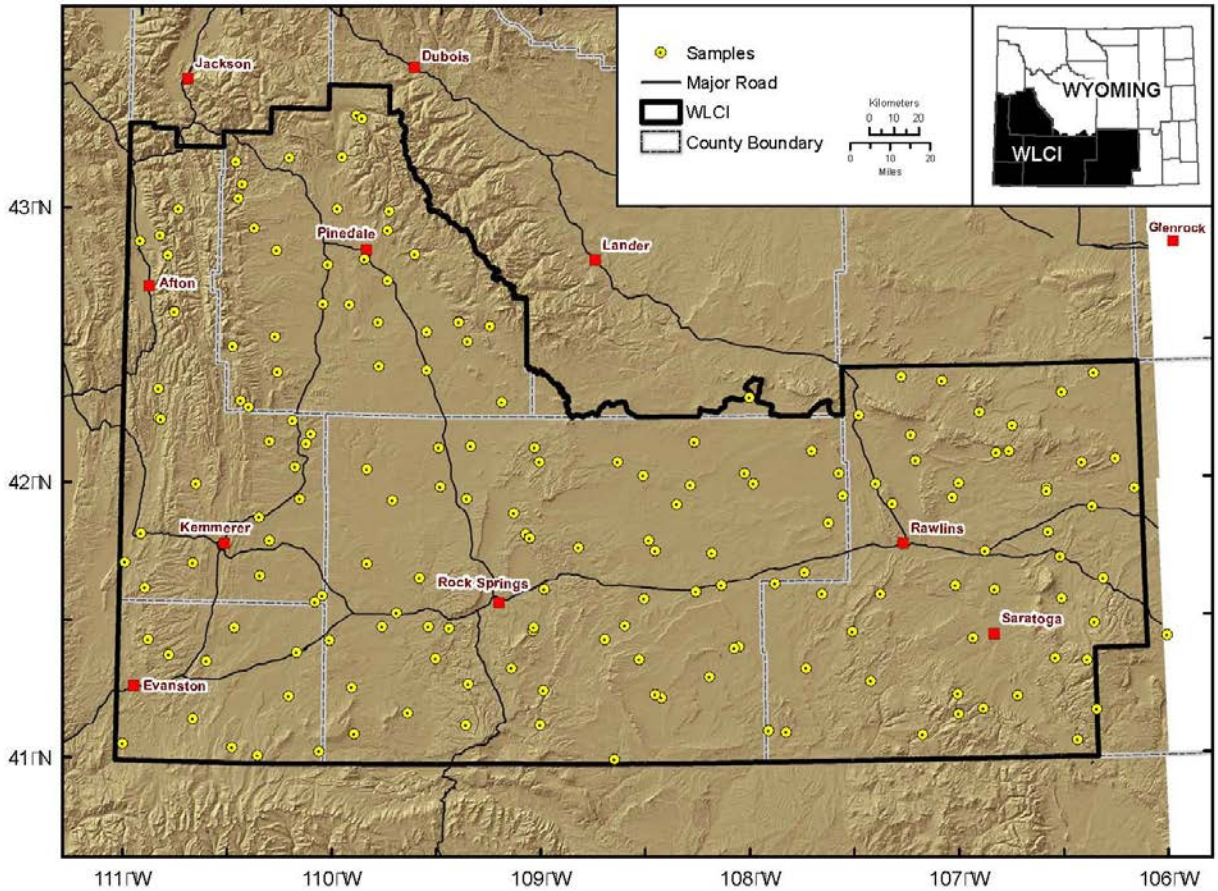

Figure 18. Soil geochemistry sampling locations for the Wyoming Landscape Conservation Initiative's (WLCI) long-term monitoring program.

With the addition of geochemical data from samples collected in 2010, the final dataset consists of 175 samples, and the newly generated data were added to USGS Data Series 510 (Smith and Ellefsen, 2010). Exploratory data analysis, including preparation of histograms, Tukey boxplots, plots of empirical cumulative distribution function, and quantile-quantile plots, was performed on the complete dataset of 175 samples. A statistical summary of the data is shown in Table 4. Geochemical maps showing the abundance and spatial distribution of each element within the WLCI study area were generated. Figures 19 and 20 are examples of these maps for organic carbon and mercury (Hg), respectively.

Products Completed in FY2011

- Smith, D.B., and Ellefsen, K.J., 2010, Soil geochemical data for the Wyoming Landscape Conservation Initiative Study Area: U.S. Geological Survey Data Series Report 510, 12 p., revised September 2011, available online at: *http://pubs.usgs.gov/ds/510/downloads/DS-510.pdf*.

- Forty-seven geochemical maps showing the abundance and spatial distribution within the WLCI study area for all 47 soil parameters in the data table published in Smith and Ellefsen (2010).
- Exploratory data analysis plots, including histograms, Tukey boxplots, empirical cumulative distribution function plots, and quantile-quantile plots for the following elements from 0–5-cm soils from the WLCI study area: Al, As, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, carbonate C, organic C, Cu, Fe, Ga, Hg, In, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Rb, S, Sb, Sc, Se, Sn, Sr, Th, Ti, Tl, U, V, W, Y and Zn.

Work Planned for FY2012

Soil geochemical data for the potentially toxic elements antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), manganese (Mn), nickel (Ni), selenium (Se), silver (Ag), vanadium (V), and zinc (Zn) will be compared to ecological- and human health-screening levels for soil established by the EPA. Maps will be prepared to show where within the WLCI study area these screening levels are exceeded. A contribution on soil geochemistry will be prepared for the IA of the WLCI study area.

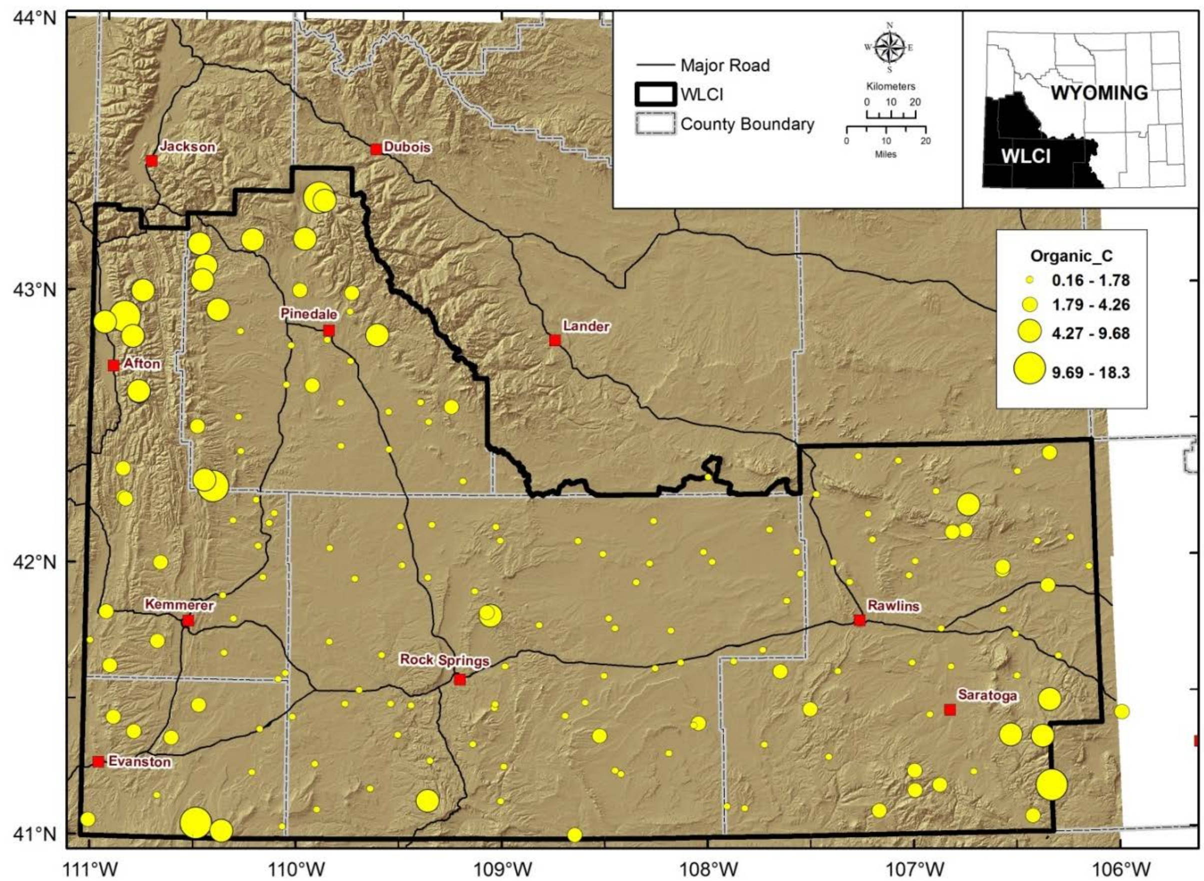

Figure 19. Distribution of organic carbon concentrations (percent) in soils collected from a depth of 0–5 centimeters (cm) in the Wyoming Landscape Conservation Initiative (WLCI) study area.

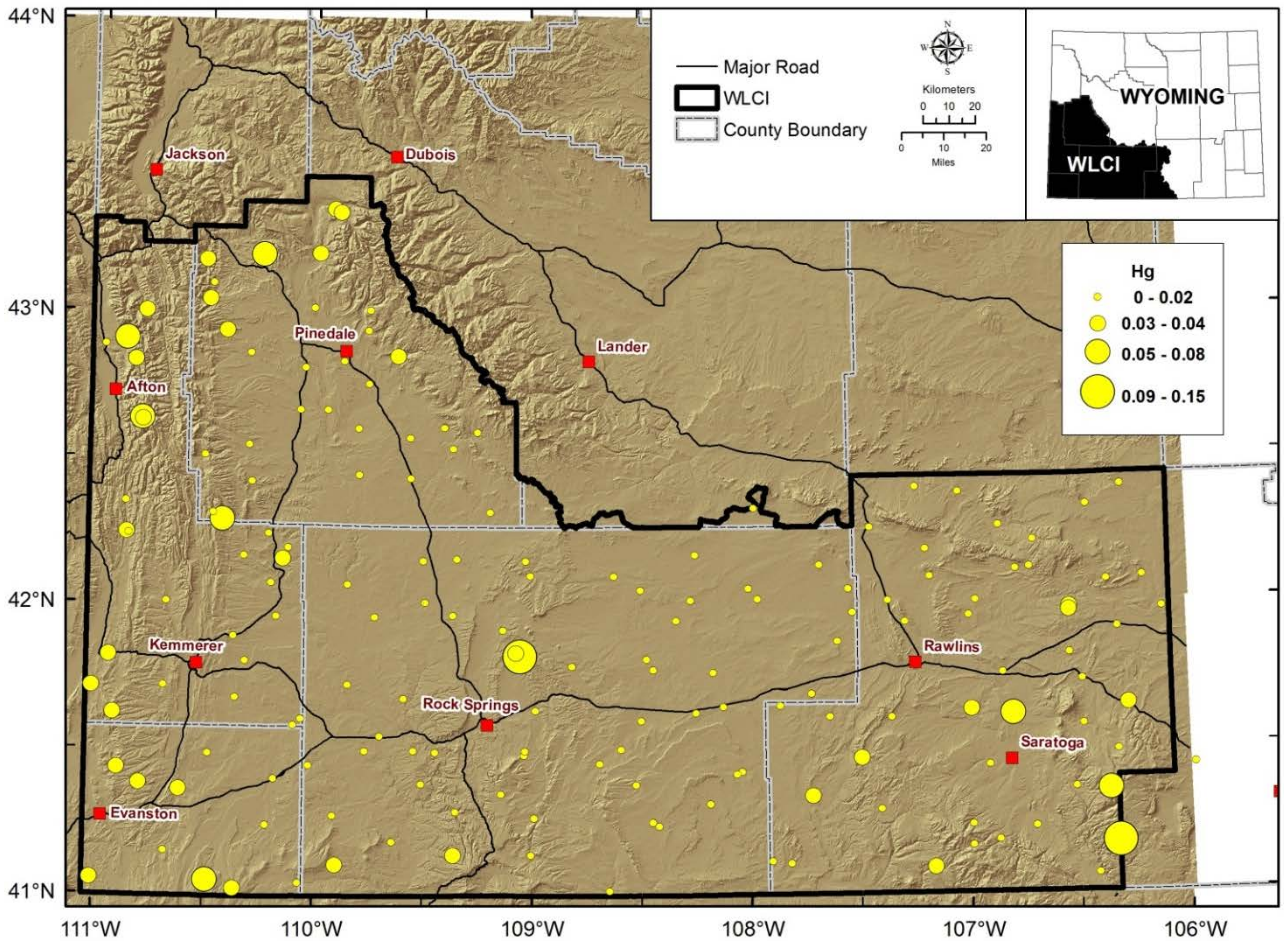

Figure 20. Distribution of mercury (Hg) concentrations (mg/kg) in soils collected from a depth of 0–5 centimeters (cm) in the Wyoming Landscape Conservation Initiative (WLCI) study area.

Table 4. Statistical summary for geochemical data on 0- to 5-cm soil depth in the Wyoming Landscape Conservation Initiative region [n = 175; LLD = lower limit of determination; Q1 = first quartile; Q3 = third quartile; and MAD = median absolute deviation].

Element	Concentration units	Number of samples below LLD	Minimum	Q1	Median	Q3	Maximum	MAD
Aluminum	Percent	0	2.11	4.38	5.27	6.24	8.09	1.36
Calcium	Percent	0	0.21	0.82	1.62	3.02	10.3	1.39
Iron	Percent	0	0.29	1.56	1.95	2.35	4.47	0.59
Potassium	Percent	0	0.83	1.62	1.88	2.15	3.87	0.34
Magnesium	Percent	0	0.07	0.49	0.73	1.06	2.42	0.43
Sodium	Percent	0	0.08	0.58	1.05	1.48	2.66	0.67
Sulfur	Percent	4	<0.01	0.02	0.03	0.04	0.29	0.015
Titanium	Percent	0	0.04	0.15	0.19	0.24	0.47	0.059
Arsenic	mg/kg	1	<0.6	3.2	5.2	7.2	30.1	3.0
Silver	mg/kg	175	<1	<1	<1	<1	<1	0
Barium	mg/kg	0	220	553	660	851	2,390	200
Beryllium	mg/kg	0	0.6	1.3	1.5	1.8	2.5	0.4
Bismuth	mg/kg	1	<0.04	0.15	0.20	0.27	0.60	0.089
Cadmium	mg/kg	4	<0.1	0.2	0.3	0.5	5.7	0.15
Cerium	mg/kg	0	18.3	45.6	59.1	70.6	161	19.1
Cobalt	mg/kg	0	0.8	5.9	7.6	9.8	24.9	2.7
Chromium	mg/kg	0	3	31.5	42	50	287	13.3
Cesium	mg/kg	138	<5	<5	<5	5	11	0
Copper	mg/kg	0	1.4	10.6	14.7	19.3	47.9	6.5
Gallium	mg/kg	0	5.6	11.0	13.6	16.0	22.2	3.7
Mercury	mg/kg	31	<0.01	0.01	0.02	0.02	0.15	0.015
Indium	mg/kg	20	<0.02	0.03	0.03	0.04	0.06	0.01
Lanthanum	mg/kg	0	10.1	17.8	23.2	36.8	75.8	9.8
Lithium	mg/kg	0	3	17	23	29	72	8.9
Manganese	mg/kg	0	63	323	460	619	2,000	214
Molybdenum	mg/kg	0	0.15	0.61	0.94	1.27	7.38	0.49
Niobium	mg/kg	0	1.5	6.0	7.7	9.4	25.8	2.5
Nickel	mg/kg	0	1.7	11.2	14.1	17.5	115	4.6
Phosphorous	mg/kg	0	150	555	800	1,030	8,590	341
Lead	mg/kg	0	10.6	16.2	19.2	21.4	32.2	3.7
Rubidium	mg/kg	0	40.9	68.0	79.3	91.6	140	18.1
Antimony	mg/kg	0	0.09	0.40	0.52	0.67	2.53	0.22
Scandium	mg/kg	0	1.5	5.0	6.3	8.0	15.4	2.2
Selenium	mg/kg	110	<0.2	<0.2	<0.2	0.3	4.2	0
Tin	mg/kg	0	0.4	1.0	1.2	1.5	2.8	0.44
Strontium	mg/kg	0	50.1	120	160	364	706	93.4
Tellurium	mg/kg	175	<0.1	<0.1	<0.1	<0.1	<0.1	0
Thorium	mg/kg	0	4.4	7.4	9.4	11.2	32.5	2.8
Thallium	mg/kg	0	0.2	0.4	0.5	0.6	1.5	0.15
Uranium	mg/kg	0	0.8	1.7	2.1	2.6	9.6	0.74
Vanadium	mg/kg	0	8	41	53	68	196	21
Tungsten	mg/kg	0	0.1	0.6	0.8	1.1	6.9	0.3
Yttrium	mg/kg	0	3.4	12.0	14.3	16.3	45.3	3.1
Zinc	mg/kg	0	12	42	55	71	210	20.8

Table 4. Statistical summary for geochemical data on 0- to 5-cm soil depth in the Wyoming Landscape Conservation Initiative region [n = 175; LLD = lower limit of determination; Q1 = first quartile; Q3 = third quartile; and MAD = median absolute deviation].—Continued

Element	Concentration units	Number of samples below LLD	Minimum	Q1	Median	Q3	Maximum	MAD
Total Carbon	Percent	0	0.16	0.89	1.73	3.30	18.3	14.2
Carbonate Carbon	Percent	18	<0.0030	0.01	0.07	0.75	3.28	0.099
Organic Carbon	Percent	0	0.16	0.54	0.96	2.66	18.3	0.85
Total Nitrogen	Percent	0	0.0036	0.079	0.11	0.24	1.10	0.076

Long-Term Monitoring of Surface Water and Groundwater Hydrology

Status

Ongoing

Contact

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Scope and Approaches

Data from the long-term monitoring of surface-water and groundwater resources are needed for assessing riparian and aquatic ecosystems in the context of changes in land use, land cover, and climate. Surface-water quality is being monitored at four sites in the WLCI region and is partially funded by the WLCI. Groundwater levels are being monitored at one site in the WLCI region and also are partially funded by the WLCI.

The WLCI water-resources monitoring locations are being selected to provide baseline characterization of the upper Green River Basin and Muddy Creek Watershed consistent with cooperator data needs. Data are being collected according to USGS methods (Kenney, 2010; Sauer and Turnipseed, 2010; Turnipseed and Sauer, 2010; U.S. Geological Survey, variously dated; Wagner and others, 2006) and published on the USGS National Water Information System Web site (NWISWeb).

Objectives

- Collect and publish results of monthly surface water-quality samples collected from three sites: 09217000 Green River near Green River, Wyo.; 09258980 Muddy Creek below Young Draw near Baggs, Wyo.; and 09205000 New Fork River near Big Piney, Wyo.; results to be published at the USGS NWISWeb Website (U.S. Geological Survey, various years). Assess these samples for a suite of water-quality parameters.
- Collect and publish results of continuous seasonal, real-time surface water-quality samples collected from three sites: (1) assess samples from 09217000 Green River near Green River, Wyo., and 09258050 Muddy Creek above Olson Draw near Dad, Wyo., for temperature, specific conductance, and computed total dissolved solids (TDS) concentrations; and (2) assess the sample from 09258980 Muddy Creek below Young Draw near Baggs, Wyo., for computed TDS concentrations.
- Collect and publish results of seasonal, daily water temperature and specific conductance samples collected from two sites: 9217000 Green River near Green River, Wyo., and 09258050 Muddy Creek above Olson Draw near Dad, Wyo.

- Collect and publish real-time water-level data for site 413850109150601 19-105-10bbb01 Rock Springs, Rock Springs, Wyo.

Study Area

The focus of this work is water quality and quantity in the Green River Basin and the Muddy Creek Watershed (fig. 21).

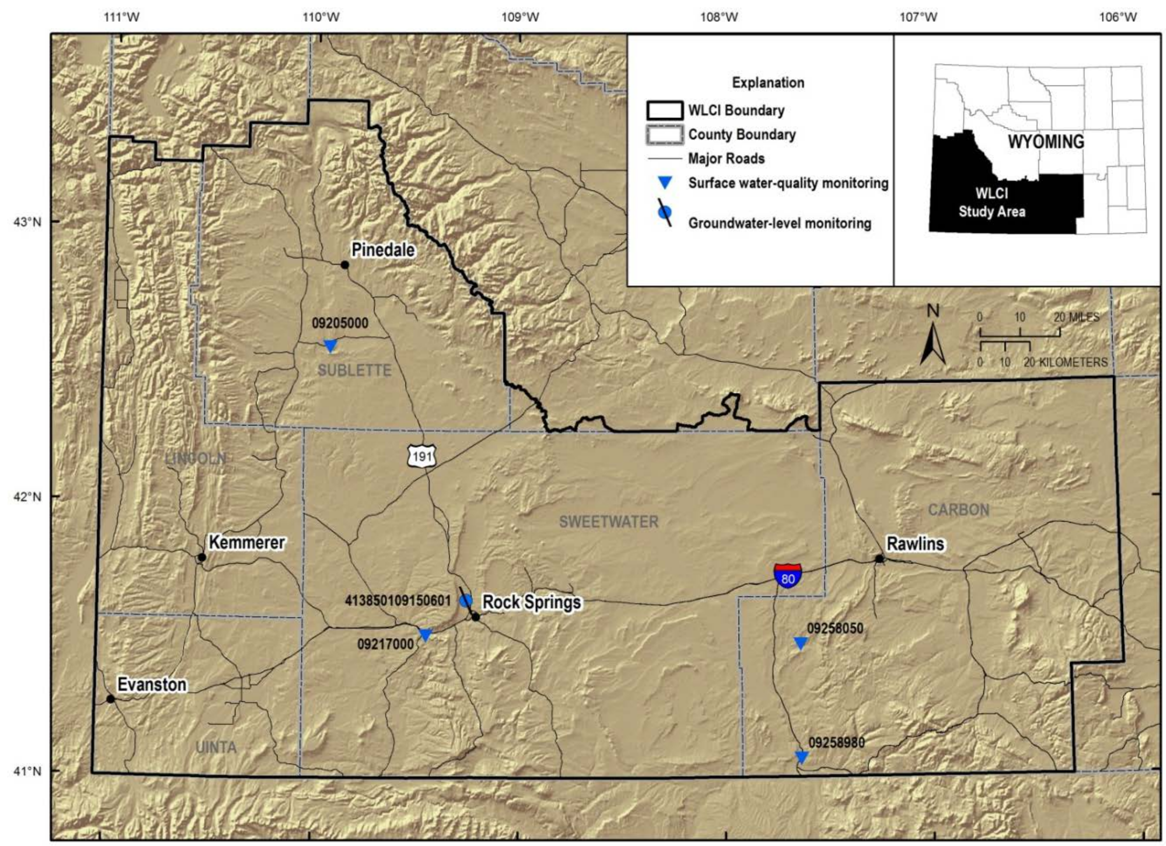

Figure 21. Locations of stations and gages for long-term monitoring of surface-water quality and groundwater levels in the Wyoming Landscape Conservation Initiative (WLCI) study area.

Work Accomplished in 2011 and Findings

Surface-water quality data were collected at four sites (09205000 New Fork River near Big Piney, Wyo.; 09217000 Green River near Green River, Wyo.; and 09258980 Muddy Creek below Young Draw near Baggs, Wyo.) in the upper Green River Basin and Muddy Creek Watershed. Data on groundwater levels were collected at one site in the Green River Basin. All data were loaded onto the Internet for public access on the USGS Water Data for the Nation Web site at *http://waterdata.usgs.gov/nwis.*

Products Completed in FY2011

- Preliminary data for water year 2011 (October 1 through September 30) were provided in real-time on the Internet via USGS NWISWeb. All data for each site are available online:

http://waterdata.usgs.gov/wy/nwis/nwisman/?site_no=09217000
http://waterdata.usgs.gov/wy/nwis/nwisman/?site_no=09258050
http://waterdata.usgs.gov/wy/nwis/nwisman/?site_no=09205000
http://waterdata.usgs.gov/wy/nwis/nwisman/?site_no=09258980
http://waterdata.usgs.gov/wy/nwis/nwisman/?site_no=413850109150601

- Final data for water year 2010 were published in the USGS Annual Water-Data Report (U.S. Geological Survey, 2011b). Individual site data sheets are available online:
- *http://wdr.water.usgs.gov/wy2010/pdfs/09217000.2010.pdf*
  http://wdr.water.usgs.gov/wy2010/pdfs/09258050.2010.pdf
  http://wdr.water.usgs.gov/wy2010/pdfs/09258980.2010.pdf
  http://wdr.water.usgs.gov/wy2010/pdfs/413850109150601.2010.pdf

Work Planned for FY2012

Water year 2011 data will be reviewed and published in the 2012 USGS Annual Water Data Report. Monitoring of surface-water quality and groundwater levels will continue in water year 2012 at the same sites. Another 4-6 groundwater quality samples will be collected in 2012.

Wyoming Groundwater-Quality Monitoring Network

Status

Ongoing

Contact

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Scope and Approaches

The Wyoming Groundwater-Quality Monitoring Network samples existing shallow wells (less than 160 ft deep) to evaluate groundwater quality in priority areas (fig. 22) where (1) groundwater represents an important source of drinking water for public and private supplies, is susceptible to contamination, and (2) is overlain by one or more land-use activities, including energy development, that could negatively impact groundwater resources (Hamerlinck and Arneson, 1998). In December 2009, the USGS, in cooperation with the WDEQ, began groundwater sampling in the Green River watershed of the WLCI region. Initially, WLCI funds allowed USGS to sample four intermediate-depth wells (160–500 ft deep) to be sampled in priority areas within the Green River Watershed. In 2011, five additional intermediate-depth wells were sampled (fig. 23). Each year, five more wells will be sampled.

Samples from the five randomly selected wells were collected in accordance with specific USGS sampling protocols (USGS, 1997–2011) to ensure a quality sample. Samples were containerized and preserved according to methods required for target analyses and shipped to either the EPA's Region 8 Laboratory or the USGS National Water Quality Laboratory, depending on the analysis to be performed. All samples were analyzed for major ions, trace elements, nutrients, volatile organic compounds, H-2/H-1 and O-18/O-16 isotope ratios (indicators of groundwater source and recharge process), waste-water compounds, tritium, gross alpha/gross beta radioactivity, radon, diesel-range organics, gasoline-range organics, and dissolved hydrocarbon gases. Alkalinity titrations were performed in the field. Total coliform bacteria, *Escherichia coli* bacteria, and biological activity reaction test samples were processed in the field.

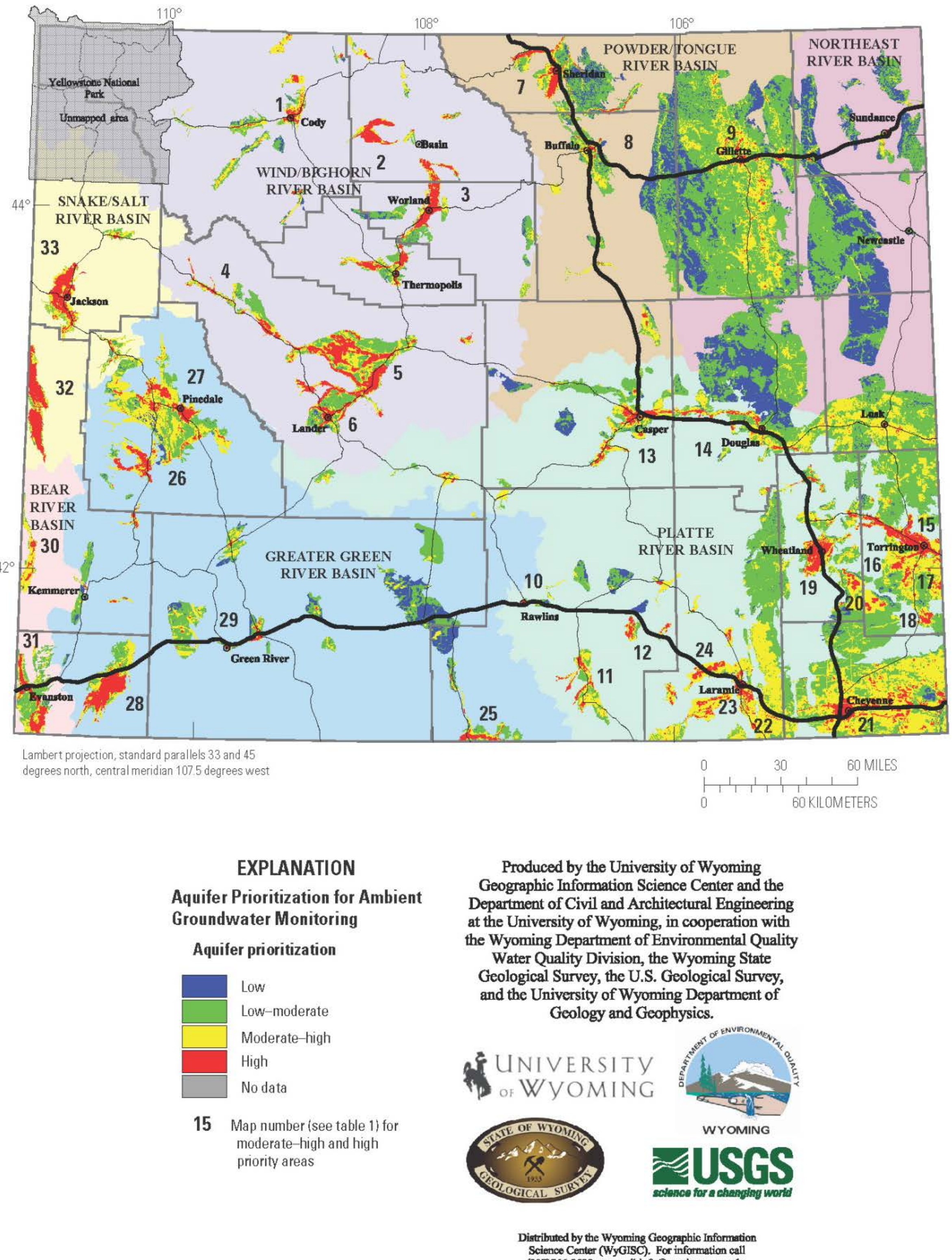

Figure 22. Aquifer prioritization for ambient groundwater monitoring across Wyoming (Hamerlinck and Arneson, 1998). Red and yellow indicate the moderate to high and high priority areas for monitoring.

Objectives

- Measure water levels and collect groundwater samples from selected wells.
- Analyze groundwater samples for a variety of natural and man-made compounds.
- Report the results through the USGS water-quality web site, http://waterdata.usgs.gov/wy/nwis/qw/.

Study Area

The overall work associated with this study applies to aquifers considered “susceptible” throughout the entire state of Wyoming (fig. 22). Figure 23 shows the locations of the intermediate-depth wells (160–500 ft deep) sampled with WLCI funds within the WLCI region during FY2010 (four wells) and FY2011 (five wells).

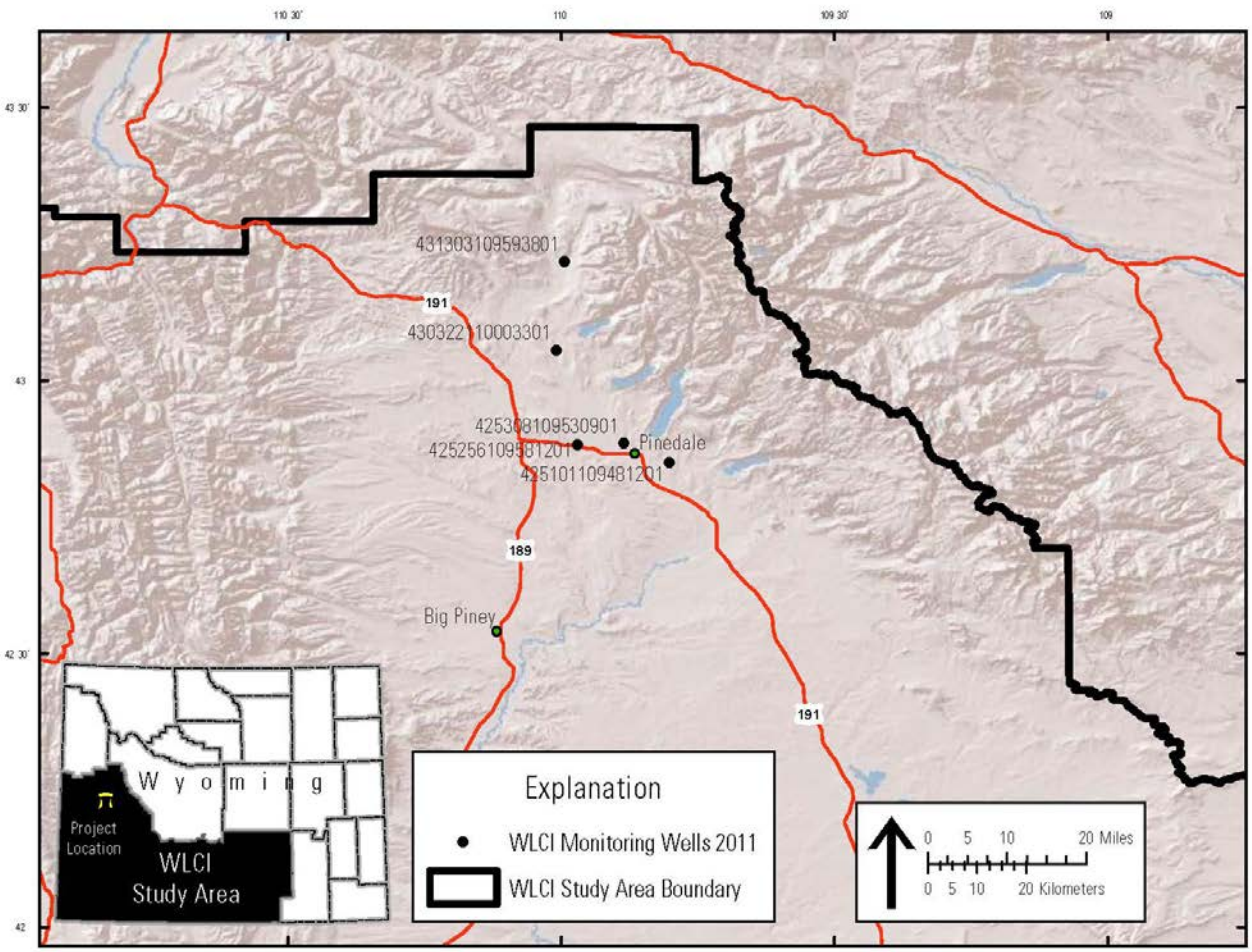

Figure 23. Locations of the five wells (greater than 160 feet deep) sampled for groundwater quality during fiscal year 2011 in the Green River Basin portion of the Wyoming Landscape Conservation Initiative (WLCI) study area.

Work Accomplished in 2011 and Findings

Groundwater samples were collected from the five deep wells in the Green River watershed (fig. 23). Groundwater-quality data were made available online in real-time (USGS NWISWeb). Drinking water standards were exceeded for iron (two samples), manganese (two samples), TDS (two samples), and sulfate (one sample). Methane was detected in all five samples. Gasoline-range organics (benzene, toluene, ethylbenzene, and xylene ("BTEX" compounds), typically found in the vicinity of oil and gas production, including drilling and production sites, refineries, and distribution points), were detected in one sample, but diesel-range organics were not detected in any samples.

Products Completed in FY2011

- 2011 groundwater-quality data were made available online at USGS NWISWeb.
- A fact sheet on the Wyoming Groundwater-Quality Monitoring Network was published (*http://pubs.usgs.gov/fs/2011/3041/*).

Work Planned for FY2012

Five additional wells (greater than160 ft deep) will be sampled in priority areas in the Green River Basin.

New Fork River Periphyton and Bed Sediment Analysis

Status

New in FY2011

Contact

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Scope and Approaches

New Fork River drainage basin is an area of active energy exploration and development in the northeastern part of the WLCI study area. Development includes conventional natural gas wells. This study was conducted to support the Sublette County Conservation District (SSCD) in ascertaining potential water-quality impacts to the New Fork River from energy development and pipeline crossings of the river in the Pinedale Anticline Project Area (PAPA). The SSCD collects marcoinvetebrate (aquatic insects) samples at eight sites within the PAPA. The USGS collected periphyton (algae), bed sediment, pebble count, discharge and water quality (pH, dissolved oxygen, specific conductance, water temperature) at five sampling sites within the PAPA (fig. 24) and at USGS streamgage 09205000 New Fork River near Big Piney, Wyoming (fig. 21).

Sampling and measurement techniques described below are drawn from the USGS National Water-Quality Assessment (NAWQA) Program protocols (Moulton and others, 2002). Sampling sites were established as part of SCCD's baseline biological monitoring network for the New Fork River.

- Water-quality parameters will be measured continuously at an upper sampling site and at a lower sampling site. Parameters include dissolved oxygen, pH, specific conductance, water temperature, and turbidity. Field parameters will be measured in accordance with protocols outlined in the USGS National Field Manual for the Collection of Water-Quality Data (U.S. Geological Survey, variously dated).

- Algae samples will be collected following the NAWQA protocol in riffles. Algae provide an integrated assessment of water quality at the local scale. The algae sample from riffles will be a composite sample of 25 collections of periphyton scraped from rocks using a PVC ring. Samples will be homogenized at each site and aliquots withdrawn for taxonomic identification and enumeration. Aliquots also will be withdrawn for analysis of chlorophyll-a. Algal taxonomy samples will be sent to Rhithron Associates, Inc., Missoula, Mont., and chlorophyll-a samples will be sent the USGS National Water Quality Laboratory, Denver, Colo.
- Bed sediments will be collected and composited at 5 to 10 depositional zones containing fine-grained sediments around the sampling site to determine total-organic carbon (TOC) and total-inorganic carbon. TOC is an indicator of contaminates transported and present in the drainage system and, when combined with analysis of biological tissue, such as periphyton, bed-sediment concentrations provide a useful measure of the potential bioaccumulation of hydrophobic organic contaminants at a particular site (Shelton and Capel, 1994).
- At riffles, a pebble count will be completed generally as described in Wolman (1954). This project will measure and record the intermediate axis of at least 100 particles across one of the riffles sampled for benthic macro-invertebrates. It is best if two persons perform a pebble count, with one person in the stream measuring particles and the second person taking notes.
- Stream discharge will be determined at all sampled sites using methods outlined in Rantz and others (1982).

Objectives

- Collect periphyton, bed sediment, water-quality, and pebble count data at six sites on the New Fork River.
- Develop an understanding of how periphyton and bed sediments relate to land use in the New Fork River basin.
- Present results to the SSCD.

Study Area

The New Fork River drains about 1,200 square miles in southeastern Wyoming. Sampling sites were located on the mainstem of the New Fork River (fig. 24). All sites except for the New Fork River near Big Piney, Wyoming, site (USGS streamgage 0920500) are within the Pinedale Anticline Project area. Riparian area vegetation was dominated by grasses, shrubs, and willows with cottonwoods dominating the upper canopy.

Work Accomplished in 2011 and Findings

Data were collected at the six sites in the New Fork River drainage according to the protocols outlined in the Scope and Approaches section above. Analyses of samples will be completed in FY2012.

Products Completed in FY2011

- Developed the database specific to this study, including the parameters as follows: periphyton (algae), bed sediment, pebble count, discharge and water quality (pH, dissolved oxygen, specific conductance, water temperature). Data are specific to five sites within the PAPA and at USGS streamgage 09205000 New Fork River near Big Piney, Wyo.

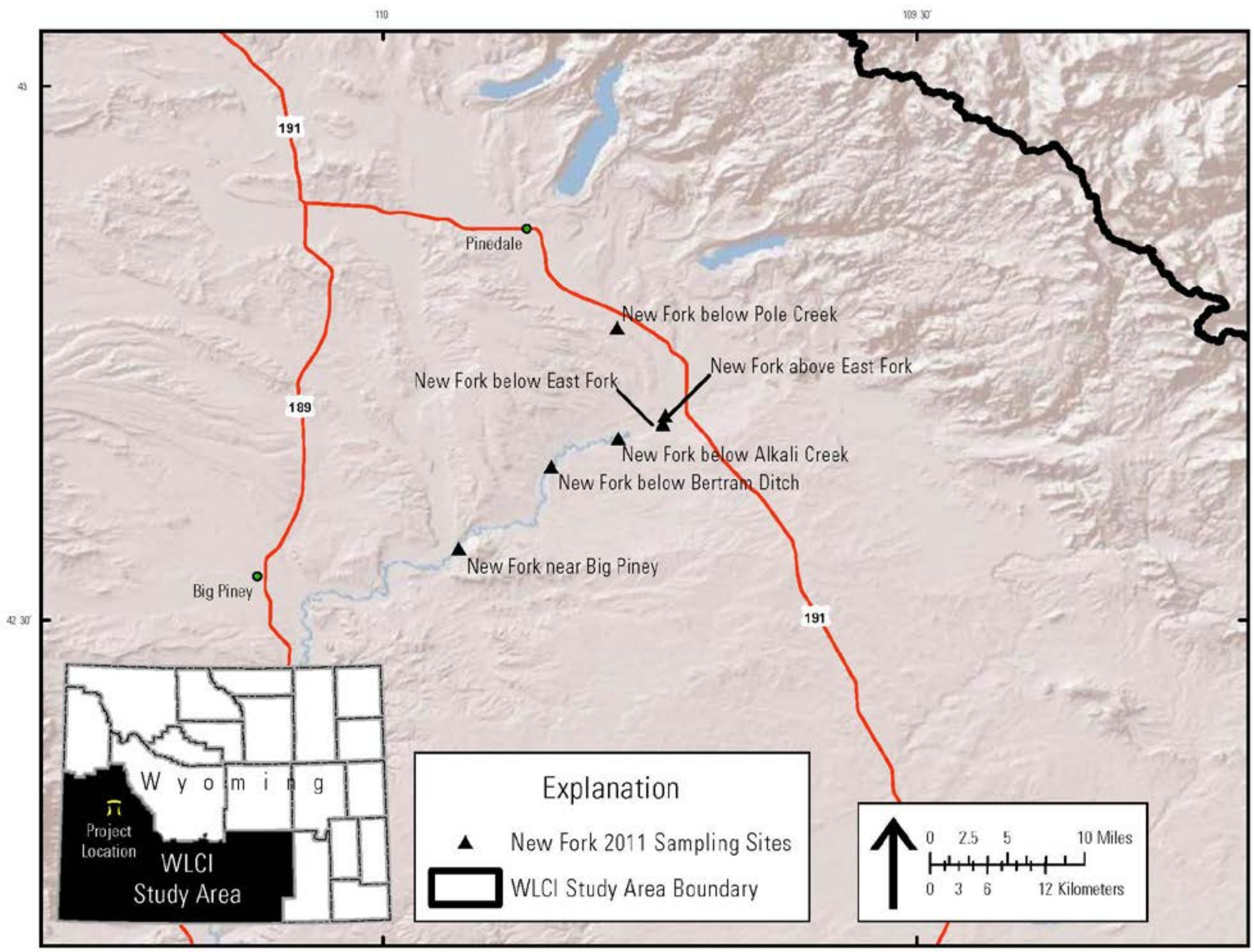

Figure 24. Sampling sites where data were collected for the synoptic study of the New Fork River drainage basin's periphyton and bed sediments.

Work Planned for FY2012

Proposed work for FY2012 includes compilation and review of study data collected by the Wyoming Water Science Center and presentation of our results to the Sublette County Conservation District.

Summary of FY2011 Activities for Effectiveness Monitoring of Habitat Treatments

Effectiveness Monitoring for the WLCI in FY2011 included 10 research activities, 8 of which were ongoing from previous years, and 2 of which were new and 1 of which was completed in FY2011: (1) *Applying Greenness Indices to Evaluate Sagebrush Treatments in the WLCI Region*; (2) *Development and Evaluation of Synthetic High-Resolution Satellite Imagery for Effectiveness Monitoring* (new) (3) *Greater Sage-Grouse Use of Vegetation Treatment Sites*; (4) *Occurrence of Cheatgrass Associated with Habitat Projects in the Little Mountain Ecosystem* (the mountainous region south of Rock Springs, Wyo.); (5) *Application and Feasibility of Mapping Aspen Stands and Conifer Encroachment Using Classification and Regression Tree (CART) Analysis for Effectiveness Monitoring* (completed); (6) *Aspen Regeneration Associated with Mechanical Removal of Subalpine Fir*; (7) *Herbivory, Stand Condition, and Regeneration Rates of Aspen on Burned and Unburned Plots for Effectiveness Monitoring*; (8) *Use of Aspen Stands by Migrant Birds for Effectiveness Monitoring*; (9) *Muddy Creek Synoptic Study*; and (10) *Natural Salinity Fluctuations in a Snowmelt-Dominated Watershed Undergoing Energy Development* (new).

The project to *Apply Greenness Indices to Evaluate Sagebrush Treatments in the WLCI Region* continued in FY2011 with collection of vegetation reflectance data from native and non-native vegetation near the Fall Creek Feedground. This was accomplished by using 14 near-surface sensors mounted on “mantis” platforms. Analyses of the data from 21 platforms, including 7 deployed in 2010 on the Jonah Field, Wyo., were initiated. USGS scientists are able to detect growing season trends in greenness and differences between native, non-native (cheatgrass), and reclamation vegetation.

The new Effectiveness Monitoring task, *Development and Evaluation of Synthetic High-Resolution Satellite Imagery for Effectiveness Monitoring*, involved a novel approach to blending satellite-based sensor data that was applied for the first time to a semi-arid, heterogeneous landscape and then evaluated for effectiveness. Predicted reflectance and NDVI estimates were accurate and highly correlated with actual values across several land cover types. The synthetic imagery produced by data blending provides the high level of spatial resolution that managers need to identify treatment areas, the high level of temporal resolution often needed to track dynamic vegetation conditions, and the large spatial extent needed for monitoring at landscape scales.

In FY2011, the *Greater Sage-Grouse Use of Vegetation Treatments* work entailed continuing the sage-grouse pellet surveys during early brood, late brood rearing, and fall. Vegetation sampling was conducted at 40 of the pellet transects with high sage-grouse use and 40 pellet transects with low sage-grouse use. Soil samples were collected to determine soil texture. Pellet surveys will continue during 2012 and analysis of pellet survey data and vegetation data will be initiated.

The *Occurrence of Cheatgrass Associated with Habitat Projects in the Little Mountain Ecosystem* study is designed to document annual variation of cheatgrass and other invasive species and how these species may influence native plant species over time. During FY2011, distribution and abundance of cheatgrass and other invasive species were assessed in 12 5- × 10-m macroplots established during FY2010 in the Little Firehole Canyon area of the Little Mountain Ecosystem. Summary data from FY2011 indicate that six non-native species were observed in the macroplots, with cheatgrass and bur buttercup (*Ceratocephala testiculata*) being the two most abundant introduced species.

The *Application and Feasibility of Mapping Aspen Stands and Conifer Encroachment Using Classification and Regression Tree (CART) Analysis for Effectiveness Monitoring* project was completed in FY2011 by refining a method for mapping aspen woodlands and producing a fine-scale map of aspen and conifer distribution in the Little Mountain Ecosystem. We evaluated the classification and regression tree analysis and applied it to temporal (leaf-on and leaf-off periods) satellite imagery and abiotic covariates to produce the final map, which fills a critical data gap and was used to support other Effectiveness Monitoring projects. The methodology developed by USGS can be applied to other areas of the WLCI.

For the study of *Aspen Regeneration Associated with Mechanical Removal of Subalpine Fir,* FY2011 activities entailed collecting core and disc samples from aspen and conifer trees within previously established plots in the Little Mountain Ecosystem. We began analyzing the core and disc samples to develop age chronologies and establishment dates for aspen. Annual aspen recruitment and browsing of aspen were measured in treated and untreated areas. This information will help WLCI project planners with an understanding of aspen systems in this area and with planning of future habitat treatments.

In FY2011, the *Herbivory, Stand Condition, and Regeneration Rates of Aspen on Burned and Unburned Plots for Effectiveness Monitoring* study continued with acquiring core and disc samples from aspen and conifer in previously established plots. Analyses of core and disc samples were initiated for developing age chronologies and dates of establishment for aspen and conifer species growing in different ecological and hydrological settings in the Little Mountain Area. This information will provide WLCI project planners with an understanding of aspen systems in this area, which, in turn, will support planning of future habitat treatments.

The *Use of Aspen Stands by Migrant Birds for Effectiveness Monitoring* study continued in FY2011 with analyses of bird-survey and habitat data collected during FY2009 and 2010 from the Little Mountain Ecosystem, Fossil Butte National Monument (southwestern Lincoln County, Wyo.), and Seedskadee National Wildlife Refuge (northwestern Sweetwater County, Wyo.).

A variety of terrestrial habitats are evident in Fossil Butte national Monument, located in the extreme western portion of the WLCI region. Photo credit: Marcia Fagnant, Lead Interpreter, Nation Park Service.

Muddy Creek drainage basin is an area of active energy exploration and development in southeastern part of the WLCI study area. In summer FY2010, the *Muddy Creek Synoptic Study* was initiated to characterize conditions in the basin by evaluating its surface-water chemistry. A second synoptic study of the basin was conducted during the summer of FY2011 to characterize potential groundwater inputs in the basin. The FY2011 approach was to sample the water chemistry of two flowing wells and nearby surface-water sites. Results of this work were prepared in a poster to be presented during early FY2012 at the American Geophysical Union fall meeting.

The new study being conducted within the Muddy Creek watershed, *Natural Salinity Fluctuations in a Snowmelt Dominated Watershed Undergoing Energy Development*, is a closer examination of the seasonal water chemistry and extractable salts from nearby soils. Based on initial results of the FY2011 samples collected, there is little evidence for elevated salt mobilization due to current natural gas development. However, previously unrecorded natural patterns in sources and loads of salinity have been documented. Documenting these patterns will provide a baseline for assessing impacts associated with development on water quality in Muddy Creek and other watersheds in the western United States.

Details of the Effectiveness Monitoring work are provided below in the 10 sections that follow.

Applying Greenness Indices to Evaluate Sagebrush Treatments in the WLCI Region

Status

Ongoing

Contacts

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Scope and Approaches

As climate change (for example, warmer temperatures and earlier snow melt) affects vegetation, plant phenology (timing of life-history events such as green-up, flowering and senescence) and species composition may shift, possibly making forage for elk, sage-grouse, other wildlife species, and livestock available earlier in the growing season. Shifts in species composition also may result in earlier senescence and reduced overall forage production (warmer and drier climate scenario and potential shift to less palatable species). Plant phenology such as green-up is influenced by weather and the species in question, and in turn, phenology can influence wildlife habitat use (for example, it can influence elk movements or sage-grouse activity). Therefore, phenology could be used as a seasonal indicator of habitat condition in treated or untreated areas, or it could be used as an indicator of when to stop feeding elk on state feedgrounds in the Green River Basin, where shorter feeding seasons are associated with reduced incidence of brucellosis (Cross and others, 2007).

Ideally, for plant phenology information to be useful to natural resource managers, remotely sensed greenness indices like the NDVI could be correlated with near-surface measurements that capture fine-scale, rapid changes in greenness (for example, caused by species-specific green-up after snowmelt, flowering, or senescence). In addition, near-surface sensing platforms can identify green-up of target plant species (perennial grasses, shrubs, or annual weeds like cheatgrass) or features (bare soil, or where annuals, including weeds, may green-up) that remote sensing cannot target. For example, the near-surface sensing could be used to identify the occurrence of green-up in plant species that may be more palatable to animal species of interest to managers. “Anomalous” or unexpected green-up could be used as an indicator that undesired plant species are present in a treated, reclaimed, or natural area, and that area could be targeted for on-the-ground examination and weed management. To collect reflectance (vegetation and interspace) data on native vegetation and areas treated with herbicide (for cheatgrass control in 2010) (see Bowen and others, 2011), the USGS is using near-surface and cloud-cover sensors mounted on mantis platforms (fig. 25).

Study Area

Work conducted during FY2011 took place near the Fall Creek Feedground (for elk) in the BLM Pinedale Field Office jurisdiction (figs. 26 and 27). This area is dominated by Wyoming big sagebrush, with an understory of herbaceous plants, forbs, and annual grasses, and is representative of this habitat type in the Upper Green River Basin portion of the WLCI study area. Sagebrush areas sampled included cheatgrass treatments (sprayed with Matrix 402), controls, and untreated areas.

Figure 25. The "mantis" near-surface sensor platform (H. Steltzer and others, developers) is mounted with a downward-facing sensor (for detecting visible and near infrared light) for measuring greenness and an upward-facing sensor for monitoring cloud cover. Photo credit: Geneva Chong, Research Ecologist, U.S. Geological Survey.

Objectives

- Evaluate ecosystem function (for example, greenness indices of productivity) using near-surface and remote-sensing platforms. Compare treated and control areas.
- Evaluate the effectiveness of cheatgrass control treatments using phenology and plant species identity measures.
- Work with BLM field offices to facilitate transfers of technology as sampling and monitoring approaches are tested and refined. For example, correlations between near-surface and remotely-sensed greenness data, combined with ground-truthed data, can be used to alert managers to rapid green-up of non-native species such as cheatgrass. Similar data could be used to assess revegetation and habitat-improvement treatments for effectiveness (desired species composition and cover). Automated approaches could greatly reduce the need for field checking and greatly increase accuracy and the area sampled.

- Continue phenology studies on and near the Fall Creek Feedground to evaluate cheatgrass detection to conduct effectiveness monitoring in cheatgrass treatments.
- Coordinate with WLCI partners to select sample sites for monitoring in FY2012.

Work Accomplished in 2011 and Findings

In spring 2011, 14 near-surface sensor boxes ("mantis"; figs. 25 and 27) were reinstalled on mantis platforms that had been set up during spring 2010 in cheatgrass-reduction treatments (near Fall Creek Feedground area of the Upper Green River Sagebrush Treatment Area; figs. 26 and 27). Because the mantis platforms were left in place over winter, it was possible to place the electronic sensors in exactly the same locations as they were in 2010. The solar-powered electric fences (fig. 27) and, likely, deep snow, protected the platforms from animal damage. Sagebrush areas sampled included cheatgrass treatments, controls, and untreated areas.

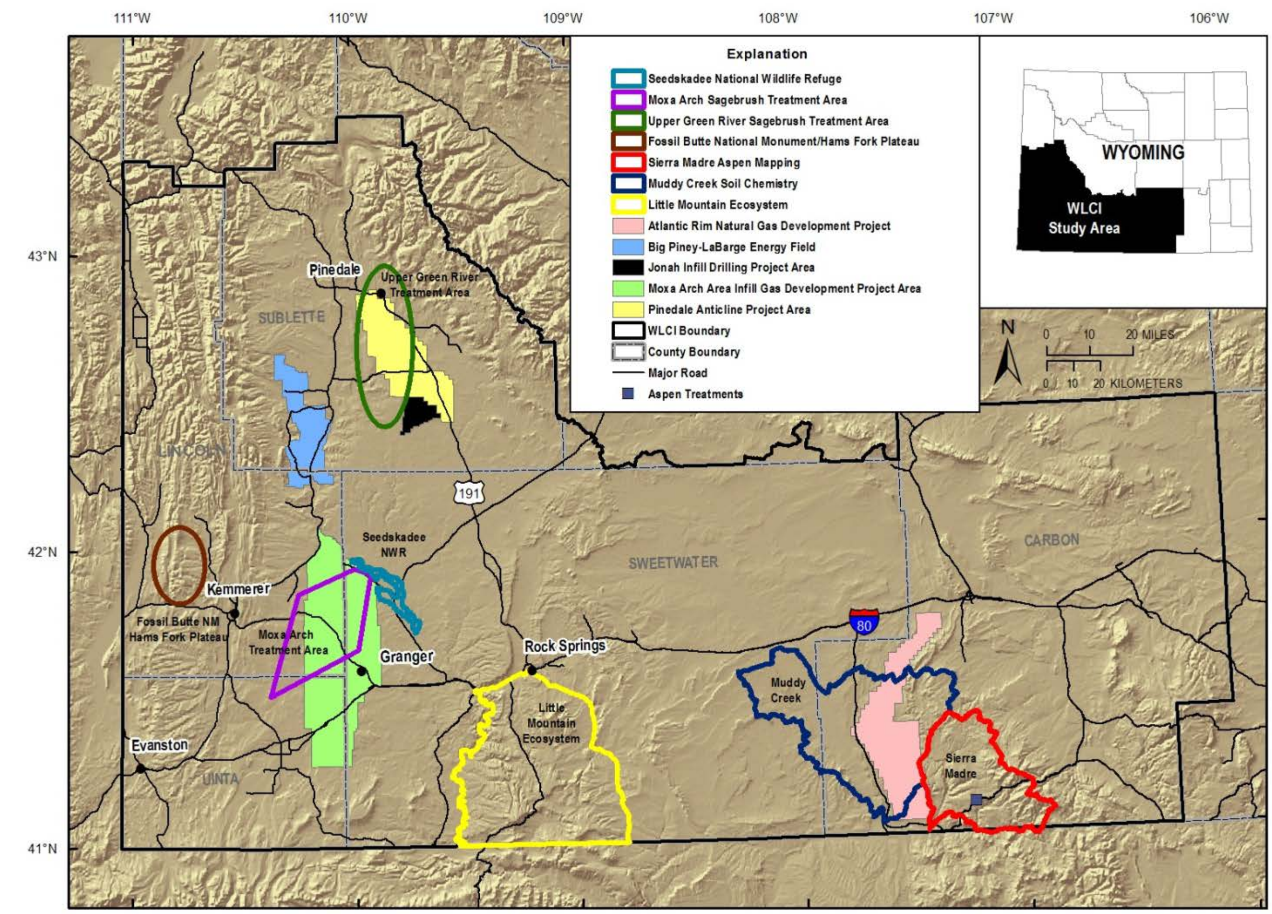

Figure 26. Locations of study areas associated with effectiveness monitoring and some of the mechanistic wildlife research activities. The area near Fall Creek Feedground where fiscal year 2011 research activities took place is located within the dark green oval in Sublette County. The solid-fill polygons are energy-development fields referenced in this document.

Figure 27. A portion of the study area near Fall Creek Feedground in the Upper Green River Sagebrush Treatment Area.

Reflectance data were collected every 10 minutes during daylight hours through August 2011. All hardware, including fencing, was taken in for maintenance during winter 2011–2012. Significant progress has been made in data management and analysis “automation” with systems for scanning data to find errors and selecting data for analyses. All plot data are being maintained in MS Excel spreadsheets.

Analyses of the 2010 sensor and phenology data collected from 21 sensors, including the 14 near the Fall Creek Feedground and 7 placed on the Jonah Field in 2010, were initiated, and Landsat TM cloud-free (0–20 percent) scenes were acquired for the 2010 growing season. USGS scientists were able to detect green-up, maximum greenness, and senescence across treatment and control areas in native, non-native and reclaimed vegetation (figs. 28 and 29). Scatter plots of data collected indicate that, on reclamation plots in the Jonah Field, the greenness of reclamation vegetation (reclaimed grasses) is most similar to that of the cheatgrass (fig. 28). From a management perspective, the difference between native and reclamation vegetation is important because it could indicate overall reduced productivity and also a change in the timing of productivity. When compared to native vegetation (sagebrush), the greenness indicates that the sagebrush maintains a relatively high and constant productivity, which is what mule deer, antelope and greater sage-grouse rely on, especially on their winter ranges. The reclamation vegetation, however, might be most useful for summer cattle grazing because its period of productivity (maximum greenness) is short. This information could be used to redefine successful reclamation to include the transition to native vegetation (sagebrush).

On the State lands near the Fall Creek Feedground, differences between native and non-native species were similar to those on the Jonah Field (figs. 28 and 29). It was also possible to detect the success of the cheatgrass control (sprayed with Matrix 402; Deej Brown, personal commun., 2011, Natural Resource Specialist/Reclamation/Weed Management Coordinator, Jonah Interagency Office Mitigation Team), and the superior productivity of the native interspace (non-sagebrush) vegetation, which had longer duration (more days) and greater measures of greenness, especially in the treated area.

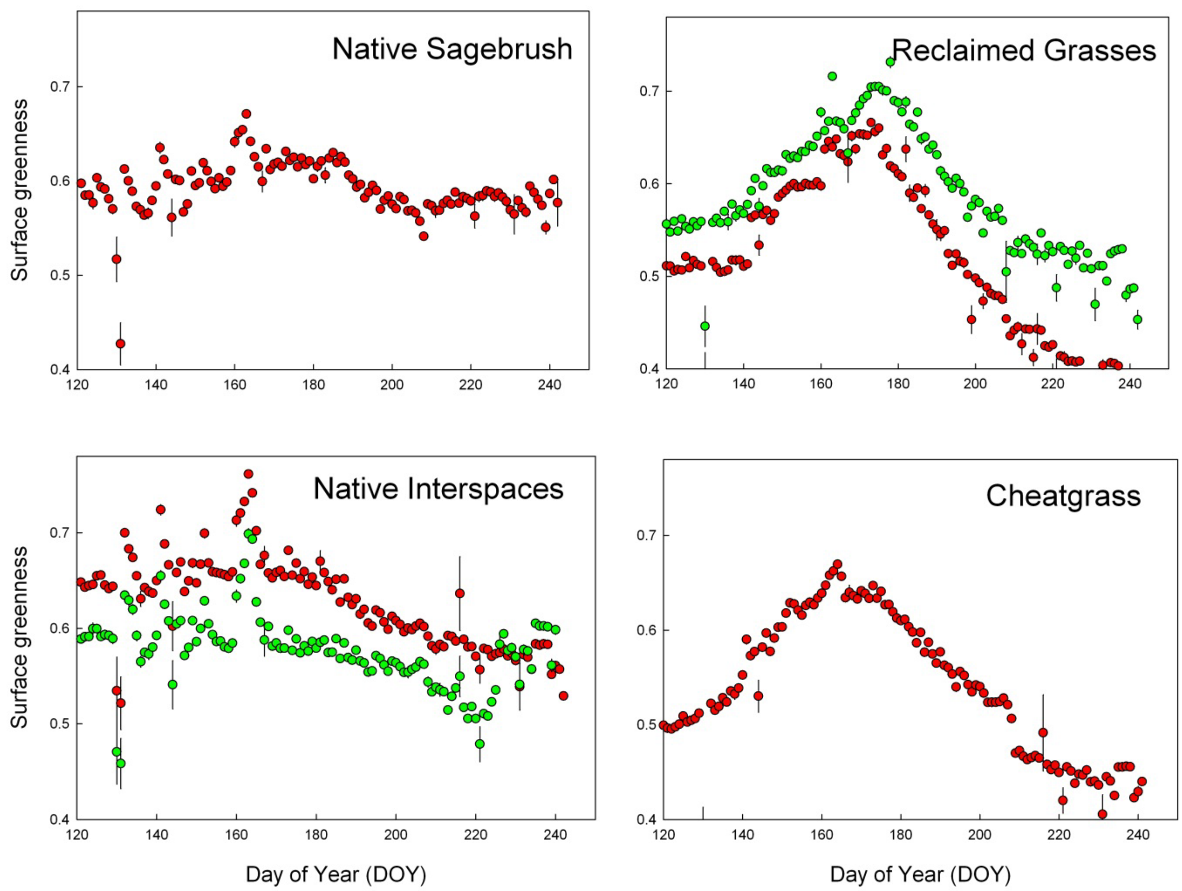

Figure 28. Scatter plots of the normalized difference vegetation index (NDVI; surface greenness; y-axis) calculated from near-surface reflectance from April 30 to September 1, 2010 [day of year (DOY); x-axis] on the Jonah Field, Wyoming. Each scatter line represents one sensor platform (seven were deployed, but one was for calibration, not for measuring NDVI, so six platforms are represented in the plots above).

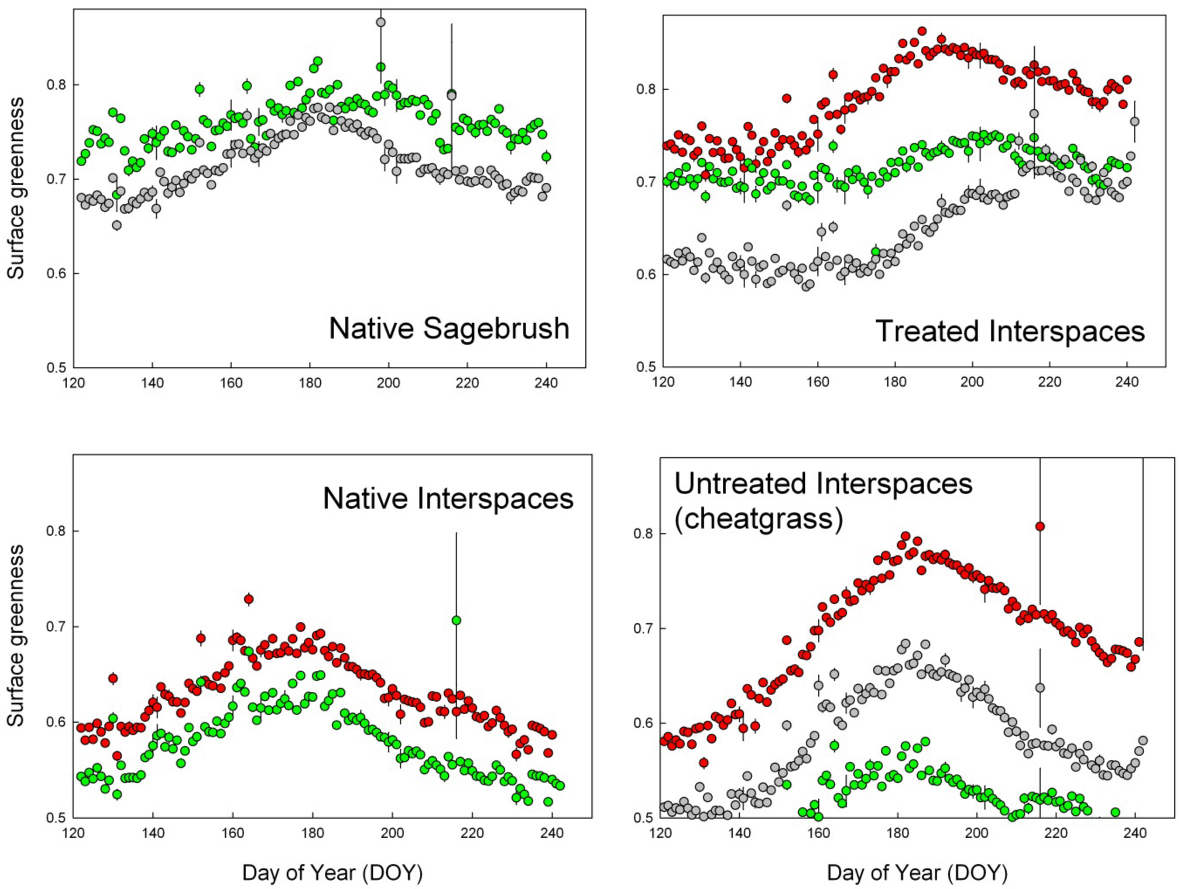

Figure 29. Mantis sensors were able to detect green-up, peak growth, and senescence near the Fall Creek elk feedground, Pinedale, Wyoming. Raw data from 10 sensors are plotted here. Calibrating data to account for individual variation between sensors would reduce the variation between replicate sensors. The normalized difference vegetation index (NDVI or surface greenness) indicates the greenness of the vegetation, which changes during the growing season (day of year [DOY], which started April 30, 2010, and ended September 1, 2010). U.S. Geological Survey scientists are gathering multiple satellite scenes for the site to test for correlations between the near-surface mantis reflectance data and the satellite data.

Products Completed in FY2011

- MSAccess and MSExcel datasets for reflectance data from 14 mantis platforms: one reading every 10 minutes over a 3-month deployment.
- Software to process the datasets for QA/QC and preparation for data analyses (beta version).
- USGS Fact Sheet (*http://pubs.usgs.gov/wlci/fs/3/*): What are plants doing and when? Using plant phenology to promote sustainable natural resources management. Geneva Chong and Leslie Allen, contacts.

- Chong, G.W., Prihodko, L., Steltzer, H. and Barnett. T., (organizers: competitive selection process for an organized oral session that included 10 presentations), 2011, Heralding change: How can plant phenology be used to facilitate natural resources management? Organized Oral Session 9, 96th Ecological Society of America Annual Meeting, August 7–12, 2011, Austin Convention Center, Austin, Tx.
- Steltzer, H., Shory, R., Chong, G.W., Brooks, D.R., Landry, C., von Fischer, J.C., and Weitraub, M,N., 2011, Observing plant community life histories and their response to environmental change. Organized Oral Session 9, 96th Ecological Society of America Annual Meeting, August 7–12, 2011, Austin Convention Center, Austin, Tx.
- Shory, R., Steltzer, H., Chong, G.W., et al. 2011. Data management to promote cross-site research on plant life history responses to environmental change. Organized Oral Session 9, 96th Ecological Society of America Annual Meeting, August 7–12, 2011, Austin Convention Center, Austin, Tx.
- USGS/National Association of Geoscience Teachers Intern: G. Chong was selected to have her 3rd USGS/National Association of Geoscience Teachers (NAGT) intern for WLCI work; however, the candidate accepted a position with the BLM before starting the position. Chong's USGS/NAGT proposal for FY2012 was accepted. This internship provides 6 weeks of salary from USGS headquarters for the intern.
- National Aeronautics and Space Administration Intern: Geneva Chong was selected by Anika Petach, Harvard University, to serve as mentor for her fully-funded National Aeronautics and Space Administration internship (with Jeff Pedelty, Goddard Space Flight Center). Anika is working on analyses to test for correlations between near-surface and remotely sensed NDVI and will continue this work in FY2012.
- Digital photos from plots and mantis deployments.

Work Planned for FY2012

In FY2012, analyses of the FY2010 and FY2011 phenology and plot data will continue. The mantis platforms will be re-deployed in conjunction with other on-going WLCI projects, likely in relation to reclamation and other habitat treatments and, hopefully, in areas scheduled for QuickBird satellite data acquisition (with Collin Homer and Cameron Aldridge). At least one manuscript on the sensor data will be prepared for publication in a peer-reviewed journal. The sensor data results will be presented for at least one international meeting, and the USGS will continue to communicate this work opportunistically with other WLCI cooperators.

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

Status

New in FY2011; project status for FY2012 unknown—depending on funding

Contact

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Scope and Approaches

Land-management agencies in the WLCI region require objective, detailed information about dynamic vegetation characteristics when evaluating habitat conditions and trends. Assessing the efficacy and duration of management activities has been problematic due to a lack of high-resolution spatial and temporal data capable of revealing patterns in vegetation response and changes in forage production. Vegetation indices, such as the NDVI, derived from satellite-based remotely-sensed data can be used to monitor seasonal and inter-annual changes in plant phenology and biomass associated with habitat-altering activities and climate conditions. Until recently, however, it was impractical to conduct such investigations across large spatial extents at fine temporal and spatial scales.

New data-fusion methods that blend high-frequency temporal data provided by MODIS (Moderate Resolution Imaging Spectroradiometer) sensors and high-resolution spatial data available via the Landsat platforms can provide the fine-resolution spatiotemporal data required to evaluate habitat responses to management activities at the landscape level. This method has been applied successfully to heterogeneous landscapes, including forested areas, cropland, and a mixture of forest and cropland (Gao and others, 2006), but it remains untested in semi-arid, shrub steppe-dominated areas. This focus of this study is to test the efficacy of that approach for a portion of Southwest Wyoming. If proven effective, this technique would facilitate the monitoring of changes in plant phenology and biomass at a spatial and temporal resolution not previously possible for the WLCI region.

For this retrospective analysis, free, downloadable satellite imagery consisting of cloud-free Landsat TM and Terra MODIS scenes collected from May through October, 2006, will be used. The STARFM (Spatial Temporal Adaptive Reflectance Fusion Model) algorithm will be used to predict TM reflectance values based on spatially weighted differences between paired TM and MODIS scenes collected on the same day and a MODIS scene collected on the prediction date. Twenty prediction scenarios with varied input and prediction dates will be investigated. The spectral quality of each predicted Landsat image will be assessed for the red and near-infrared bands on a per-pixel basis, based on the difference between actual and predicted reflectance values, and then a pixel-based regression analysis will be used to determine the relationship between observed and predicted reflectance values.

Subsequently, synthetic NDVI estimates will be calculated by using the reflectance values of each predicted TM scene and stratified by land cover/land use. The spectral quality of each set of NDVI estimates will be assessed on a per-pixel basis, based on the difference between actual and predicted NDVI values. Finally, pixel-based regression analysis was used to determine the relationship between observed and synthetic NDVI values.

Objectives

- Acquire and process cloud-free Landsat Thematic Mapper (Path 38 Row 31) and Terra MODIS (Horizontal 09 Vertical 04) scenes collected during the 2006 growing season (May–October).

- Assess the quality of predicted surface reflectance data produced by fusion of Landsat TM and Terra MODIS images through cross comparison of paired daily synthetic and actual surface reflectance values.
- Assess the quality of predicted NDVI data, stratified by land cover/land use, through cross comparison of paired daily synthetic and actual NDVI values.

Study Area

A Landsat TM scene, coincident with extensive sagebrush steppe, aspen, and mountain shrub habitats managed by the BLM Kemmerer Field Office, Fossil Butte National Monument, the Bridger-Teton National Forest, and the Cokeville National Wildlife Refuge, defined the spatial extent of the study area (fig. 30). The methods developed and evaluated can be applied to the entire WLCI region.

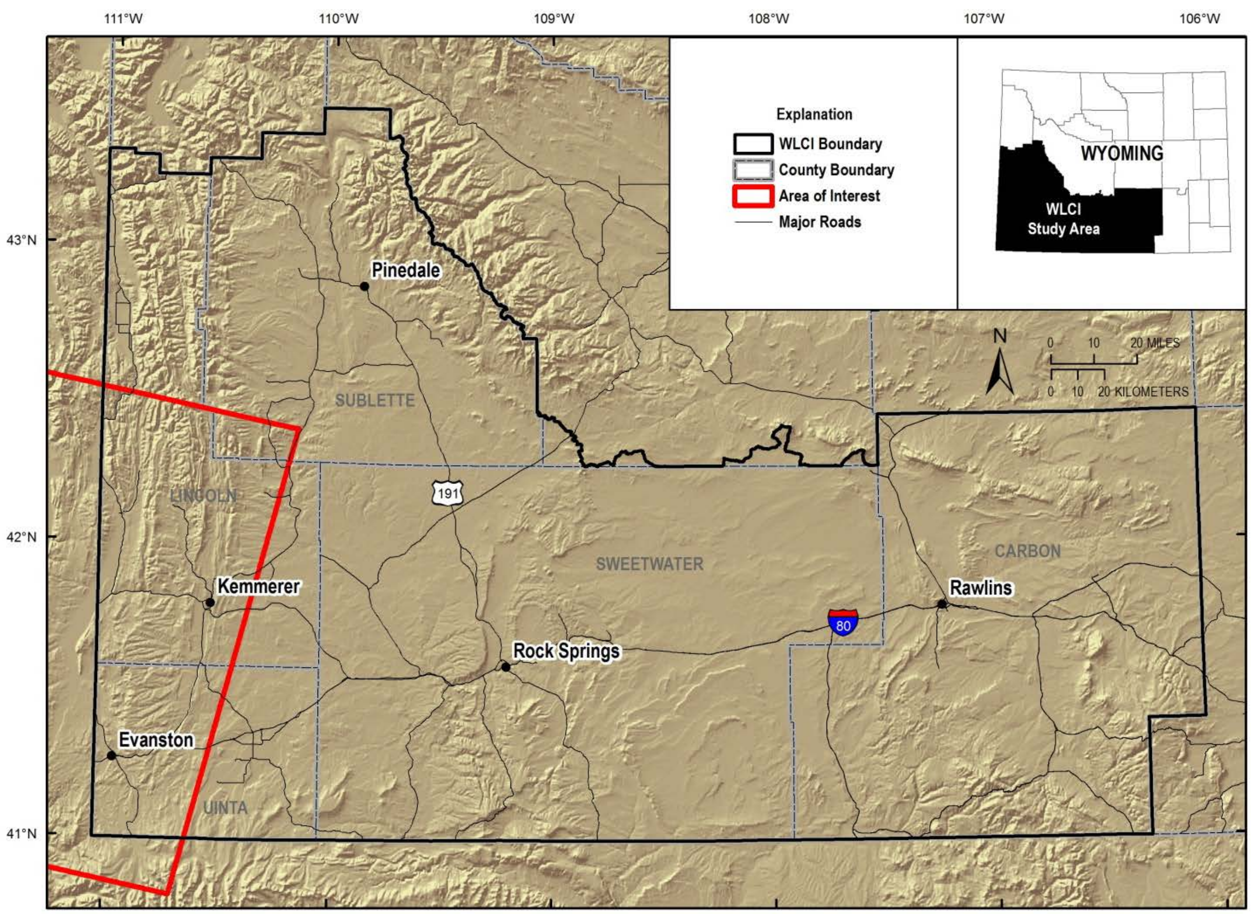

Figure 30. Extent and location (Landsat Path 38 Row 31) of area used to evaluate the accuracy of predicted reflectance and Normalized Difference Vegetation Index (NDVI) values produced by Landsat-MODIS data fusion.

Work Accomplished in 2011 and Findings

Two time-series of satellite imagery consisting of 5 Landsat TM and 41 Terra MODIS scenes were acquired, processed to at-surface reflectance values, and spatially and radiometrically subset. Twenty sets of synthetic data consisting of red and near-infrared reflectance values and NDVI estimates were produced by applying the STARFM data fusion algorithm to five Landsat-MODIS date-pairs. Statistical data analysis methods for very large raster datasets were identified and scripts were developed to examine the effect of varying the start and prediction dates. NDVI products were stratified by land cover type and further analyzed.

The STARFM algorithm successfully predicted reflectance and NDVI values across the study area. Estimates correlated well with measured values and were reasonably accurate and unbiased when prediction dates were near the date of the paired Landsat-MODIS image set. Results from a single prediction scenario are provided in Table 5. The strength of these relationships decreased as time increased between the date-paired set and the prediction date. The performance of the data-fusion process also varied among land cover types. For example, NDVI estimates associated with steppe and sagebrush shrubland cover types were highly correlated with known values, whereas those associated with cropland and pasture/hay exhibited a weaker relationship (fig. 31).

Products Completed in FY2011

- Olexa, E.M., Lawrence, R.L., and Watts, J.D., 2011, Filling the gaps—Using STARFM to create synthetic Landsat images for dates when Landsat imagery is unavailable [abstract submitted for the AmericaView 2011 Fall Technical Meeting, Cleveland, Oh., to be presented October 10–11, 2011].
- A database of preliminary NDVI accuracy results, stratified by land cover/land use, was provided to the BLM Kemmerer Field Office.

Table 5. Pixel-based regression and difference image results from Landsat TM and STARFM-predicted synthetic data. All predictions are based on a June 22, 2006, base pair of Landsat TM and Terra MODIS scenes.

Prediction date	TM band	r^2	Intercept	Slope	Mean absolute difference	Mean difference
June 06						
	Red	0.77	0.01	0.79	0.015	-0.010
	NIR	0.81	0.03	0.89	0.021	0.005
	NDVI	0.88	0.07	0.95	0.063	0.047
August 09						
	Red	0.84	0.02	0.85	0.016	0.003
	NIR	0.78	0.04	0.81	0.024	-0.003
	NDVI	0.82	0.02	0.89	0.066	-0.025
September 26						
	Red	0.72	0.03	0.64	0.025	-0.016
	NIR	0.66	0.07	0.62	0.047	-0.032
	NDVI	0.68	0.02	0.91	0.082	-0.014
October 12						
	Red	0.52	0.03	0.51	0.041	-0.033
	NIR	0.44	0.05	0.52	0.084	-0.068
	NDVI	0.36	0.05	0.78	0.126	-0.034

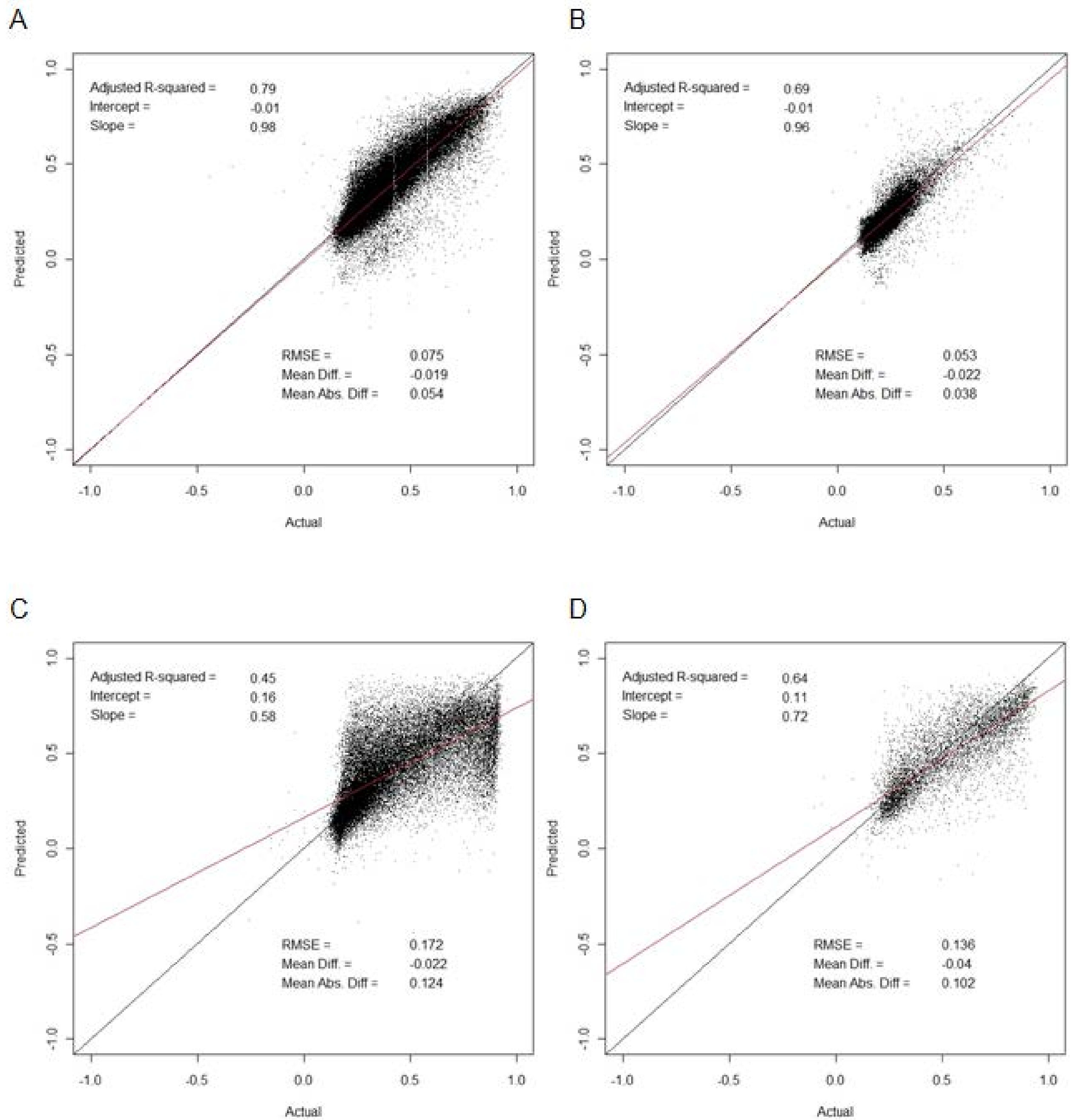

Figure 31. Per-pixel comparison of observed normalized difference vegetation index (NDVI) values versus those predicted for August 9, 2006 using a Landsat-MODIS image pair collected on June 22, 2006. Accuracy and bias estimates from the the associated difference image are also presented. A, B, C, and D indicate the steppe, sagebrush shrubland, cropland, and pasture/hay land cover-land use types, respectively.

Work Planned for FY2012

A Northern Rocky Mountain Science Center Information Sheet highlighting the data-fusion process and its application to semi-arid, shrub-steppe dominated areas is in preparation and will be published in 2012. This work and the FY2011 results will be presented at the AmericaView 2011 Fall Technical Meeting in Cleveland, Oh., October 10–11, 2011. A dense time series of synthetic NDVI products also will be developed based on the suite of 2006 MODIS scenes.

Funding for continuing this work in FY2012 remains uncertain; however, continued support would permit the testing of fusion products developed from several years of additional imagery, and the development of related dense time series of NDVI products needed to identify intra- and inter-annual changes in plant biomass and phenology. Collaborative work with the BLM Kemmerer Field Office will continue to identify pasture and treatment areas to evaluate with the synthetic imagery.

Greater Sage-Grouse Use of Vegetation Treatments

Status

Ongoing

Contact

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Scope and Approaches

Members of the WLCI LPDTs have raised questions about whether sage-grouse are benefiting from past vegetation treatments, and if so, which treatment types (for example, prescribed burns, mowing, or herbicide applications) best support the birds' habitat needs. This work activity is designed to answer these and related questions by evaluating sage-grouse use of past and current vegetation treatments. More specifically, this work evaluates how treatment components (treatment types, treatment designs, treatment location, and ecological variation among sites) might influence seasonal use and foraging behavior by sage-grouse.

Moxa Arch Infill Natural Gas Development Project (hereafter, Moxa Arch) is located in the western WLCI study area (fig. 26). As part of the BLM Pronghorn Habitat & Livestock Forage Mitigation Plan for Moxa Arch, numerous vegetation treatments (mowing and applications of herbicide) were conducted from 1997 through 2002 in the Moxa Arch Sagebrush Treatment Area (figs. 26 and 32). 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 habitats that represented habitats selected by pronghorn, and by sage-grouse for nesting and early brood rearing. Treatment sites were dominated by Wyoming big sagebrush, and treatment types included mowing and applications of the herbicide, tebuthiuron (Spike®). Vegetation surveys of treated sites were conducted in June, 2008 by Wyoming Wildlife Consultants, LLC, to ascertain potential short- and long-term effects of these treatments on nesting and early brood-rearing habitat suitability for sage-grouse (Holloran, 2009). Holloran (2009) concluded that, over time, mowing treatment may be suitable for sage-grouse by enhancing herbaceous cover in nesting and early brood-rearing habitats, especially at locations with loamy soils. Holloran (2009) further concluded that sites with characteristics similar to those in the herbicide-treated areas should be treated with tebuthiuron only cautiously or avoided altogether because these treatments resulted in greater cover of invasive forbs and grasses.

In 2009, the USGS initiated a long-term study at Moxa Arch to evaluate (1) sage-grouse use of mowed and tebuthiuron-treated areas and (2) whether the birds are responding to differences in vegetation composition, treated patch size, patch shape, distance to edge, distance between treated patches and occupied leks (assembly areas for communal courtship display), and influence of energy infrastructure. 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. In 2010, the spatial extent of this study was expanded to include all vegetation treatments in the Moxa Arch Sagebrush Treatment Area (fig. 32).

Both treated and adjacent, untreated "control" sites were located on BLM lands. To measure sage-grouse use, pellet counts were conducted within 4- × 100-meter belt transects established within treatment and control sites. In late May 2009, 44 transects were established at sites treated with herbicide or mowing at Cow Hollow and Ziegler's Wash, and during May and June 2010, 85 additional transects were established within Zeigler's Flats, Hampton, Fontenelle, Dodge Rim, and Seven Mile Gulch treatment sites (fig. 32). Transects established for sampling treatment sites were randomly located and stratified by treatment type, treatment location, distance to treatment edge, and distance to nearest lek. Transects established for sampling untreated areas were randomly located within 500 m of treatment areas. Individual pellets (indicative of a bird moving while foraging), pellet piles (indicative of roosting), clocker droppings (indicative of females nesting nearby), and cecal casts (indicative of the terpenes in sagebrush-dominated diet) were counted within each belt transect. All pellets within belt transects and 0.5 m beyond each belt transect were removed after each survey. In spring, reconnaissance surveys were conducted within 5 m of each belt transect perimeter to record nests, eggshells, and clocker droppings as indicators of nearby sage-grouse nesting activity. Pellets were not removed from reconnaissance survey areas.

Objectives

- Assess the treatments of sage-grouse habitats and their ability to maintain or increase sage-grouse distribution.
- Evaluate use of sagebrush vegetation treatments by sage-grouse during early and late brood-rearing periods.
- Determine differences in use by sage-grouse between sagebrush areas treated with herbicides, mowing, or prescription burning.
- Evaluate the spatial and temporal relationship between placement of vegetation treatments and the centers of sage-grouse activity.
- Evaluate sage-grouse habitat use with respect to distance from nearest road, well pad, or other related infrastructure.
- Evaluate how patch size, shape, and distribution influence the use of treatment sites by sage-grouse.
- Evaluate sage-grouse use of treatment areas and distance to the edge of a given treatment area.
- Correlate vegetative structure with sage-grouse pellet counts.

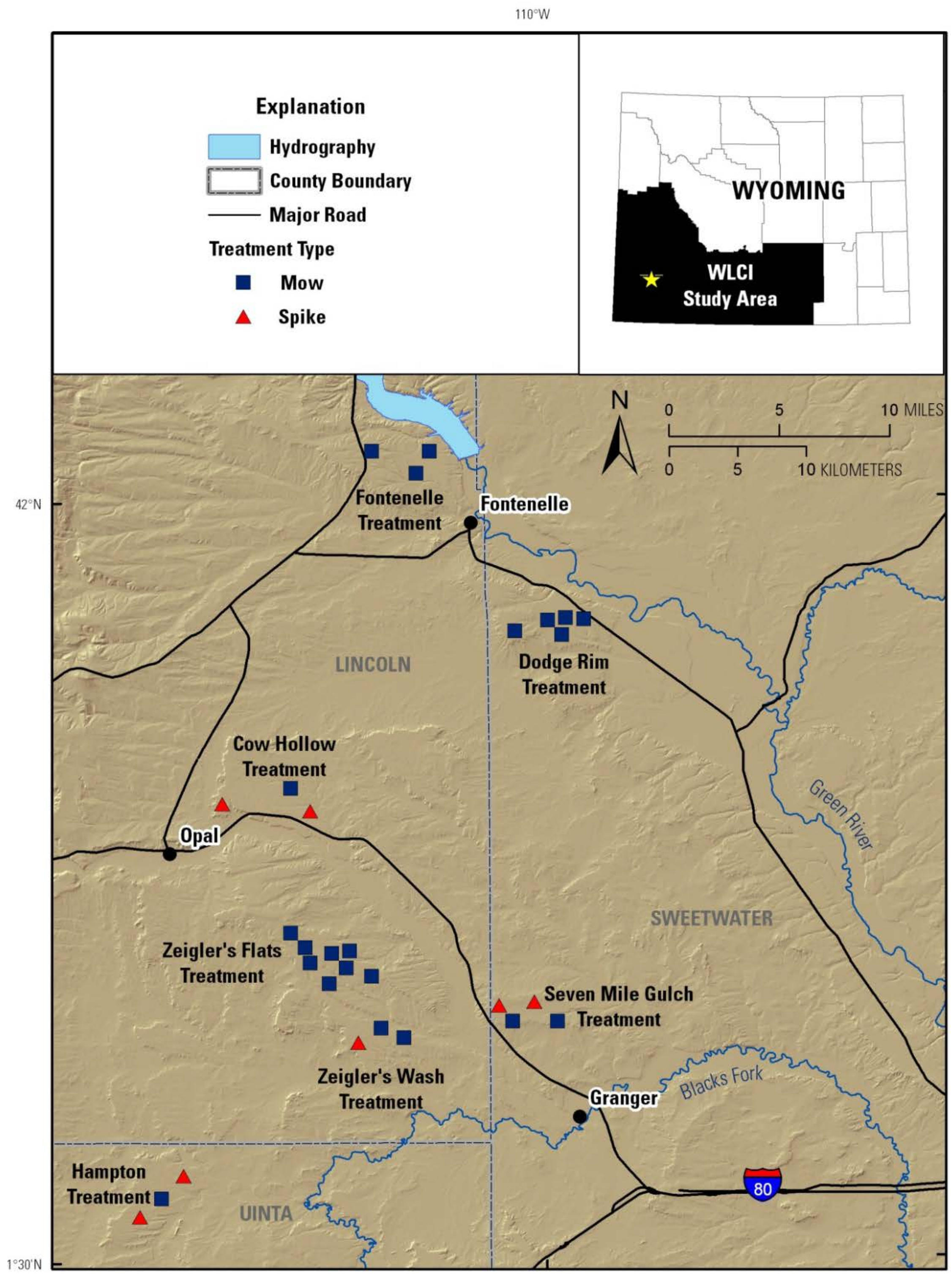

Figure 32. Locations of vegetation mowing and herbicide (tebuthiuron, trade name Spike®) treatment sites in the Moxa Arch Natural Gas Development Project Area in Southwest Wyoming.

Study Area

The Moxa Arch treatment area, encompassed by portions of Sweetwater, Lincoln, and Uinta Counties, is approximately 476,300 acres of mixed Federal, State, and private lands (figs. 26 and 32). Within the treatment area, there are seven general project areas located near the towns of Opal and Granger, Wyo. (figs. 26 and 32), where predominantly Wyoming sagebrush was treated with either (1) tebuthiuron or (2) mowing. Treatment information (treatment type, year treatments were conducted, acreage treated, and pattern of treatment features) are provided in Table 6. The dominant shrub within the treated and adjacent untreated areas is Wyoming big sagebrush, followed by a mix of smaller shrubs, including shadscale saltbush (*Atriplex confertifolia*), Gardner's saltbush (*Atriplex gardneri*), spiny hopsage (*Grayia spinosa*), winterfat (*Krascheninnikovia lanata*), and shortspine horsebrush (*Tetradymia spinosa*). Common forbs growing in the study area include milkvetch (*Astragalus* spp.), fleabane (*Erigeron* spp.), dwarf goldenweed (*Stenotus acaulis*), stoneseed (*Lithospermum* spp.), desert parsley (*Lomatium foeniculaceum*), globemallow (*Sphaeralcea coccinea*), halogeton (*Halogeton glomeratus*), and prickly-pear cactus (*Opuntia polyacantha*). Common grasses growing in the area include Indian ricegrass (*Achnatherum hymenoides*), Sandberg bluegrass (*Poa secunda*), squirreltail (*Elymus elymoides*), needle and thread (*Hesperostipa comata*), thickspike wheatgrass (*Elymus lanceolatus*), and crested wheatgrass (*Agropyron cristatum*). The invasive species, crested wheatgrass and halogeton, were observed primarily in areas treated with tebuthiuron and in association with energy-related development (well pads, roads, and pipelines) located within treatment areas.

Table 6. Vegetation treatments conducted within the Moxa Arch Natural Gas Development project area, 1997–2002.

Treatment area[1]	Treatment type	Year treatment conducted	Acres treated	Treatment pattern (number of areas)
Ziegler's Wash	Mow (more than 6 inches)	January 1997	485	Large polygons with narrow unmowed strips
Ziegler's Wash	Tebuthiuron	October 1997	460	Large polygon
Ziegler's Flats	Mow (8–10 inches)	Fall 2001	525	Multiple long narrow mosaic strips
Hampton	Mow (6–8 inches)	October 1998	314	Multiple long and short narrow mosaic strips
Hampton	Tebuthiuron (0.2–0.3 lbs./acre)[2]	October 1999	1140	Two large polygons
Fontenelle (west)	Mow (10 inch)	October 2002	230	Large polygon
Fontenelle (east-a)	Mow (4–6 inches)	October 2002	221	Large polygon
Fontenelle (east-b)	Mow (4–6 inches)	October 2002	341	Large polygon
Seven Mile Gulch	Mow (8–10 inches)	October 1998	245	Multiple long and short narrow mosaic strips
Seven Mile Gulch	Tebuthiuron (0.2–0.3 pounds per acre)	October 1999	530	2 large polygons
Dodge Rim	Mow (8–10 inches)	Fall 2000	436	Multiple long narrow mosaic strips
Cow Hollow	Mow (about 4–6 inches)	October 1997	138	Multiple long wide mosaic strips
Cow Hollow	Tebuthiuron	October 1997	425	2 large polygons

[1] Locations of treatment areas are shown in Figure 32.

[2] Project leads noted that the calibration of the applicator was off, so actual application rate may have been higher.

Work Accomplished in 2011 and Findings

Pellet count surveys were conducted during sage-grouse early brood (April 28–May 12), late brood rearing (July1–July 21), and fall (September 7–September 29). Individual foraging pellets, roost piles, brood pellets, hen clockers, and cecal casts were counted and collected within each belt transect. The presence of clockers and brood pellets and evidence of nesting were documented 2 m beyond the entire boundary of each belt transect; subsequently, clockers and brood pellets were removed. Vegetation measurements and soil samples were collected June 1–August 7 from a random point on each of 80 of the pellet belt transects. These locations represent pellet survey transects with the highest and lowest sage-grouse use based on pellet counts. Measurements included plant species richness, abundance of native and invasive herbaceous plants and shrubs, vegetation height, and percent cover. Soil samples were collected at these sites to determine soil texture (table 7). Soils samples were collected at a depth of 10 cm. Soil texture analysis (hydrometer method) was conducted at the Soil-Water-Plant Testing Laboratory at Colorado State University.

Products Completed in FY2011

- 2011 vegetation dataset with plot photos.
- Revised 2011 pellet transect data.
- Soil texture data.

Work Planned for FY2012

Seasonal monitoring of sage-grouse use within the Moxa Arch habitat treatment areas will continue and preliminary analyses of pellet survey and vegetation data will be conducted. In addition, the 2009–2011 pellet transect database will be revised with the 2012 data.

Table 7. Percent sand, silt, and clay, and texture (assessed using the hydrometer method), of soils at mowed and tebuthiuron-treated sites and in adjacent, untreated controls sites within the vegetation treatments areas of the Moxa Arch Natural Gas Development Project vegetation treatment areas.

Treatment area	Treatment type	Sand	Silt	Clay	Soil texture
Cow Hollow	Mow	45.6	25.2	29.2	Sandy clay loam
Cow Hollow	Mow reference	51	20	29	Sandy clay loam
Cow Hollow	Tebuthiuron	48.8	22	29.2	Sandy clay loam
Cow Hollow	Tebuthiuron reference	44	27	29	Clay loam
Dodge Rim	Mow	58	13.2	28.8	Sandy clay loam
Dodge Rim	Mow reference	64	9	27	Sandy clay loam
Fontenelle A	Mow	48.0	22.7	29.3	Sandy clay loam
Fontenelle A	Mow reference	42.0	26.0	32.0	Clay loam
Fontenelle B	Mow	57	17	26	Sandy clay loam
Fontenelle B	Mow reference	48	18	34	Sandy clay loam
Fontenelle (west)	Mow	41.6	27.2	31.2	Clay loam
Fontenelle (west)	Mow reference	48	23	29	Sandy clay loam
Hampton	Mow	46.3	23.0	30.7	Sandy clay loam
Hampton	Tebuthiuron	47.6	23.6	28.8	Sandy clay loam
Hampton	Reference for mow and tebuthiuron	38	33	29	Clay loam
Seven Mile	Mow	59	11.7	29.3	Sandy clay loam
Seven Mile	Tebuthiuron	48.8	19.6	31.6	Sandy clay loam
Seven Mile	Reference for mow and tebuthiuron	52.0	16.0	32.0	Sandy clay loam
Ziegler's Flats	Mow	37.4	30.2	32.4	Clay loam
Ziegler's Flats	Mow reference	34	29	37	Clay loam
Ziegler's Wash	Mow	46.4	22.4	31.2	Sandy clay loam
Ziegler's Wash	Mow reference	50	20	30	Sandy clay loam
Ziegler's Wash	Tebuthiuron	48	21.2	30.8	Sandy clay loam
Ziegler's Wash	Tebuthiuron reference	48	24	28	Sandy clay loam

Occurrence of Cheatgrass Associated with Habitat Projects in the Little Mountain Ecosystem

Status

Completed

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Scope and Approaches

The spread of cheatgrass was identified by the WLCI LPDTs as a serious threat and a high priority for WLCI managers. Team members also wanted to know whether past habitat treatments were effective in restoring ecological function and stability. This is of particular interest in areas with potential for cheatgrass invasion, because treatments either could promote systemic resistance to cheatgrass invasion or lead to greatly reduced habitat quality. Wildfires and prescribed burns have been linked with the expansion of cheatgrass in similar systems in the Great Basin; however, in some situations, burning has been documented to support more stable plant communities that resist cheatgrass and other invasive plant species (Shinneman and Baker, 2009). Differentiating effective and ineffective treatments, based on environmental and management-induced conditions, should help alleviate concerns about similar future habitat projects (especially prescribed burns) by evaluating the effectiveness of previous efforts.

Since 1990, numerous restoration and enhancement projects have been implemented in the Little Mountain Ecosystem (fig. 26). Many of these projects involved prescribed burns to reduce sagebrush cover and increase herbaceous cover, retard the expansion of junipers (*Juniperus* spp.) into sagebrush habitat, and reduce conifer encroachment in aspen stands. To address questions about the role of habitat treatments in the occurrence and distribution of cheatgrass in the Little Mountain Ecosystem, the USGS is measuring vegetation within a representative sample of former treatment areas. Long, narrow belt-transects were randomly distributed across burn treatments using a stratification of size classes (mean areas for the four size classes, from smallest to largest, were 7 km^2, 287 km^2, 954 km^2, and 14,387 km^2). The field protocols are based on another ongoing USGS study to model invasive species and major disturbance features across Southwest Wyoming. By incorporating these protocols, it will be possible to compare the distribution of cheatgrass in burn areas to the distribution of weeds across the region and to other disturbance features in Southwest Wyoming. The original protocol was augmented to include soil sampling (for determining soil texture) and documenting the presence of biological soil crusts. Biological soil crusts, which can be disturbed through burning, are thought to help resist invasive species; therefore, a lack of crust may be associated with increased invasion potential. A second component of this research is to assess the ability of biological soil crusts to resist cheatgrass at unburned sites. Twelve multi-scale, long-term monitoring plots (5 × 10 m) were established in Firehole Canyon south of Rock Springs, Wyoming, where cheatgrass has been expanding. Vegetation measurements will be repeated in subsequent years to track trends associated with the interaction between biological soil crusts and cheatgrass.

Objectives

- Evaluate occurrence of cheatgrass and other invasive plants with past and proposed habitat projects.

- Evaluate the ability of stable vegetative communities and biological soil crusts to resist cheatgrass expansion on burned and unburned plots.
- Compare distribution patterns of invasive species from burned treatments to a range of other disturbances in Southwest Wyoming.
- Determine prevalence of cheatgrass and other invasive species associated with human disturbance (for example, roads) associated with project areas.

Study Area

The study area is located within the Little Mountain Ecosystem south of Rock Springs, Wyo. (fig. 26). This area is defined as land bounded by Wyoming Highway 430 on the east, Interstate 80 on the north, Flaming Gorge Reservoir on the west, and the Wyoming-Colorado state line on the south. Sagebrush, mountain shrub, and aspen communities are interspersed throughout the area. Firehole Canyon is located in the northern portion of the Little Mountain Ecosystem south of Rock Springs (fig. 33).

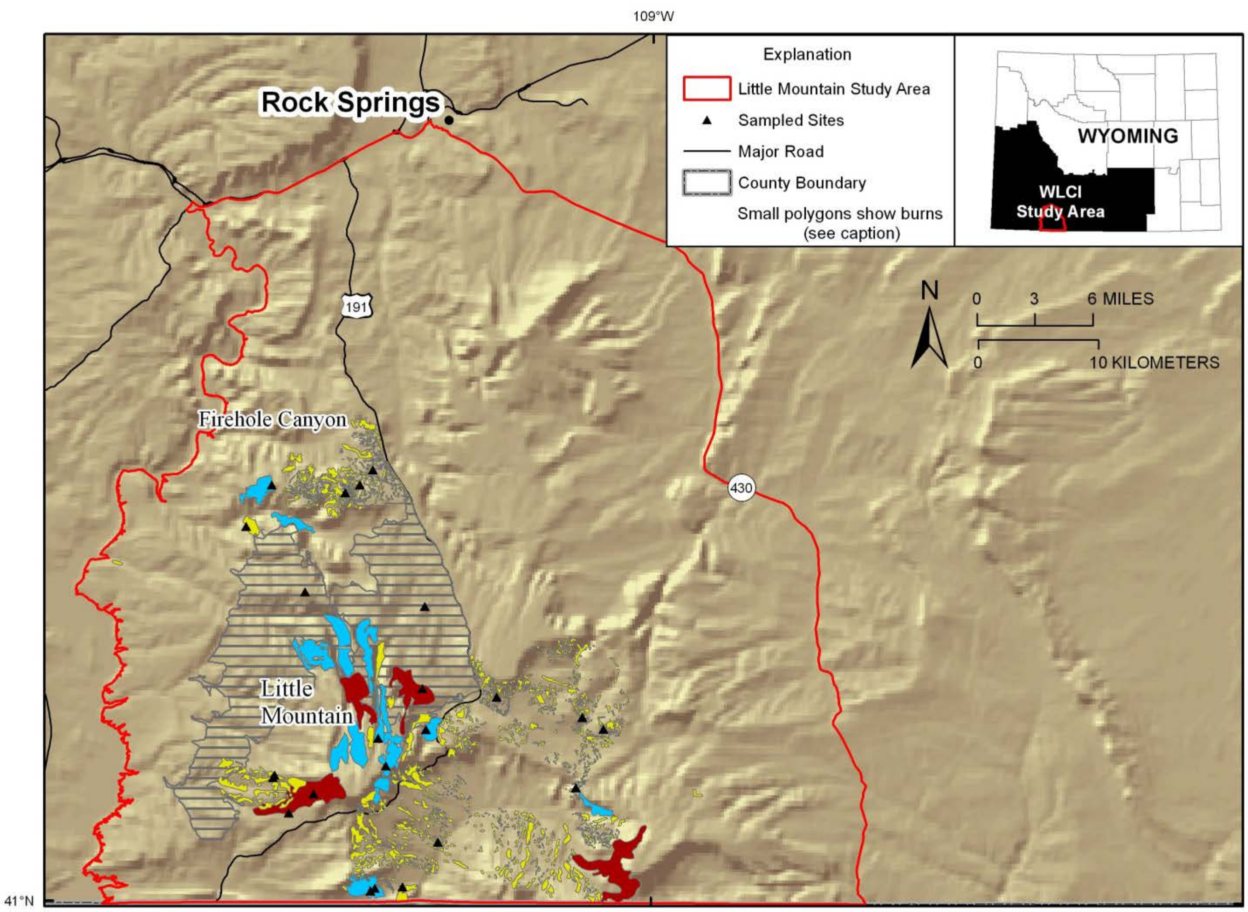

Figure 33. The distribution of recent fires (colored polygons) and sample units (black triangles) included within the Little Mountain Ecosystem, near Rock Springs, Wyoming. The distributions of cheatgrass and other invasive species are being investigated using a stratified random sampling design across these areas to differentiate effects of fires (wildfire and burn treatments) and environmental patterns on plant invasion and persistence of biological soil crusts. Colored polygons represent burned areas based on the size classes described in Table 6.

Work Accomplished in 2011 and Findings

In 2010, 12 multi-scale, long-term monitoring macroplots (5 × 10 m) were randomly placed in Firehole Canyon, Wyo. (Bowen and others, 2011). Within each macroplot, 12 subplots (50 × 50 cm) were randomly placed. From July 26–August 9, 2011, the number of stems (for woody and herbaceous plant species) and the percent cover of biological soil crusts within each subplot were recorded, and each subplot was photographed. Each macroplot was searched for any additional invasive or native species not recorded in the subplots of a given macroplot. Eleven of the 12 plots were monitored successfully. In the 12th macroplot, the subplot stakes had been disturbed; the stakes were replaced, however, for future monitoring efforts.

During the 2011 field season, six species of introduced plants were identified in the macroplots: cheatgrass, bur buttercup (*Ceratocephala testiculata*), halogeton, (*Halogeton glomeratus*), clasping pepperweed (*Lepidium perfoliatum*), desert alyssum (*Alyssum desertorum*), and flixweed (*Descurainia sophia*). Cheatgrass and bur buttercup were the most abundant species.

Products Completed in FY2011

- Revised draft 2010 vegetation dataset with 2011 data and photos.

Work Planned for FY2012

During FY2012, monitoring of invasive and native plant species will continue at the multi-scale plots in the Little Firehole Canyon area of the Little Mountain Ecosystem.

Application and Feasibility of Mapping Aspen Stands and Conifer Encroachment Using Classification and Regression Tree (CART) Analysis for Effectiveness Monitoring

Status

Completed; preliminary objectives have been met, although there may be additional work in the future (depending on funding), in which case it would be reported as a new project

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Scope and Approaches

Restoration and maintenance of aspen communities is a BLM priority in the Little Mountain Ecosystem (figs. 26 and 33), and the USGS has been working with the BLM and the WGFD to monitor aspen stands in that area as part of its WLCI Effectiveness Monitoring work. LANDFIRE and ReGAP maps are considered the best spatial products for representing aspen distribution at regional and landscape scales; however, these products were not designed to support decisions at localized scales, such as that of the Little Mountain Ecosystem. In 2010, this study filled a critical information gap with production of a model (fine-scale map) that delineates aspen distribution for the Little Mountain Ecosystem. To accomplish this, we used classification and regression tree (CART) analysis applied to uncompressed National Agriculture Imagery Program (NAIP) color-infrared imagery. (Imagery is compressed to reduce the image file sizes, but this can introduce error and a loss of data. Furthermore, uncompressed imagery is necessary for machine analysis used by remote-sensing software.) Although our effort was successful, we identified several shortfalls in the method that would make it untenable for mapping aspen stands across large areas, such as the entire WLCI study area. The two primary limitations of the CART method developed in 2010 were (1) the amount of noise associated with the fine-scale resolution (1 m) of the imagery, and (2) the large sizes of input files, which limits the transferability of this method at the landscape scale. To address these limitations, we modified the methodology developed in 2010 and applied it to SPOT 5 imagery (10-m resolution).

The modified method entailed using photographs and stand-evaluation data collected in 2010 (July) and 2011 (June and August) in the Little Mountain Ecosystem to inform the development of data we used to "train" the model. Two cloud-free SPOT 5 scenes of the Little Mountain area, preprocessed to level 1T (terrain-corrected data), were obtained from the USGS EarthExplorer archive (*http://edcsns17.cr.usgs.gov/NewEarthExplorer/*). We then conducted a temporal analysis of summer imagery (aspen leaf-on) and autumn imagery (aspen leaf-off) to improve delineation of deciduous aspen trees from coniferous species, such as subalpine fir (*Abies lasiocarpa*) and Douglas-fir (*Pseudotsuga menziesii*). The leaf-on and leaf-off scenes had been acquired on September 7, 2010 and October 19, 2010, respectively. The imagery was georectified (root mean square error less than 0.5 pixel) and converted to Top-of-Atmosphere reflectance. This ensured proper radiometric calibration between the images, which is necessary for creating the high-quality data series needed for change-detection analysis (Chander and others, 2009).

To mask out non-woodland areas from the analysis, a woodland mask was developed from Landsat-derived NDVI representing the peak of the growing season (July 2010). For the training dataset, more than 250 points were randomly generated in the mapped woodland area, with an enforced minimum distance of 50 m between each point. Each point was manually classified as aspen, conifer, or non-woodland based on field data and aerial photos. For each training point, a series of covariates was generated from the satellite imagery and other biophysical features (table 8). CART was employed using the TREE package in the R Statistical Package (R Development Core Team, 2011). The fitted tree contained 15 nodes and had an overall accuracy of 89.9 percent. However, CART tends to generate complex and over-fit models (Brown and others, 2006), so a cross-validation procedure (prune tree function in R) was used to select a model that maximized the deviance explained while minimizing the misclassification error rate.

The final model had only 4 nodes but an overall accuracy of 86 percent. A smoothing algorithm (3 × 3 window) was applied to the data to remove isolated pixels and improve the interpretability of the map. Visual inspection of the classified map revealed that small, irrigated meadows were misclassified as aspen (seasonal reflectance values for aspen and irrigated meadows are similar); thus, aspen cover likely would be overestimated (false positive) if this methodology is applied in other areas. A new model was developed by using image texture as an additional covariate; however, this did not improve the classification, so we used expert knowledge of the study area to reclassify the irrigated meadows appropriately in the final map. The output map was converted from a raster dataset to the vector environment to ease usability for WLCI partners. Several attributes were calculated for each contiguous woodland patch type, including patch area and perimeter (fig. 34). We have distributed the dataset to our partners and will work with them to ensure proper interpretation and usability of the product.

Objectives

- Evaluate feasibility of CART analysis applied aerial imagery to produce a fine-scale aspen distribution map of Little Mountain.
- Provide USGS, land managers and LPDTs with empirical spatial information and map products on aspen communities to support the prioritization and implementation of aspen treatments across the study area.

- Develop the methodology for this approach and apply this method to other areas of the WLCI, such as the north and west slope of the Sierra Madre Range.
- Validate BLM burn-treatment map.

Table 8. Predictor variables considered and those used in the classification and regression tree analysis.

Predictor variable	Description	Source[1]	Included in final model
Leafb1	Leaf-on: SPOT Band 1 (green)	SPOT	Yes
Leafb2	Leaf-on: SPOT Band 2 (red)	SPOT	Yes
Leafb3	Leaf-on: SPOT Band 3 (near infrared)	SPOT	No
Leafb4	Leaf-on: SPOT Band 4 (short-wave infrared)	SPOT	No
Leafndvi	Leaf-on: Normalized Difference Vegetation Index	SPOT	No
Offb1	Leaf-off: SPOT Band 1 (green)	SPOT	No
Offb2	Leaf-off: SPOT Band 2 (red)	SPOT	No
Offb3	Leaf-off: SPOT Band 3 (near infrared)	SPOT	Yes
Offb4	Leaf-off: SPOT Band 4 (short-wave infrared)	SPOT	No
Offndvi	Leaf-off: Normalized Difference Vegetation Index	SPOT	No
Elev	Elevation Raster Dataset	NED	No
Slope	Slope Raster Dataset	NED	No
Eastness	Transformed Aspect Data; sin(aspect)	NED	No
Northness	Transformed Aspect Data; cos(aspect)	NED	No

[1] NED = 30-m National Elevation Dataset.

Study Area

The study area is associated with the Little Mountain Ecosystem south of Rock Springs, Wyo. (fig. 33). This area is bounded by Wyoming Highway 430 on the east, Interstate Highway 80 on the north, Flaming Gorge Reservoir on the west, and the Wyoming-Colorado state line on the south. Aspen communities are interspersed throughout the area at the higher elevations. The area surrounding Little Mountain was prioritized to meet monitoring needs while minimizing the amount of data needed to perform the modeling exercise.

Work Accomplished in 2011 and Findings

Supplementary training data were collected in June and August and additional photographs were added to the photo database that was created in 2010. This information was used to inform and execute the statistical classification process through identification of woodland areas and discrimination of aspen and conifer patches. The methodology was developed for this process to be applied to other areas. We developed and distributed to WLCI partners the metadata for the final woodland and patch size map.

A subjective evaluation based on field visits and inspection of NAIP imagery indicated that this process successfully identified woodland distribution and discerned aspen from conifer stands. Small woodland patches are characteristic of the Little Mountain Ecosystem, and this method is capable of identifying dense woodland patches less than one acre in size (fig. 34). Patch-size characteristics of

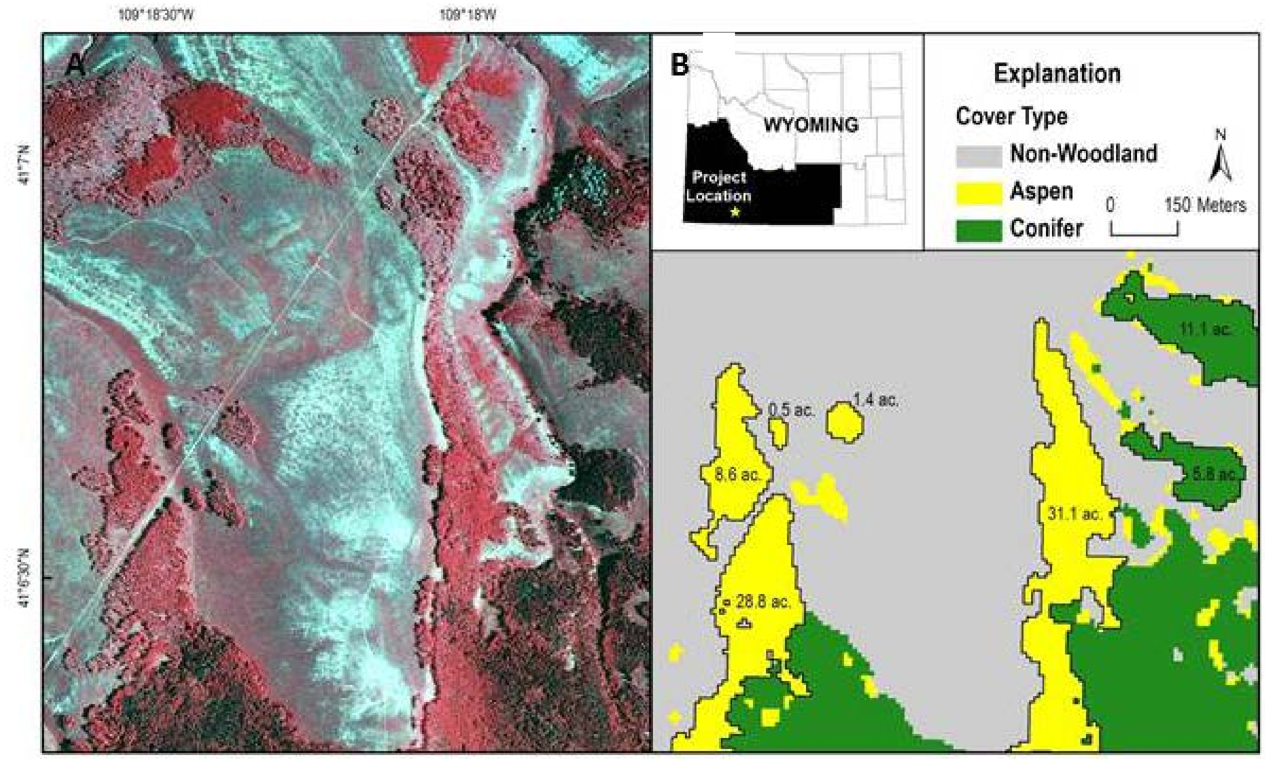

Figure 34. (A) National Agricultural Imagery Product imagery acquired in 2009 with contrast stretch of woodland patches characteristic of Little Mountain; (B) classified woodland map of the same area with size (acres) identified in several patches (black outline). Map credit: Tim Assal, U.S. Geological Survey.

woodlands at this scale were unknown prior to this baseline work. Methods shortcomings that we identified included overestimating aspen (false-positives) in steep draws and canyons and in irrigated meadows; however, these areas were minimal. Overall, the map fulfills the need for a fine-scale aspen map of the Little Mountain Ecosystem and was used to support sample-plot selection for effectiveness monitoring. In addition, the predictor variables (table 8) and methodology used in this study can be applied to other areas of the WLCI to map aspen distribution. These methods improve on the use of aerial photography, the input files of which are too large for landscape-scale mapping, apparently without compromising the results. The data associated with our new map provide context for the BLM's Little Mountain fire-treatment map. Preliminary work has identified that temporal remote sensing could improve the historical fire treatment map.

This remote-sensing method is not practical when imagery is affected by cloud cover (due to occlusion) or snow cover (due to excessive reflectance) during leaf-off periods; however, cloud-free, leaf-off SPOT imagery was not available for the Sierra Madre study area. Therefore, we provided our partners with enhanced aerial photography for use in this area. In the future, however, imagery collected during aspen foliage senescence likely could be substituted for leaf-off imagery.

Products Completed in FY2011

- Final map of aspen and conifer stands in Little Mountain Ecosystem to provide baseline information on their size, location, and so on.
- Map of Sierra Madre area of interest with contrast stretch applied to aerial photography to improve interpretation and delineation of aspen and conifer forest.
- Map used to support other tasks, such as informing sampling design for sample site selection.
- Methodology and covariates completed.
- Final map used to inform BLM fire-treatment map.

Work Planned for FY2012

There is no plan to continue this work in FY2012 because the development and application of CART analysis for mapping woodlands in the Little Mountain Ecosystem is complete. However, we will continue to develop associated and/or derived products in the future. We also will continue collaborating with WLCI partners to incorporate these products in planning, management, and effectiveness-monitoring tasks.

Aspen Regeneration Associated with Mechanical Removal of Subalpine Fir

Status

Ongoing

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Scope and Approaches

The WLCI has supported numerous aspen treatments in the Sierra Madre Range to reduce conifer densities, increase aspen regeneration, and diversify stand dynamics. Specifically, mechanical removal of subalpine fir and lodgepole pine (*Pinus contorta*) has taken place on approximately 100 acres in the Medicine Bow National Forest. WLCI partners are seeking information on how aspen and under-canopy vegetation have responded to the 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 removals. To address these and similar questions, the USGS developed a study during the summer of 2008 to investigate aspen regeneration and growth rates, and to document how soil chemistry and under-canopy vegetation change after mechanical treatments. This study was also designed to evaluate how long-term encroachment of conifers into aspen stands may influence the recovery of aspen and under-canopy vegetation. Aspen sucker density and growth rate from this treatment site will be compared with other aspen-restoration projects being conducted in the WLCI area. This information will be used to develop an index that will help to establish objectives for future aspen projects.

Vegetation measurements were conducted during the summer of 2008 prior to conifer removal at 45 randomly selected plots. Fifteen of these plots were located in pure aspen stands and 30 were located in aspen stands characterized by a gradient of conifer density and canopy cover. Sampling methods were based on a modified use of the Forest Inventory and Analysis multi-scale, circular vegetation plot (Barnett and others, 2007). To accommodate the high densities of trees in the study area, the suggested plot size was adjusted from 168 to 78.5 m^2. Each plot consisted of three 1-m^2 subplots. In 2009, 2010, and 2011, vegetation measurements were conducted at the same locations (plots) sampled in 2008. In 2009, percent soil disturbance (area) and litter depth (debris from logging operations) were recorded, and, in 2009 and 2010, annual growth (stem densities and height) and herbivory of aspen ramets (shoots or suckers growing from root buds of mature trees) and conifer and serviceberry (*Amelanchier alnifolia*) seedlings were recorded in each plot.

In 2011, we measured annual growth (stem densities and height); extent of browsing by livestock, mule deer, and elk on aspen ramets and serviceberry; and conifer seedling recruitment in all the plots. In addition, each plot was re-photographed with a digital camera. Also in 2011, the sampling effort was expanded to include collection of core and disc samples from live aspen and conifers, which will be used to determine dates of tree establishment and ascertain tree responses (in terms of radial growth) after the conifer-removal treatment. Whenever possible, at least three aspen were sampled within each of four size classes: sapling (less than 2-m height), recruit (greater than 2 m but clearly beneath the canopy), canopy, and large canopy (greater than 30-cm diameter at breast height [dbh]). Aspen within a given plot were preferentially chosen for sampling, but when adequate samples could not be obtained within a plot, we sampled representative trees within 15 m of the plot center. We used an increment borer to remove two opposing cores from trees large enough to core (approximately greater than 5-cm dbh). To reconstruct dates of aspen establishment, at least one core per tree was removed from the tree base (<10 cm above ground level), and the tree was resampled until the core appeared to be within approximately five years of the pith. For aspen too small to core, a disc sample was removed at ground level. We used the same methodology to sample any conifers present within a given plot.

Objectives

- Evaluate the spatial and temporal response of aspen to mechanical removal across a gradient of conifer encroachment.
- Relate aspen regeneration to levels of disturbance to the top soil and the litter layer.
- Evaluate conifer removal and the response of native and invasive herbaceous species.
- Compare aspen regeneration associated with mechanical removal to burn treatments.
- Reconstruct stand demographics and pre-treatment aspen establishment dates.

Study Area

The study area is located in the Sierra Madre Range on Medicine Bow National Forest property in Carbon County (fig. 26). The treatment area (fig. 35) is characterized by mature aspen with areas of encroachment by subalpine fir and, to a lesser extent, lodgepole pine. Based on tree-ring counts of subalpine fir, the majority of subalpine firs in the treatment area were less than 100 years old and the stands were characterized by the presence of shade-tolerant herbaceous species. The treatment area is located on both sides of Forest Service road 114S south of Highway 70 and east of Stock Drive Road.

Work Accomplished in 2011 and Findings

A total of 577 samples were collected during 2011: 499 from aspen, 69 from subalpine fir, and 9 from lodgepole pine. Core samples were mounted to wood and sanded with fine-grit sandpaper, and discs were finely sanded on the bottom surface. All samples will be examined under a microscope using cross dating and other standard dendroecological methods to reconstruct establishment dates. A

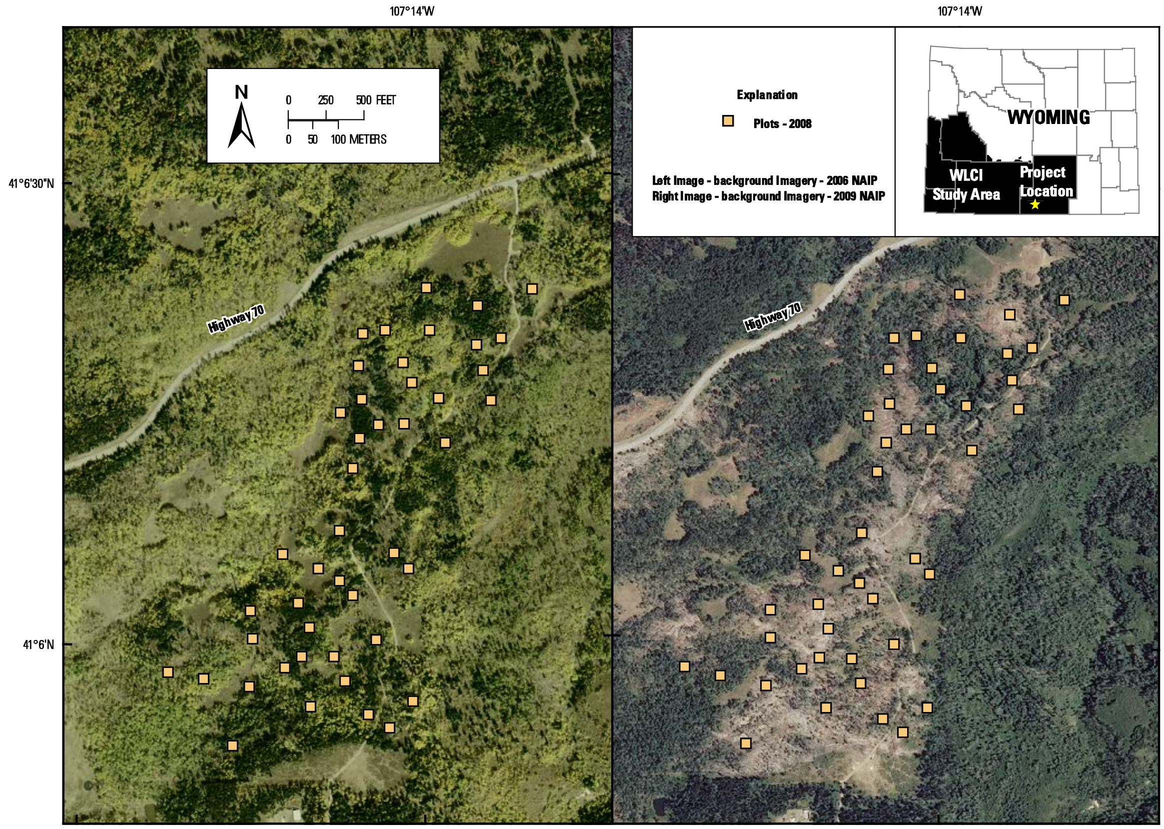

Figure 35. Locations of aspen-treatment plots being monitored for effectiveness of habitat treatments in the Sierra Madre, Medicine Bow National Forest, Carbon County, Wyoming.

calibrated slide bench will be used to develop master ring-width chronologies and to analyze radial growth responses associated with the conifer removal treatment.

Products Completed in FY2011

- 2011 vegetation dataset with plot photos.

Work Planned for FY2012

Monitoring of aspen regeneration and biomass of herbaceous plants in treated plots will continue in FY2012. We also plan to evaluate tree responses to conifer-removal treatment by measuring ring-width (i.e., radial growth) at each study site. Finally, we will initiate our development of a chronology of aspen establishment dates and responses to conifer-removal treatments.

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

Status

Ongoing

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Scope and Approaches

Since 1990, more than 2 million dollars have been spent on habitat-restoration and enhancement projects in the Little Mountain Ecosystem. Many of these efforts have focused on restoring aspen communities to maintain or improve water quality and to enhance ungulate habitat. Both fish and ungulate populations appear to have increased as a result. During 2009, biologists from the WGFD Green River Regional Office established long-term monitoring plots to evaluate whether the increased number of ungulates using those stands is in balance with targets set for aspen regeneration. The USGS is supporting this effort by augmenting protocols used by the WGFD 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 the stand size (patch area and shape) and stand location (Aspen Mountain, Pine Mountain, and Miller Mountain; fig. 36) across a gradient of conditions and extent of conifer encroachment. Measurements related to stand composition (dominant and subdominant canopy structure, size classification, age structure, regeneration, and conifer encroachment) were added to the WGFD protocol. The extended study design and protocol will be used to evaluate the effectiveness of past and current aspen treatments, determine herbivory rates (for aspen and serviceberry), and determine aspen-regeneration potential (density and annual growth rate of aspen suckering) at treated and untreated aspen stands.

Aspen sucker density and growth rate in the Little Mountain Ecosystem area will be compared to aspen treated with burning and mechanical removal of conifers at other locations in the WLCI region. An index based on sucker density and growth rate will be developed for establishing regeneration benchmarks to determine the effectiveness of future treatments across the WLCI area. In addition to evaluating effectiveness of aspen treatments, this effort was designed to support another USGS study that entails assessing use of burned versus unburned aspen stands by migratory birds (see section below, “Use of Aspen Stands by Migrant Birds for Effectiveness Monitoring”). These efforts were expanded in 2010 to include classification of aspen regeneration based on ecological and hydrological settings (ecohydrology). Results from 2009 and 2010 will be used to support the mapping and classification of aspen stands across the Little Mountain Ecosystem. The classification and map products are intended for the Sweetwater County LPDT for prioritizing and designing future treatments based on stand condition and conifer encroachment. We are collaborating with the BLM Rock Springs Field Office and the Wyoming Natural Diversity Database (WYNDD) to support development of the mapping products.

Sampling was expanded during 2010 to evaluate aspen-regeneration trends and rates based on the ecohydrological setting of aspen stands. In addition, aspen-regeneration potential and herbivory at edge locations and within the stand were sampled for later evaluation. The ecological and hydrological settings included in this study were based on three predominant stand types in the Little Mountain Ecosystem: (1) contiguous or nearly contiguous stands of aspen and mixed aspen-conifer on high-

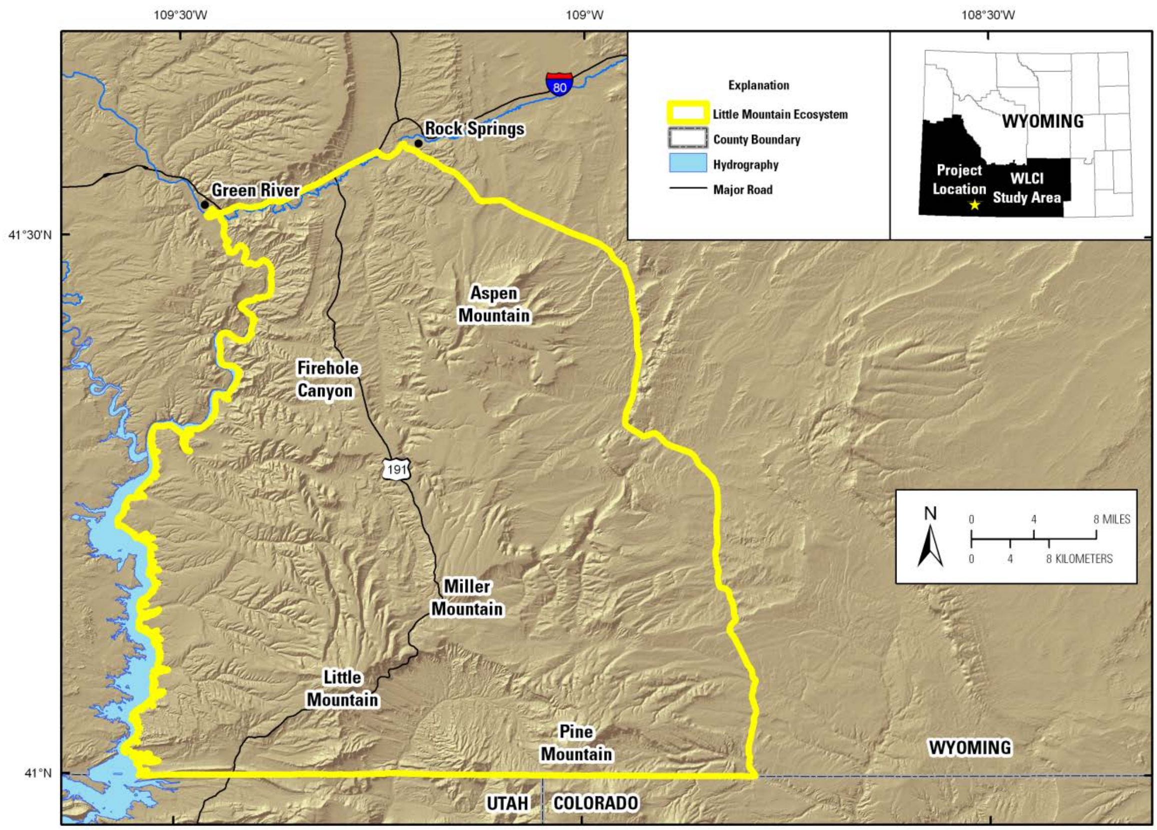

Figure 36. Locations of habitat treatment areas within the Little Mountain ecosystem, Wyoming.

elevation plateaus or gentle hillsides; (2) aspen stands in drainages and canyons with steep sides that promote the accumulation of snow and retard moisture loss due to shading; and (3) aspen stands in depressions that accumulate windblown snow because they are located on the leeward shoulders of or below high-elevation mountains.

Maps generated with classification and regression tree analysis (see section above on "Application and Feasibility of Mapping Aspen Stands and Conifer Encroachment Using Classification and Regression Tree Analysis for Effectiveness Monitoring") were used to locate aspen and mixed aspen-conifer forests. Thirty sample locations were selected randomly, stratified by the three predominant stand types in the Little Mountain Ecosystem. An additional 30 sample locations (plots) were randomly selected within the interiors and at the edges of pure aspen and mixed aspen-conifer stands. Sampling methods were based on a modified version of the multi-scale vegetation plot from the Forest Inventory and Analysis circular (expanded to 2,827 m^2 to accommodate variable tree densities). Each plot consists of a center point from which three 4- × 25-m belt transects originate (starting at 5 m from the center point) at azimuths 30°, 150°, and 270° if the slope was less than two percent. If the slope was greater than two percent, the first belt transect was located perpendicular to the slope and the second and third transect locations were adjusted to 120° and 240°, respectively, from the first transect. Vegetation measurements at each belt transect included tree density (live and dead aspen and conifers), tree canopy cover for each species (aspen, serviceberry, conifers; estimated with a Geographic Resources Solutions densitometer), tree size (diameter at breast height; by species for aspen and conifers), and herbivory of aspen ramets. The entire plot was used to document tree-size classes that were not observed in belt transects, and it was used for terrain measurements (aspect, percent slope, and elevation). During FY2011, core and disc samples were collected from aspen and conifer within each plot that was established in 2010 (Bowen and others, 2011) to reconstruct establishment dates and recruitment rates for aspen and conifer species.

In FY2011, sampling efforts were expanded to include acquisition of core and disc samples from aspen and conifer within each plot; subsequently, the samples will be used to reconstruct establishment dates. Whenever possible, at least three trees of each species were sampled within each of three size classes: sapling (less than 2 m high), recruiting (greater than 2 m, but clearly beneath the canopy), and canopy. Height and dbh were recorded for each tree sampled. A core was removed with an increment borer from the base of trees large enough to core (approximately greater than 5 cm in dbh), coring from the downslope side of the tree and angling the borer slightly downward to intercept the pith at the root/shoot interface. Trees were resampled until we obtained a core that appeared to be within approximately five years of the pith. For individuals too small to core, a disc sample was removed at ground level. At the laboratory, core and disc samples were air dried prior to mounting. Core samples were mounted and glued onto grooved wood platforms. Both cores and disc samples were sanded with progressively finer sandpaper grit for better ring identification. Standard dendrochronological techniques and a microscope were used to determine establishment years and to discern early and late wood, respectively. Ring widths were measured with a calibrated slide bench for assessing radial growth and to improve cross dating. The presence of white rings in aspen wood is indicative of defoliation events. The presence of white rings and the corresponding year was recorded for all aspen samples.

Objectives

- Evaluate big-game herbivory on aspen and serviceberry in the Little Mountain area.
- Correlate stand dynamics with use of burned and unburned aspen stands by migratory songbirds.
- Compare aspen regeneration associated with burning to aspen regeneration associated with mechanical aspen removal of aspen and other treated aspen stands in the WLCI area.
- Develop an aspen index based on sucker density and growth rate.
- Develop geospatial products associated with aspen stand demographics to support prioritization of restoration projects.
- Construct stand demographics by using aspen and conifer establishment dates.

Study Area

The study area is associated with the Little Mountain Ecosystem south of Rock Springs, Wyo. (fig. 36). This area is defined as land bounded by Wyoming Highway 430 on the east, Interstate Highway 80 on the north, Flaming Gorge Reservoir on the west, and the Wyoming-Colorado state line on the south. Aspen communities are interspersed throughout the area on higher elevations. During 2009, sampling was conducted at a total of 15 plots in burned and unburned aspen stands.

Work Accomplished in 2011 and Findings

In total, 908 samples were collected (456 cores, 452 discs): 560 samples from aspen, 272 from subalpine fir, 35 from Douglas-fir, 23 from lodgepole pine, 4 from pinyon pine (*Pinus monophylla*), 5 from Rocky Mountain juniper (*Juniperus scopulorum*), 4 from blue spruce (*Picea pungens*), and 6 from serviceberry. Core samples were mounted to wood and sanded with fine-grit sandpaper, and discs were finely sanded on the bottom surface. All samples will be examined under a microscope using cross dating and other standard dendroecological methods to reconstruct establishment dates. A calibrated slide bench will be used to develop master ring-width chronologies.

Products Completed in FY2011

- 2011 dataset with tree height and dbh measurements, and plot photos.

Work Planned for FY2012

In FY2012, we will continue analysis of core and disc samples and develop establishment dates and chronologies for aspen and conifer species. Continue ring width measurements using a calibrated slide bench for development of master chronologies. We will construct stand demographics using aspen and conifer establishment dates, and we will begin analysis and development of species-specific models associated with drought and other condition indicators (for example, white-ring development) for establishment and growth.

Use of Aspen Stands by Migratory Birds for Effectiveness Monitoring

Status

Ongoing

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Scope and Approaches

The shrub-steppe system that dominates the WLCI region separates the northern and southern Rocky Mountains; thus, forested areas in the WLCI region are limited. In the Green River Basin of southwest Wyoming, riparian and aspen woodlands comprise only a small fraction of the landscape, but many agencies perceive them as priority habitats because they make important contributions to landscape connectivity and biodiversity at local, regional, and geographic scales. Not only do aspen communities support a unique and diverse suite of species in the WLCI region, they provide important forage and cover for ungulates, help maintain headwater stream function, and they may serve as stepping stones for migratory forest birds traversing the semi-arid WLCI region.

A primary goal of the WLCI effort is to restore aspen to ensure the sustainability of fish and wildlife in southwestern Wyoming. To that end, WLCI partners need information on the effectiveness of aspen-restoration treatments (for example, thinning and burning) for promoting desirable stand structure, but little is known about how stand structure affects the ways in which most wildlife species use aspen stands. Without this crucial information, WLCI partner efforts to identify and prioritize aspen stands for restoration and conservation are hampered. This work activity assesses how landscape and forest structure affects use of aspen stands as stopover sites by migratory birds in southwest Wyoming. In 2010, fall migrants were surveyed through point counts and mist-netting during August and September. Associated landscape attributes will be quantified from existing GIS layers. This information will be used to develop spatially explicit, multi-scale wildlife habitat models for priority species.

Objectives

- Characterize how the landscape structure of aspen and riparian stands affects use by migratory birds.
- Evaluate the diversity and abundance, migratory status (for example, Neotropical migrant, short distance migrant, partial migrant, resident species), and breeding range of migratory birds to determine whether the stands are locally, regionally, or geographically important to migratory birds.
- Assess how species of migratory birds use different structures of burned and unburned aspen stands.

Study Area

The study area includes aspen and riparian areas in the Little Mountain Ecosystem, Fossil Butte National Monument and adjacent Ham's Fork Plateau, and Seedskadee National Wildlife Refuge (fig. 26). Riparian and aspen stands in this area provide a range of landscape conditions at multiple spatial scales (for example, size, shape, isolation, and distance to the northern/central Rocky Mountains). Isolated patches occurring on BLM, National Park Service, and FWS lands represent a gradient in forest patch size and isolation.

Isolated islands of aspen in Southwest Wyoming are important stopovers for migrating songbirds. Photo credit: Tim Assal, Ecologist, U.S. Geological Survey.

Work Accomplished in 2011 and Findings

In FY2011, initial data analyses were conducted.

Products Completed in FY2011

- Initial analyses quantifying the effects of landscape structure at multiple scales on the densities of migrating and resident bird species in aspen and riparian forests in the Green River Basin

Work Planned for FY2012

In FY2012, data analyses will be completed and a final report will be drafted.

Muddy Creek Synoptic Study

Status

Ongoing

Contact

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Scope and Approaches

Muddy Creek drainage basin, located in the southeastern part of the WLCI study area, is an area of active energy exploration and development. The development, which includes conventional natural gas wells and coalbed natural gas wells, could be causing changes within the drainage, including increased concentrations of chloride and selenium, which the Wyoming Department of Environmental Quality (2010) has listed as impairments to aquatic life in Muddy Creek. The occurrence of selenium in the various media and how it relates to basin characteristics, including geology, is of particular interest to USGS scientists. Dissolved solids also are a concern in the basin, as Muddy Creek is part of the Upper Colorado River Basin, a watershed in which dissolved solids are regulated, and for which there are programs underway to reduce the amount of dissolved solids in that drainage.

In FY2010, we conducted a synoptic study to characterize the stream-water chemistry, basin sediments, and macroinvertebrates of Muddy Creek drainage Basin. Sampling sites were selected on Muddy Creek and three of its tributaries based on site characteristics and site access. Field measurements were made and water-quality samples were collected according to methods established by the USGS (U.S. Geological Survey, 1997–2011). Samples were processed and preserved in the field and then analyzed for major ions and trace elements at the USGS National Water Quality Laboratory (Fishman, 1993; and Garbarino and others, 2006).

In FY2011, this synoptic study was expanded to include characterization of potential groundwater inputs in the Muddy Creek Basin. The approach in this case was to sample the water chemistry of two flowing wells and nearby surface waters.

Objectives

- Conduct additional water-chemistry sampling to describe major-ion and trace-element chemistry, including selenium, in the Muddy Creek drainage basin.
- Relate water chemistry to basin geology and sediment geochemistry.
- Relate selenium concentrations in water and sediment to aquatic insects.
- Develop an understanding of how land-use changes in the drainage basin may affect salinity and selenium.

Study Area

Muddy Creek drains about 1,200 mi^2 of south-central Wyoming. Sampling sites were located on the mainstem of Muddy Creek and on tributaries in the eastern part of the drainage basin (fig. 37). Bedrock geology of the study area includes Cretaceous-age marine shale in the eastern uplands and Tertiary-age sedimentary rocks in the lower basin. Plant community types in the basin are primarily arid grasslands and shrublands. About 69 percent of the Atlantic Rim Project Area is in the Muddy Creek drainage basin (U.S. Bureau of Land Management, 2006).

Work Accomplished in 2011 and Findings

Flowing wells occur sporadically in the eastern part of the Muddy Creek drainage basin. Many of these wells (probably exploration wells) were drilled and abandoned decades ago on BLM land. Some of these flowing wells have substantial, artesian-pressured outflows, such that there is surface drainage flowing from them. Two areas were selected for sampling during summer FY2011 (fig. 37). At Well Group #1, one flowing well (streamflow below it was measured at 0.3 ft^3/sec) and three surface-water sites were sampled along an unnamed drainage issuing from the well. At Well Group #2, which is in the Deep Gulch drainage, one flowing well (which had a geyser-like eruption about every 20 minutes that resulted in surface pooling but no surface run-off) and two surface-water sites on nearby Deep Gulch (naturally flowing) were sampled. Water-quality samples were collected for assessing major ions and selected trace elements (including selenium). Basin sediment samples collected included bed-sediments from within the stream channel and soils from the surrounding upland. Aquatic and terrestrial insects also were collected.

Two groundwater wells were sampled. The wells are located in Cretaceous-age geologic units. The groundwater type of these sites was sodium bicarbonate. The groundwater samples contained larger

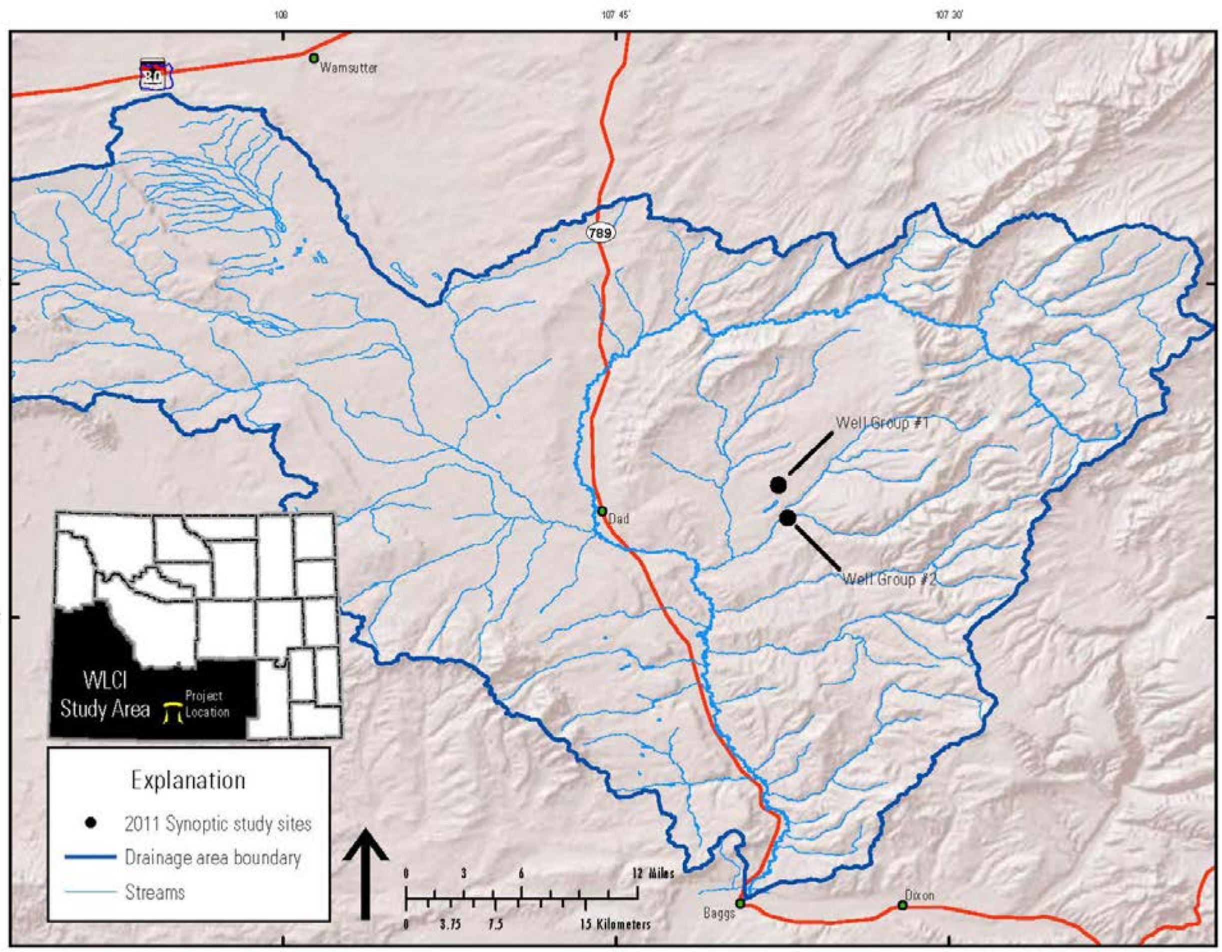

Figure 37. Sampling sites for the fiscal year 2011 synoptic study in the Muddy Creek drainage basin.

concentrations of dissolved solids than did the samples collected during the 2010 synoptic of Muddy Creek. Water chemistry of samples collected from the unnamed drainage near the first well was similar to that of the groundwater. In contrast to the groundwater type, results of the FY2010 sampling effort indicate that the water type of Muddy Creek and its tributaries was mixed cation (calcium, magnesium, and sodium) and mixed anion (sulfate bicarbonate). Deep Gulch had a mixed water type as well.

Barium concentrations in samples collected from Muddy Creek during the FY2010 effort were smaller than barium concentrations in samples from flowing wells and surface-water sampling sites on the unnamed drainage. Selenium concentrations in samples collected from Muddy Creek during the FY2010 sampling generally were larger than selenium concentrations in samples from flowing wells and surface-water sampling sites on the unnamed drainage. Generally, selenium is associated with Cretaceous shales throughout Wyoming, and it can be mobilized from soils in oxidized environments through dissolution of desorption processes. Generally, selenium is associated with cretaceous shales in Wyoming, and there are sediments derived from those shales in the Muddy Creek and Deep Gulch basins. The selenium is becoming mobilized through dissolution processes. Concentrations of barium and selenium in samples from Deep Gulch were similar to those from Muddy Creek.

Products Completed in FY2011

- Holloway, J.M., Bern, C., Schmidt, T.S., McDougal, R.R., Clark, M.L. Stricker, C.A., and Wolf, R.E., 2011, Evaluating natural gas development impacts on stream ecosystems in an Upper Colorado River watershed: American Geophysical Union, Fall Meeting 2011, abstract (submitted for a poster to be presented in late fall 2011; now available online at *http://adsabs.harvard.edu//abs/2011AGUFM.H31A1124H*).
- Water-quality data were made publicly available on the National Water Information System Web Interface (NWISWeb) at *http://nwis.waterdata.usgs.gov/wy/nwis/qwdata*.

Work Planned for FY2012

Proposed work for FY2012 includes compilation and review of the synoptic study data collected by the USGS Wyoming Water Science Center, Fort Collins Science Center, and Central Mineral and Environmental Resources Science Center. A poster illustrating this study and the results will be presented at the American Geophysical Union fall meeting in December 2011, and a publication that includes interdisciplinary findings of the two synoptic studies will be produced.

Natural Salinity Fluctuations in a Snowmelt-Dominated Watershed Undergoing Energy Development

Status

New in FY2011

Contact

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Scope and Approaches

Soils in arid lands often contain significant quantities of salts just below the surface. In the Muddy Creek watershed, disturbance related to natural gas development has the potential to mobilize such salts and degrade surface water quality. Examination of the seasonal water chemistry of Muddy Creek and extractable salts in soils has found little evidence for additional salt mobilization from current natural gas development. However, previously undocumented natural patterns in salinity sources and loads have been noted. Documenting these patterns will provide a baseline for assessing impacts from development on water quality in Muddy Creek and other watersheds in the western United States.

Soil, water, and snow sample were collected throughout the Muddy Creek watershed in 2011 and are being analyzed for salinity, elemental composition, and trace elements, such as arsenic and selenium.

Objectives

- Examine the chemistry of Muddy Creek to understand natural processes driving patterns in salinity levels.
- Establish a baseline for monitoring change in the watershed resulting from potential additions of produced waters.
- Understand the nature and magnitude of fluctuations in baseline natural salinity and distinguish them from anthropogenically driven changes.

Study Area

The study area is the Muddy Creek watershed in south-central Wyoming, north of Baggs, southwest of Rawlins, and south of the Atlantic Rim. The watershed, which is dominated by alluvial soils, drains the western slope of the Sierra Madre. Figure 8 shows the locations of sampling sites.

Work Accomplished in 2011 and Findings

Soil, water, and snow samples were collected throughout the Muddy Creek watershed in FY2011 and are being analyzed for salinity, elemental composition, and trace elements, such as arsenic and selenium. Discharge, gaged near Baggs, Wyoming, can range from 0.005–10.000 square meters per second, originating largely from spring snowmelt. Stream salinity varies inversely with discharge. Soil water and shallow groundwater inputs carry products of sedimentary rock weathering and are the dominant sources of salinity. Deeper groundwater issuing from springs and historical failed wells contributes to salinity in certain tributaries, but it makes negligible contributions to the main stem of Muddy Creek. Salinity, as measured by electrical conductivity, increased from 2009−2011 compared to 2005−2008 in Muddy Creek near Baggs. Specific conductance was 53−71 percent greater at typical low rates of discharge and 33−34 percent greater at typical high rates of discharge. Multiple natural and anthropogenic causes are being investigated to determine which are more likely to be driving increased salinity.

Products Completed in FY2011

- Holloway, J.M., Bern, C., Schmidt, T.S., McDougal, R.R., Clark, M.L. Stricker, C.A., Wolf, R.E., 2011, Evaluating natural gas development impacts on stream ecosystems in an Upper Colorado River watershed: American Geophysical Union 92, Fall Meeting Supplement, Abstract H31A-1124.

Work Planned for FY2012

In FY2012, analyses of soil, water, and snow samples will be completed. Subsequently, a manuscript detailing the study and results will be submitted to a peer-reviewed journal for publication.

Summary of FY2011 Activities for Mechanistic Research of Wildlife

Mechanistic research of wildlife is conducted to elucidate (1) the relationships between the habitats and distributions of important and protected species, and (2) species' responses to changes in land use (particularly energy development) and other factors. The species or community of species selected for mechanistic studies in the WLCI region include the (1) pygmy rabbit, which is a species of conservation concern in Wyoming; (2) greater sage-grouse, which is a candidate for listing under the Endangered Species Act; (3) sagebrush-obligate songbird community, which includes several species of conservation concern; and (4) mule deer, an economically important game species in Wyoming.

In FY2011, the *Pygmy Rabbit* study continued with collection of field data to support the development of a new, state-of-the-art pygmy rabbit habitat model, and to help identify the relationship between gas field infrastructure and pygmy rabbit distributions. This information is important for managers who wish to identify areas of suitable pygmy rabbit habitat, and to help sustain viable pygmy rabbit populations in areas undergoing gas-development activities. Furthermore, the habitat map will be the first step in identifying habitat components necessary for restoring disturbed habitats in a manner that will support pygmy rabbits in the future. Work on developing and testing the usefulness of LiDAR for predicting the distributions and/or abundances of pygmy rabbits and sagebrush-obligate songbirds also continued. LiDAR performed well at predicting songbird abundances, and initial analyses are underway to determine how well it performs at predicting pygmy rabbit distributions.

The *Sage-Grouse* study in FY2011 entailed developing models of seasonal habitat selection for greater sage-grouse across Wyoming. These models will result in maps that identify priority seasonal habitats for sage-grouse in Wyoming. USGS scientists also generated an extensive, time-stamped, database that quantifies both the density and distribution of oil and gas wells surrounding lek sites. Efforts were initiated to model the influence of well density and distribution on long-term trends of sage-grouse while accounting for the nonlinearities documented in our previous work.

In FY2011, the study design for Phase II of the *Songbird Community* study was finalized, and the first of two field seasons was conducted to evaluate the effects of gas well density on daily nest survival rates (DSR) of songbirds. Preliminary data analyses were conducted and initial results were presented at two conferences. Preliminary results indicate that, for some species [Brewer's sparrow (*Spizella breweri*) and sage sparrow (*Amphispiza belli*)], nest predation rates increased with increasing density of gas wells. Detections of some nest predators, including common raven (*Corvus corax*) and small mammals [Wyoming ground squirrel (*Spermophilus elegans*) and chipmunks (*Tamias* spp.)] tended to increase with increasing well density.

The *Mule Deer* study continued in FY2012 with a phenological analysis to assess the quality of forage at stopovers when stopovers were being used. Results indicate that stopover use consistently occurred an average of 44 days (± 6 days standard deviation) before peak green-up, suggesting that the timing of stopover use was tied to phenological changes along the elevational migrations. These findings suggest that migrating ungulates require access to stopover locations along their migration routes where they can forage at specific time periods that coincide with beneficial plant phenology. Overall, thus far this work suggests that migrating ungulates derive considerable foraging benefit from the habitats through which they migrate. Continued research will identify whether migrating animals experience diminished foraging opportunities due to the presence of roads and human disturbance.

Details of these mechanistic studies of wildlife are provided in the four sections that follow.

Pygmy Rabbit

Status

Ongoing

Contact

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Scope and Approaches

Several key information gaps must still be filled to effectively manage for pygmy rabbit conservation. To address these gaps, USGS scientists are (1) developing a landscape-scale habitat model that characterizes habitat components, climate, and anthropogenic disturbance levels at sites occupied and unoccupied by pygmy rabbits; (2) evaluating the relationship between gas-field infrastructure and site occupancy by pygmy rabbits; and (3) determining whether LiDAR vegetation measurements can be used to predict the distributions or abundances of pygmy rabbits and sagebrush-obligate songbirds, respectively. Collectively, this work will provide resource managers with new information about the distributions, habitat relationships, and responses to energy development of pygmy rabbits, and the abundances of songbirds.

In FY2008 and FY2009, 189 sites were surveyed for pygmy rabbits across and near the WLCI region (fig. 38) to generate data for use in developing a new habitat-association model for the pygmy rabbit. In FY2010 and FY2011, pre-development site-occupancy data were collected on the Non-Pressurized Lands (NPL) gas field, which is slated for development southwest of and adjacent to the Jonah Field, and at three adjacent control sites (fig. 39). Also in FY2011, we conducted a pygmy rabbit survey in 78 plots on the Atlantic Rim, PAPA, and Jonah gas fields (fig. 26 illustrates locations of these three energy fields), and we used these data to begin examining the relationships between pygmy rabbit occurrence and densities of energy infrastructure (specifically, gas wells, well pads, and roads). Finally, we measured the strength of the relationship between vegetation characteristics and as measured by LiDAR imagery versus vegetation data collected in the field, and we examined how well LiDAR vegetation measurements predicted the abundances of sagebrush–obligate songbirds by using songbird survey data collected in FY2010.

Objectives

- Generate a new habitat-association model for the pygmy rabbit.
- Evaluate the relationship between gas-field infrastructure and pygmy rabbit site occupancy.
- Complete analyses of LiDAR-derived pygmy rabbit site-occupancy data, and conduct analyses of LiDAR-derived songbird-abundance data.

Study Area

The pygmy rabbit habitat modeling research conducted by the USGS encompasses all of the predicted pygmy rabbit range in Wyoming, which extends beyond the WLCI boundary (including parts of Park County near Cody). The gas field- and LiDAR-based research is occurring entirely within WLCI study area. The focal habitat type is sagebrush. Ongoing fieldwork is concentrated in Carbon, Sublette, and Sweetwater counties. Figure 38 illustrates where in the WLCI region (and immediately outside of it) the pygmy rabbit surveys were conducted for model validation and habitat research (not shown are the sampling sites near Cody, Wyo.).

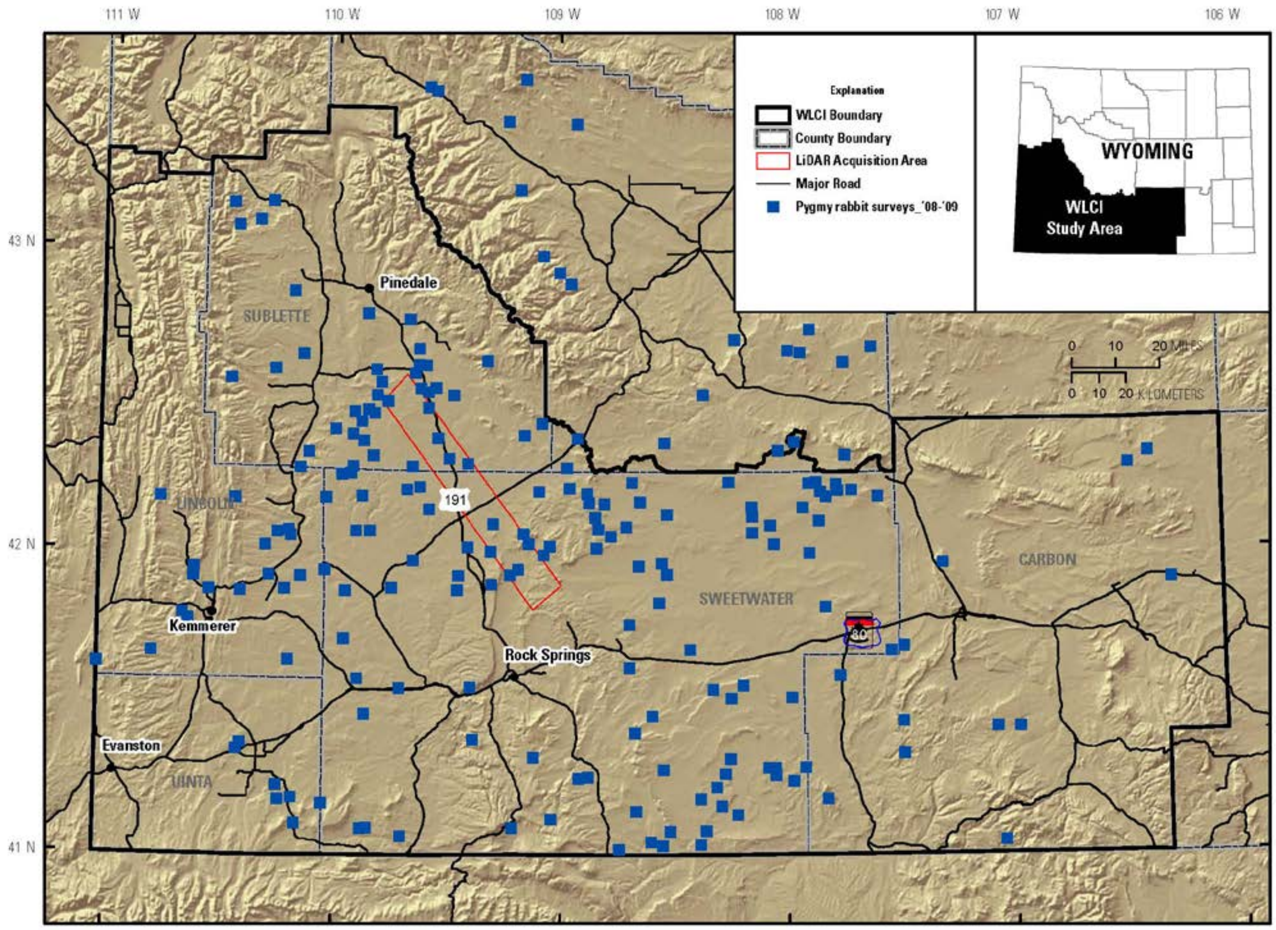

Figure 38. Location of pygmy rabbit surveys (blue squares) conducted throughout southwestern Wyoming for use in validating pygmy rabbit habitat models developed by the U.S. Geological Survey, new model development, and Light Detection and Ranging (LiDAR) imagery-based analyses (LiDAR data acquired for the area outlined in red).

Work Accomplished in 2011 and Findings

Pygmy rabbit surveys were completed at 150 sites on the NPL and adjacent lands, at 78 sites on the Atlantic Rim, Jonah, and PAPA gas fields, and at 43 sites in the LiDAR-acquisition area. Analysis of year one data was conducted for the infrastructure-density pygmy rabbit-occupancy work, and analyses were completed for the LiDAR-vegetation and LiDAR-songbird work.

Pygmy rabbit occupancy rates in 2010 and 2011, respectively averaged 16 and 25 percent on our control sites and 23 and 28 percent on the NPL, suggesting that pygmy rabbit populations increased slightly in 2011. Results of the pygmy rabbit surveys in relation to infrastructure density indicated that occupied sites were surrounded by fewer well pads and gas wells, and occupied sites tended to have fewer roads nearby than unoccupied sites. LiDAR did well at predicting some important aspects of sagebrush vegetation structure (for example, average canopy height and average distance from the ground to the bottom of the canopy), and it did moderately well at predicting the abundances of two bird species (horned lark and Brewer's sparrow).

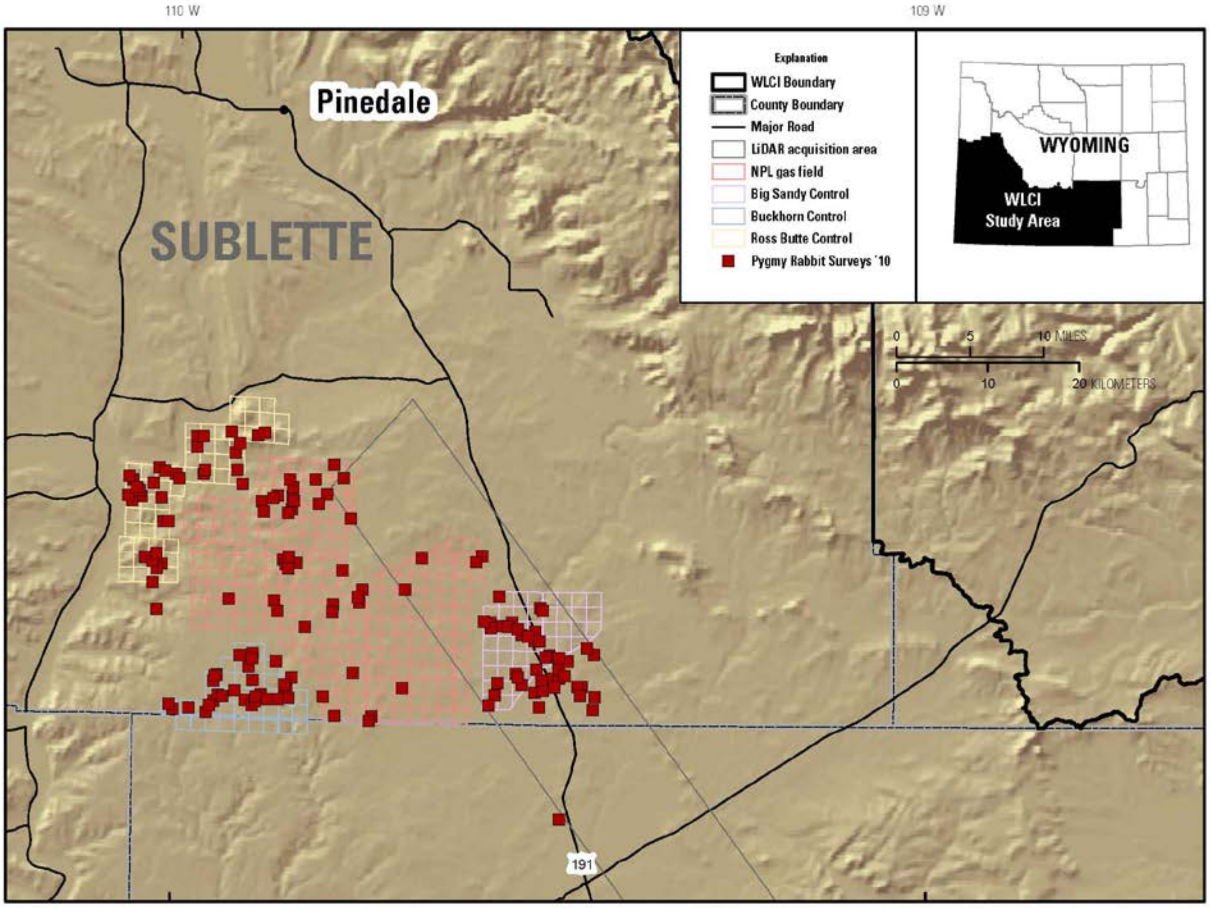

Figure 39. Pygmy rabbit survey sites (red squares) associated with the U.S. Geological Survey new gas field and Light Detection and Ranging (LiDAR) data acquired for the polygon (outlined in gray) in the Wyoming Landscape Conservation Initiative (WLCI) study area..

Products Completed in FY2011

- Germaine, S., 2011, Progress on LiDAR-sagebrush vegetation mapping project: Invited presentation given to the WLCI Executive Committee, July 2011.
- Germaine, S., and Newton, W., 2011, Using LiDAR to remotely measure wildlife habitat structure in a sagebrush setting: Oral presentation to the Wyoming Chapter of The Wildlife Society, 2011 annual meeting, Jackson, Wyo.
- Germaine, S., Kemper, J., Woolwine, D., and Ignizio, D., 2011, Pygmy rabbit (*Brachylagus idahoensis*) response patterns to natural gas energy development in Wyoming: Poster presented at the Wyoming Chapter of The Wildlife Society, 2011 annual meeting. Jackson, Wyo.

Work Planned for FY2012

In FY2012, the new landscape-scale habitat model for the pygmy rabbit will be completed. Data collection will continue for the NPL and infrastructure-density studies. Finally, manuscripts describing the new habitat model and the LiDAR project will be drafted for publication in peer-reviewed journals.

Sage-Grouse

Status

Ongoing

Contacts

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Scope and Approaches

Persistence of the greater sage-grouse depends on the quantity, quality, and distribution of habitat within its range (semi-arid sagebrush steppe). Recent work on greater sage-grouse has focused on developing spatial models assessing sage-grouse responses across large landscapes. A long-term analysis of population trends across the WLCI area and the rest of Wyoming was conducted to identify key time periods in historical sage-grouse population fluctuations and to quantitatively address many analysis concerns associated with using very large time-series databases. These studies provided a solid foundation and informed research conducted in FY2011 by providing greater focus on the timing and mechanisms that influence population fluctuations, specifically climate and energy development. In addition to this work, major efforts in FY2011 focused on developing predictive habitat-selection models for sage-grouse.

This research entails using long-term, large-scale datasets on sage-grouse movements and associated habitat components. The habitat-selection modeling incorporates telemetry data from multiple studies across Wyoming, as part of a larger effort. In addition, we have amalgamated and generated one of the most comprehensive GIS libraries consisting of habitat and landscape data for Wyoming. We are using resource selection functions (RSF) to model the probability of habitat use and identify priority areas for sage-grouse. Our assessments of long-term population trends in sage-grouse entail using lek count data managed by the WGFD. We are using a combination of linear and non-linear modeling approaches to analyze the long-term impacts of climate, energy development, and habitat change on sage-grouse lek counts.

Objectives

- Develop spatial models assessing sage-grouse responses to energy development and climate variation across large landscapes using existing population data from lek counts.
- Develop seasonal, predictive habitat-selection models for sage-grouse using data from radio-telemetry studies within WLCI and across Wyoming.
- Assess changes to sage-grouse populations over time using lek-trend data and attempt to assess relationships between vegetation changes from 1985–2006 (see *Remote Sensing and Vegetation Inventory and Monitoring* section above) and sage-grouse populations.

- Complete analyses comparing the utility of the newly developed maps for components of sagebrush cover to other more traditional cover-type mapping products for predicting sage-grouse nesting habitat within WLCI.

Study Area

This study is not associated with a particular location or site. The analyses and models apply to the entire WLCI study area (fig. 1).

Work Accomplished in 2011 and Findings

Influence of Energy Development Density and Distribution on Long-Term Sage-Grouse Trends—Localized and short term impacts of energy development on sage-grouse habitat use and population viability have been documented during several previous studies. However, we still do not understand the long-term impacts of energy development on sage-grouse population trends. In particular, the relative impacts of well distributions and densities are poorly understood. In FY11, we generated an extensive, time-stamped, database that quantified both the density and distribution of oil and gas wells surrounding lek sites. We have begun modeling the influence of these two factors on long-term population trends while accounting for the nonlinearities documented in our previous work (Fedy and Doherty, 2011; Fedy and Aldridge, 2011).

Male sage-grouse displaying on a lek. Photo credit: U.S. Fish & Wildlife Service, Stephen Ting.

Seasonal Habitat Selection Models for Greater Sage-Grouse—In FY11, development of habitat-selection models for greater sage-grouse were completed for the nesting, late brood rearing, and winter seasons. A manuscript is being prepared for publication in a peer-reviewed journal.

Products Completed in FY2011

- Fedy, B.C., Aldridge, C.L., Doherty, K.E., O'Donnell, M., Beck, J.L., Bedrosian, B., 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., 2012, Interseasonal movements of greater sage-grouse, migratory behavior, and an assessment of the core regions concept in Wyoming: Journal of Wildlife Management, v. 76, no. 5, p. 1062–1071.
- Fedy, B.C., Aldridge, C.L., Doherty, K.E., O'Donnell, M., Beck, J.L., Bedrosian, B., 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., 2011, Across space and time: Seasonal and regional variation in habitat selection of greater sage-grouse across large spatial scales: The Wildlife Society Annual Meeting, November 5–10, 2011, Kona, Hawaii [presentation].

- Fedy, B.C., 2011, Long-term trends in well density and distribution surrounding greater sage-grouse lek sites in Wyoming [dataset].

Work Planned for FY2012

Work in FY2012 will focus on completing and publishing predictive habitat-selection models for sage-grouse in the WLCI study area and across Wyoming, with manuscript submission expected in early summer 2012. We will work to complete analyses and draft a manuscript assessing climate and weather influences on sage-grouse trends. We also will work towards completing our analysis of the long-term influence of well density and distribution on sage-grouse lek counts, ultimately preparing another manuscript for peer-reviewed publication. Finally, recently developed products which delineate changes in cover components of sagebrush rangeland characteristics over time (Xian and others, 2011; Homer and others, 2012) can be used to assess whether changes in habitats that surround leks are correlated with 1985–2006 trends in sage-grouse populations. We will begin to summarize maps of bi-annual changes in components of sagebrush habitat for areas surrounding leks located in the southwestern portion of the WLCI region, allowing us to ultimately assess patterns related to annual peak male counts at leks.

We also will continue our analyses comparing the utility of the newly developed sagebrush cover-component maps (see section on *Long-Term Monitoring*) to that of other more traditional mapping products delineating vegetation cover types for predicting wildlife-habitat relationships in Wyoming. Specifically, we are generating spatial datasets summarizing sage-grouse habitat characteristics from the USGS sagebrush map products, as well as Landfire, National Land Cover Data, ReGap, and a Wyoming Geographic Information Science Center cover map product. We have been compiling a dataset composed of more than 700 sage-grouse nest locations from 5 different study areas within the WLCI region, which will be used to assess how well each product predicts wildlife (sage-grouse nesting) habitat.

Songbird Community

Status

Ongoing

Contact

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Scope and Approaches

Many sagebrush-obligate bird species are undergoing range-wide population declines, and there is concern that energy development in sagebrush ecosystems may be contributing to these declines. The songbird research, now in Phase II, is designed to investigate the mechanisms underlying patterns revealed during Phase I: (1) decreasing abundance of sagebrush songbirds, including two sagebrush obligates [Brewer’s sparrow (*Spizella breweri*) and sage sparrow (*Amphispiza belli*)], along a gradient of increasing gas-well density, and (2) decreasing nesting success of sagebrush species along a gradient of increasing gas-well density and with closer proximity to the nearest well pad. Phase II of this work will entail ascertaining the potential mechanisms driving these effects of energy development. Our approach is to examine nest predation and the assemblage of nest predators, and to assess important habitat components associated with sagebrush songbird nest-site selection. These data will allow us to test potential drivers of reduced avian productivity and the ways in which various stages of energy development may be affecting population and community dynamics of breeding sagebrush songbirds in Wyoming and beyond. Understanding the mechanisms of nest predation associated with energy development will help to better inform management and mitigation decisions for maintaining healthy sagebrush bird species. More specifically, the results of this work will be used to update the Wyoming State Wildlife Plan and develop better monitoring and mitigation strategies for sagebrush songbirds most at risk from energy development. Ultimately, the study results will be disseminated to the scientific community in the form of peer-reviewed manuscripts and presentations at scientific conferences. Reports will be provided to all WLCI partners including the USGS, BLM, and WGFD.

Sage sparrow (above) and Brewer's sparrow (below).
Photo credits: U.S. Fish & Wildlife Service, Dave Menke.

To document songbird nesting success in relation to intensity of energy development, 25-ha nest-monitoring sites have been established across gradients in density of natural gas wells in the PAPA and Jonah Infill energy fields. A sub-set of nests are being monitored via 24-hour infrared cameras to document species of nest predators. Surveys for nest predators will be conducted across the well-density gradients to evaluate how the assemblage of nest predators changes along the gradients within a given energy-development field. The relationship between nest concealment and nesting success will be evaluated for all observed Brewer's sparrow, sage sparrow, and sage thrasher nests in areas with and without energy-development activities. Field data are to be collected over two breeding seasons: May–August, 2011 and 2012.

Objectives

- Document songbird nesting success in relation to density of oil and gas wells.
- Use video monitoring of songbird nests to document and identify nest predators associated with energy development across a gradient of energy development intensity.
- Determine specific mechanisms shaping observed patterns in nest predation via observational and experimental approaches to testing alternative hypotheses.
- Ascertain management alternatives that maximize songbird nesting productivity in areas with energy extraction infrastructure.

Study Area

Study areas were established across gradients of lower to greater well density within two natural gas fields located in Sublette County, southwestern Wyoming: the Jonah Field and the Pinedale Anticline Project Area (fig. 40). All work took place within sagebrush habitats.

Work Accomplished in 2011 and Findings

In FY2011, the study design was finalized, a field crew was hired, and necessary equipment was purchased. Field personnel found and monitored 306 nests, 279 of which represented the 2 focal species (144 Brewer's sparrow nest, 63 sage sparrow nest), and 72 of which were sage thrasher nests that also were monitored. Sixty nest cameras were deployed throughout the season and seven predation events were recorded. Field staff (1) conducted nearly 400 point counts to survey for avian predators, (2) conducted 90 surveys for diurnal mammalian predators, and (3) maintained 70 scent/camera stations set up to attract local meso-predators and photographically document which species occur within the study area. Habitat metrics were measured at each nest site and at a paired random site within each territory to assess crucial habitat components associated with nest-site selection.

Preliminary analyses of the FY2011 data indicate that the daily nest survival rates (DSR) for sage sparrows and sage thrashers declined along the gradient of increasing well density (fig. 41); however, the DSR varied between years and species. During previous years, the DSR for Brewer's sparrow decreased along the gradient of increasing well density more than it did for other species, whereas in FY2011 the DSR for sage sparrow and sage thrasher decreased more along the gradient of increasing well density than it did for Brewer's sparrow. Overall, however, throughout both phases of this study, the DSR for each species has tended to decrease with increasing well density. Confirmed nest predators included Wyoming ground squirrel, chipmunks, badger (*Taxidea taxus*), raccoon (*Procyon lotor*), and loggerhead shrike (*Lanius ludovicianus*). Detections of common ravens (*Corvus corax*) during point counts increased along the gradient of increasing well density ($\beta = 0.0077 \pm 0.0033$; $P = 0.024$), and detections of ground squirrels and chipmunks during systematic searches showed a shallow increasing trend with increasing well density ($\beta = 0.019 \pm 0.012$; $P = 0.11$). Predator detections at scent stations, however, did not change across the gradient of well density ($\beta = 0.000012 \pm 0.005$; $P = 0.99$).

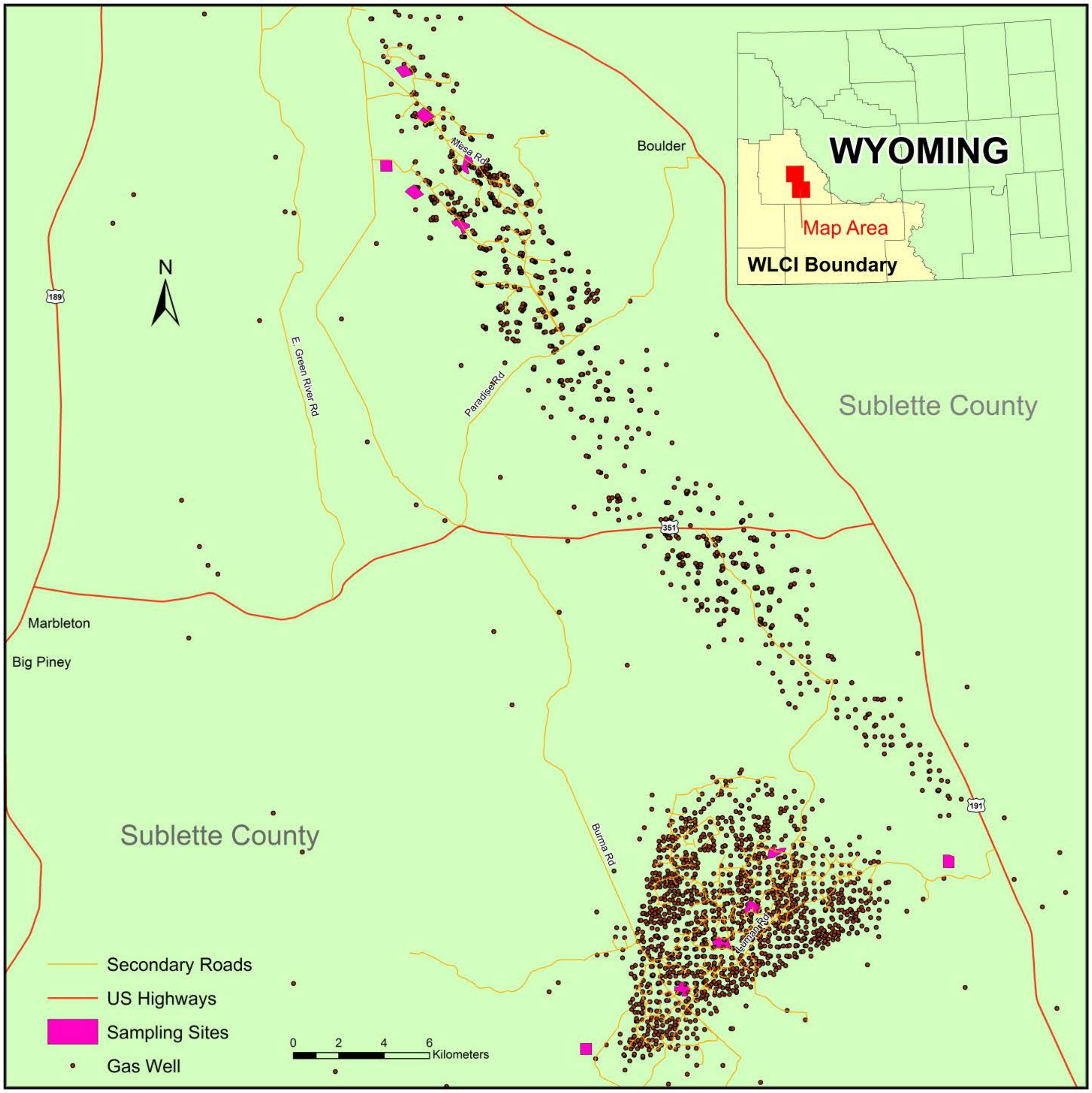

Figure 40. Sampling sites for Phase II of the *Songbird Community* study (pink squares) were established across gradients in well density of the Pinedale Anticline (loose cluster of wells trending northwest to southeast upper-to-lower part of the map) and Jonah (tight cluster of wells in the lower central part of the map) natural gas fields.

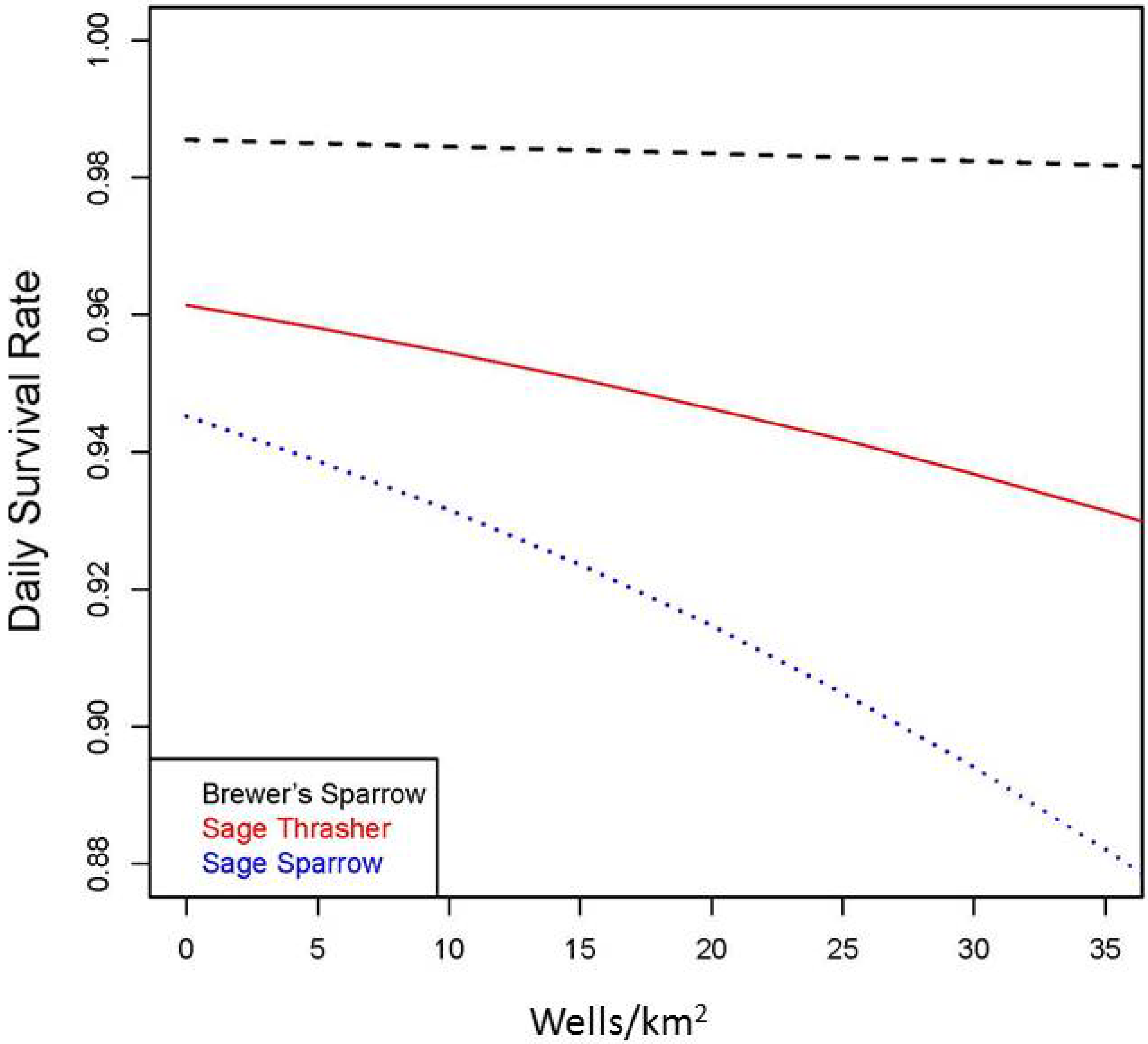

Figure 41. Daily nest survival rates regressed against well density (per square kilometer [km^2]) for three sagebrush-obligate songbird species nesting in the Pinedale Anticline Project Area and the Jonah Field natural gas fields in Sublette County, Wyoming.

Products Completed in FY2011

- Hethcoat, M.G., and Chalfoun, A.D., 2011, Increased nest predation and energy development—Understanding the mechanisms: Annual Meeting of The Wyoming Chapter Wildlife Society, December 2011, Jackson, Wyo. [presentation].
- Hethcoat, M.G., and Chalfoun, A.D., 2011, Mechanisms underlying increased songbird nest predation in natural gas fields: Annual Meeting of The Wildlife Society, December 5-10, 2001, Kona, Hawaii [poster].

- Hethcoat, M.G., and Chalfoun, A.D., 2011, Energy development and nest predation—A proposal: University of Wyoming Zoology Department Brown Bag Seminar Series, April 2011, Laramie, Wyo. [presentation].
- Gilbert, M.M., and Chalfoun, A.D., (in revision), Increased nest predation and food limitation as potential mechanisms underlying sagebrush-obligate songbird declines within energy development fields: Condor (in revision).

Work Planned for FY2012

During FY2012, suggestions for relevant changes to the study methods made by collaborators and other researchers will be incorporated. The field season will be conducted from May–August. Additional camera setups will be deployed in an effort to record more predation events in the 2012 breeding season. Analysis of the data collected in FY2011 will continue, and results will be presented in August at the North American Ornithological Conference in Vancouver, Canada. In fall 2012, analysis of the data collected in both 2011 and 2012 will be initiated in preparation for publication in peer-reviewed journals.

Mule Deer

Status

Ongoing

Contact

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Scope and Approaches

As habitat loss and fragmentation increase across ungulate ranges, identifying and prioritizing migration routes for land-use planning and conservation have taken on a new urgency. During an earlier phase of this work (Sawyer and others, 2009), a general framework was created for identifying and mapping migration routes with the greatest conservation value within a network of routes. This approach has been applied to migratory mule deer populations that winter near the Atlantic Rim and Pinedale Anticline Project Areas of southwestern Wyoming. In addition to identifying key migration corridors for conservation and enhancement, these analyses identified the consistent use of stopover areas by migrating deer, similar to what has been found along long-distance migration corridors used by avian taxa.

Overall, so far the results of this work suggest that migrating ungulates derive considerable foraging benefit from the habitats through which they migrate (Sawyer and Kauffman, 2011). Although migrating ungulates are able to navigate through habitats that have some level of development, the levels of development at which ungulate migration routes become compromised are unknown. In particular, it is not known when threshold levels of development are met or exceeded (Saunders and others, 1991; Frair and others, 2008). This represents an important research need because it strongly affects both the necessity for and efficacy of on-the-ground conservation measures aimed at altering development to avoid possible negative effects on migration routes. An understanding of threshold levels of development will allow resource managers to best manage Wyoming’s ungulate populations while designing for sustainable energy development.

The approach to this work entails analyzing GPS movement data collected during previous studies (conducted by the Wyoming Cooperative Fish and Wildlife Research Unit) of mule deer, elk, moose (*Alces alces*), and pronghorn (approximately 400 animals total), where migration routes overlap key energy-development areas within the WLCI study area. Although these data were not originally collected for the purpose of evaluating thresholds, their rich spatial nature makes them ideal for such analyses and will provide valuable information to managers at low additional cost. Our overall approach to evaluating threshold levels of development is to quantify attributes that pertain to how individual animals use migratory routes (for example, speed of travel, time spent in stopovers, fidelity), and then ask whether these behavioral patterns are altered along routes where levels of development are high. Behavioral response variables measured via GPS movement paths include (1) migration speed, (2) migration duration, (3) timing of migration, (4) route fidelity, and (5) stopover use. After evaluating the migratory behavior of marked individuals along each route, we will use GIS layers of roads, well pads, and other disturbance to score the level of development for each route and evaluate the influence of development on the use of corridors by migrating ungulates. This analysis will indicate whether ungulates move faster or stop over less frequently in highly developed areas, and it may allow us to determine whether ungulates have abandoned migration routes in highly developed areas.

Mule deer moving through snow. Photo credit: Tim Glenner, California Department of Fish and Game.

Objectives

- Map and characterize migration corridors for several species of ungulates by using existing ungulate-movement data collected with a GPS during past studies.
- Quantitatively assess the influence of energy development and other anthropogenic disturbances on the use of migration routes and the behavior of sampled ungulates.
- Evaluate use and avoidance of migration routes across an intensity gradient of energy development and disturbance, and identify potential threshold levels of development.

Study Area

Since migration routes cover vast areas and several different species are being studied (moose, elk, deer, and pronghorn), this study is being conducted over the entire WLCI region (fig. 1). Recorded migration routes pass through or around the Atlantic Rim, Moxa Arch, Jonah Infill, Pinedale Anticline, and Big Piney-LaBarge energy-development project areas (fig. 26).

Work Accomplished in 2011 and Findings

FY2011 work entailed continuing to build spatial (GIS) migration datasets suitable for the threshold analysis. The GIS is not yet complete, but it includes movement data from pronghorn, elk, mule deer, and moose, mostly in the WLCI study area. USGS scientists also have been in discussion with other researchers in Wyoming about the possibility of including their GPS ungulate-movement data in the analyses. Because this requires identifying the migratory periods of hundreds of animals, we are developing GIS visualization tools to assist with identifying and measuring migration bouts within the GIS movement datasets. In collaboration with other WLCI researchers, we are also developing a means of quantifying the level of surface disturbance experienced by each migrating animal. In FY2011, the focus was to evaluate how development influences the rate of movement of migrating mule deer in the Atlantic Rim and Pinedale Anticline Project Areas. To do this, existing GIS datasets of roads and well pads were used to identify "pristine" and "disturbed" segments within the migration route taken by an individual deer. The movement rates of individual deer in pristine and disturbed habitats were calculated and compared.

The analysis of disturbance influence on migration rate yielded very clear results. Across spring and fall migrations, for deer in two study areas, deer moved more quickly when migrating through disturbed habitat as compared to movement rates in more pristine habitats (fig. 42). Previous work associated with this project showed that mule deer migrating through undisturbed habitat spend considerable time (95 percent of their 3-week long migrations) stopping over to forage in identified habitat patches. The finding that migrating deer speed up while migrating through disturbed areas suggests that human disturbance likely diminishes foraging opportunities associated with stopover sites.

Products Completed in FY2011

- Wyckoff, T.B., Kauffman, M.J., and Albeke, S.E., 2001, Evaluating the influence of development on ungulate migrations: Annual Meeting of The Wildlife Society, November 5–10, 2011, Kona, Hawaii [poster].
- Wyckoff, T.B., Kauffman, M.J., and Albeke, S.E., 2001, Evaluating the influence of development on ungulate migrations: Annual Meeting of the Wyoming Chapter of The Wildlife Society, December 6–9, 2011, Jackson, Wyo. [poster].

- Allen, L.A., and Kauffman, M.J., 2012, WLCI researchers employ new approaches to help managers conserve deer migrations: U.S. Geological Survey, WLCI Fact Sheet 2, 4 p., online at *http://pubs.usgs.gov/wlci/fs/2/WLCI_fs_2.pdf*.

Work Planned for FY2012

As a result of past data collections, there is now movement data for approximately 400 individual ungulates with which to work. For each dataset, the seasonal ranges and migratory periods will be identified, and then the duration, speed of travel, stopover use, distance, timing, and fidelity will be measured for each migration path. Much of this work has been completed for two mule deer populations (fig. 42). In FY12, the development-footprint summary will be completed, resulting in a relative development score for each movement path. This will then allow an analysis for ascertaining whether level of development influences migration behavior.

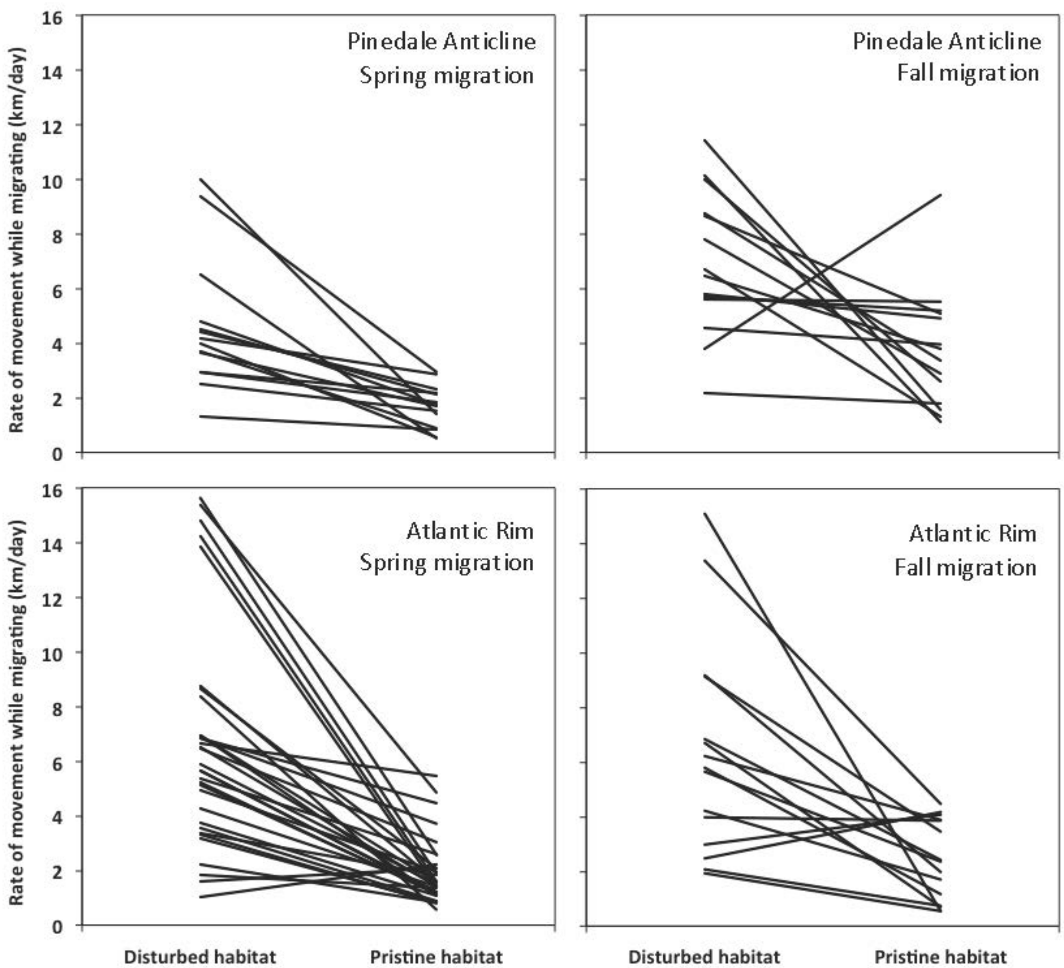

Figure 42. Individual deer migrations from the Atlantic Rim and Pinedale Anticline Project Areas were identified, and segments along the route were categorized as either pristine or disturbed. Movement rates [kilometers per day (km/day)] were calculated for each pair of disturbed and pristine segments. Results indicate that deer, from both study areas during both seasonal migrations, speed up when they encounter portions of their migration routes that have high levels of human use.

Data and Information Management

Summary of FY2010 Activities for Data and Information Management

Having an infrastructure for data and information management is crucial for WLCI partners to effectively coordinate and maintain information resources, communicate and disseminate information to users on the WLCI Website, and provide data-management tools for decisionmaking. The three tasks associated with this work are (1) *Data Management Framework and Clearinghouse*, (2) *Science and Conservation Projects Database*, and (3) *Outreach and Graphics Products*. Further development and enhancement of all three data and information-management tasks and associated products continued in FY2011.

More specifically, progress on the *Data Management Framework and Clearinghouse* entailed making improvements through advancement of the technology being used to host and serve data in the WLCI Data Clearinghouse and efforts of the DIMT to enhance and develop information sharing methods among WLCI partners. The information resources cataloged in the WLCI Data Clearinghouse were updated and enhanced through the acquisition of updated information records for WLCI region. Several important and useful datasets quantifying animal and plant distributions in Wyoming were added to the WLCI Data Clearinghouse. Methods to add and describe datasets in the WLCI Data Clearinghouse were improved through implementation of a comprehensive user interface.

During FY2011, work on the WLCI *Science and Projects Database* entailed adding information for new, funded projects and on-going projects to the Database. Science project information cataloged in the WLCI Data Clearinghouse was prepared for dynamic display using Web services within the WLCI Website. Virtual, collaborative community spaces in the myUSGS Confluence system were established for (1) the WLCI CT to organize and store information for annually proposed and funded conservation projects, and (2) the MT to store an Access database for gathering information about monitoring efforts conducted by WLCI partner agencies.

Finally, FY2011 work on the *Outreach and Graphics Products* activity entailed revamping the WLCI Website by employing a powerful content-management system, allowing (1) the use of Web services to feed cataloged information (projects, citations) from the WLCI Data Clearinghouse into the WLCI Website, and (2) the WLCI CT and Communication Team members to add and edit Website content. The WLCI bibliography was improved, and citations were cataloged in the WLCI Data Clearinghouse. The USGS fact sheet focusing on data management and development for the WLCI was published.

Details of the Data and Information Management work are provided in the three sections that follow.

Data Management Framework and Clearinghouse

Status

Ongoing

Contact

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Scope and Approaches

Providing, managing, analyzing, and using information assembled or generated for the WLCI is essential for supporting WLCI goals. The Data Management Framework and Clearinghouse work meets those needs by providing a Web-based platform for (1) discovering and taking advantage of existing data and information, (2) cataloging new data and information, (3) making data and information resources available online to the public and WLCI researchers and decisionmakers, and (4) collaboration promoted by the use of an online utility that allows management of knowledge and documents and fosters social interaction. Cataloging appropriate data resources for the WLCI community requires identifying the existing availability, content, scale, and resolution of data for resources relevant to the WLCI. Protocols for assembling data originating from monitoring and scientific fact-finding efforts are being established for the WLCI Data Clearinghouse by the WLCI DIMT.

Comprehensive access must be provided to data resources, enabling WLCI data users to characterize data and understand how data may be used. This access must include (1) downloading data to a local system, (2) viewing data with a map browser, and (3) visiting a Website for information. A data management framework must be developed continuously to meet user needs and evolve with fast-paced technological innovations. Likewise, the WLCI Data Clearinghouse must be maintained continuously to ensure that the information resources are current and relevant.

The myUSGS system, an additional online tool within the Data Management Framework, serves the internal WLCI community by providing an online platform for sharing and storing documents. Initiated during FY2011, the myUSGS collaborative tools are gradually being upgraded to the Confluence software toolset, which offers powerful document-management capabilities, along with additional methods to organize content, conduct and record discussions, and manage community access. The myUSGS online community platform is restricted to WLCI community members, which allows for storage and sharing of sensitive material, including preliminary data and information.

Development of a Data Management Framework and Clearinghouse requires the USGS DIMT to communicate routinely with the USGS Science Team and WLCI partners to identify data needs and determine data availability. Relevant data sources are routinely sought for addition to the WLCI Data Clearinghouse. Once identified, data are acquired and hosted on USGS systems or metadata are harvested and made available in the WLCI Data Clearinghouse. Harvesting methods using Web services are developed to catalog and document resources made available by external data providers. Periodic harvests of data providers' systems occur to ensure that the most up-to-date resources are made available in the WLCI Data Clearinghouse. The WLCI DIMT collaborates with external data providers and owners to determine optimum data sharing and handling methods.

The ScienceBase infrastructure, of which the WLCI Data Clearinghouse is part, is being refined continuously to aid in the management and advancement of information resources for scientific projects. User comments and suggestions direct development of the ScienceBase user interface and production of new data-management tools and capabilities. Activities and studies for the WLCI conducted by the USGS Science Team and agency partners are used to understand required capabilities of data-management tools sought by the WLCI community. The USGS Science Team is contributing information resources for the WLCI to guide development of data-integration tools that provide visualization capabilities for spatial information.

The DIMT, tasked with developing data-management capabilities for the WLCI, communicates with WLCI CT and Science Team members to identify data-management needs. These information resource needs are described to technical developers of the ScienceBase Data Management Framework to guide advancement of methods for cataloging, archiving, accessing, and visualizing resources in the WLCI Data Clearinghouse. Advancement of data management tools and techniques is shared with the WLCI CT and Science Team to garner input for (1) ensuring that the needs of WLCI are accommodated, (2) improving the development of products, and (3) helping to advance the use of and accessibility to WLCI resources.

Objectives

- Build and maintain a WLCI Data Clearinghouse.
- Identify the existing availability, content, scale, and resolution of data for resources relevant to the WLCI.
- Establish protocols for assembling data originating from monitoring and scientific fact-finding efforts for the WLCI Data Clearinghouse.
- Provide comprehensive access to data resources, enabling WLCI data users to understand data and what may be accomplished with the data.
- Advance data-management tools and capabilities to enable efficiency and progression of WLCI efforts.
- Work with the DIMT to establish an effective data-management framework and clearinghouse to meet the needs of WLCI partners.

Study Area

Activities associated with this work apply to the entire WLCI region (fig. 1).

Work Accomplished in 2011 and Findings

The WLCI Data Clearinghouse is a searchable online database that enables use of WLCI data and products (for example, maps, study locations, and information about science and habitat projects, key results, and summaries). The amalgamation, refinement, and management of WLCI data and information resources is performed using ScienceBase, a scientific data and information management system developed by the USGS for broad application. The WLCI Data Clearinghouse references many datasets, which are in various formats and derived from different sources; this complicates the ability for ScienceBase users to organize, select, and display project data in a coherent manner. The primary focus of Data Management Framework and Clearinghouse work in FY2011 consisted of (1) developing protocols for assembling, cataloging, and serving datasets in the WLCI Data Clearinghouse; (2) discovering and cataloging data and information useful to researchers, land managers, decision-makers, and the public; (3) refining and promoting the value of these existing information artifacts by completing and enhancing associated metadata; and (4) enabling access to these resources online through the use of comprehensive downloading and visualization methods.

During FY2011, Web-servicing techniques for using and displaying cataloged data within the WLCI Website (*www.wlci.gov*) were explored and implemented in a new WLCI Website, which is scheduled for release during FY2012. Through the use of Representational State Transfer (RESTful) Web Services, information items cataloged in the WLCI Data Clearinghouse are queried and dynamically displayed on the WLCI Website. Dynamically displayed information items include WLCI science projects and publication documents.

The Wyoming Geographic Information Science Center (WYGISC) at the University of Wyoming is responsible for hosting and maintaining geospatial data for Wyoming, which were harvested into the WLCI Data Clearinghouse during 2009. During FY2011, WYGISC's data resources were re-harvested into the WLCI Data Clearinghouse, ensuring the availability of the most current information resources for WLCI region. Because WYGISC provides information resources for the entire State of Wyoming, the harvested resources were examined and records relevant to Southwest Wyoming were selectively added to the WLCI Data Clearinghouse.

During FY2011, the DIMT conducted monthly meetings to identify relevant information resources controlled by WLCI partner agencies and efficient methods for adding these data holdings to the WLCI Data Clearinghouse. The DIMT determined it most appropriate and efficient for the WGFD to continue providing metadata records to WYGISC. In the future, the WGFD staff will alert the USGS about the availability of new and updated WGFD records, which will trigger a re-harvest of WYGISC systems and result in the availability of current and updated WGFD records in the WLCI Data Clearinghouse.

WLCI Wyoming Landscape Conservation Initiative

"Conserving world-class wildlife resources. Facilitating responsible development."

Wyoming Landscape Conservation Initiative Data Management and Integration

Discover and Access Scientific Data and Resource Management Information

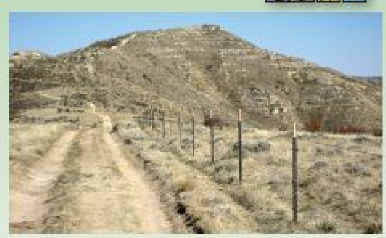
Image showing digital WLCI Data Catalog records, with associated descriptive and geospatial information, accessible through the WLCI Web site (*www.wlci.gov*).

Six Federal agencies, two State agencies, and two local entities formally support the Wyoming Landscape Conservation Initiative (WLCI) and work together on a landscape scale to manage fragile habitats and wildlife resources amidst growing energy development in southwest Wyoming. The U.S. Geological Survey (USGS) was tasked with implementing targeted research and providing scientific information about southwest Wyoming to inform the development of WLCI habitat enhancement and restoration projects conducted by land management agencies. Many WLCI researchers and decisionmakers representing the Bureau of Land Management, U.S. Fish and Wildlife Service, the State of Wyoming, and others have overwhelmingly expressed the need for a stable, robust infrastructure to promote sharing of data resources produced by multiple entities, including metadata adequately describing the datasets. Descriptive metadata facilitates use of the datasets by users unfamiliar with the data. Agency representatives advocate development of common data handling and distribution practices among WLCI partners to enhance availability of comprehensive and diverse data resources for use in scientific analyses and resource management. The USGS Core Science Analytics and Synthesis (CSAS) team is developing and promoting data integration tools and techniques across USGS and partner entity endeavors, including a data management infrastructure (described below) to aid WLCI researchers and decisionmakers.

WLCI Data Catalog

The WLCI Memorandum of Understanding (available at *www.wlci.gov*) specifies the need to integrate new data with existing knowledge and technologies to enable information exchange among agency partners. In collaboration with the USGS Fort Collins Science Center, CSAS established and maintains the WLCI Data Catalog to facilitate exchange of information, data, and research findings among partners, industry, and stakeholders. Agency partners are being engaged to identify relevant information resources to share with the WLCI community through the Data Catalog.

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



Photograph showing Grizzly Wildlife Habitat Management Area fencing project. Source: WICL

About the WLCI

The WLCI, established in 2007, is a long-term science-based partnership created to assess and enhance aquatic and terrestrial habitats in southwest Wyoming on a landscape scale while facilitating responsible development through local collaboration and partnerships. Partners in the WLCI include the Bureau of Land Management, U.S. Fish and Wildlife Service, U.S. Geological Survey, National Park Service, Bureau of Reclamation, Natural Resources Conservation Service, Wyoming Game and Fish Department, Wyoming Association of Conservation Districts, Wyoming County Commissioners' Association, and Wyoming Department of Agriculture, as well as university and private-sector collaborators.

Repeatable Methodology

A key strategic objective of the USGS in providing support to the WLCI is to establish repeatable methodologies in both science and management that can be applied to other projects and interagency partnerships in other areas of the United States with resource management challenges. For example, integrated ecological assessments, which incorporate several scientific fields into interdisciplinary evaluations of environmental systems, are being developed by USGS researchers. Large-scale, multidisciplinary, and multipartner endeavors such as the WLCI promote the sharing, advancement, and application of scientific data and information management tools and techniques in understanding pressing scientific and management issues.

Prepared in cooperation with the

USGS
science for a changing world

The BLM provided several datasets for animal and plant distributions in Wyoming, produced by the WYNDD for the Wyoming BLM. These sensitive datasets are permission-restricted and available through the WLCI Data Clearinghouse to WLCI community members.

Products Completed in FY2011

- Refined and updated information products in the ScienceBase catalog: updated data records harvested from the WYGISC, which include current datasets produced by the WGFD.
- Cataloged animal and plant species occurrence data produced by the WYNDD for the Wyoming BLM in the WLCI Data Clearinghouse.
- Improved uploading capability allowing WLCI community members to add information resources directly to the WLCI Data Clearinghouse.
- Latysh, N., and Bristol, S., 2011, Wyoming Landscape Conservation Initiative Data Management and Integration: WLCI Fact Sheet 1, 2 p. (pictured above).

Work Planned for FY2012

During FY2012, work will continue on (1) maintaining and refining datasets in the WLCI Data Clearinghouse, ensuring they are adequately described; (2) advancing data-harvesting methodologies by working with existing data providers and seeking new data providers holding pertinent information resources for WLCI; (3) developing and advancing Web-service techniques to use cataloged information resources for WLCI on other Websites, including *www.wlci.gov*; (4) coordinating with partner agency members of the DIMT to determine effective information-sharing processes among WLCI participants; and (5) engaging with the WLCI CT, MT, and Science Team to coordinate information needs among WLCI efforts. In FY2011, ScienceBase technology was revamped to incorporate RESTful Web services, which will allow the use of cataloged information in other applications, and in FY2012 the new ScienceBase version 2.0 will be released, allowing WLCI information resources to be queried and used in other Websites, including *www.wlci.gov*.

Science and Conservation Projects Database

Status

Ongoing

Contacts

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Scope and Approaches

Partners and stakeholders of the WLCI have expressed the need to have access to the descriptive information and locations of (1) "on-the-ground" conservation projects managed by the WLCI CT and (2) science projects being conducted by the USGS and other science-agency partners. In response to this need, WLCI project database maps were developed for science and conservation projects and are available on the WLCI Website. The interactive map environment enables users to click on geospatially referenced points, view project information, link to additional resources, including data, and use search and filter capabilities to constrain information. Information about science and conservation projects is stored in a geodatabase, which includes point and polygon footprints, and a simple set of attributes used to describe the projects (title, description, responsible entities, funding year(s), and annual updates). Project information is entered into the project database, which is part of the ScienceBase data-management system, and made available on the WLCI Website. The CT is using the myUSGS Confluence system to store, organize, and track information for annually proposed and funded projects. The USGS data and information personnel tasked with developing data management capabilities for the WLCI routinely update project information in the WLCI Data Clearinghouse and communicate with WLCI CT, MT, and Science Team members to identify data-management needs for project tracking and management.

USGS data management representatives attend meetings with the WLCI CT, MT, Science Team, and LPDTs to understand various project activities engaged by separate WLCI entities, including information products generated by project work and the methods and tools needed to efficiently share, manage, and track project information. Data management representatives coordinate with WLCI team members to catalog project information in the WLCI Data Clearinghouse for display on the WLCI website. Data representatives work with the CT to provide comprehensive methods and tools to track project information using the myUSGS Confluence system, which is only accessible to WLCI representatives. Data representatives work closely with the WLCI Science Team to identify effective methods of displaying and providing project information in the WLCI website.

Objectives

- Develop and enhance the online system to display habitat and science-project locations on a map with descriptive (attribute) information.
- Develop more comprehensive and robust methods for capturing project information.
- Use relevant data sources and data-management methods for the WLCI. (Some of these sources and models will have been developed for other broad USGS scientific efforts.)
- Provide and support virtual methods allowing WLCI community members to manage information for the Project Database.

Study Area

Activities associated with this task apply to the entire WLCI region (fig. 1).

Work Accomplished in 2011 and Findings

During FY2011, the WLCI Project Database was maintained and updated with information about new projects and additional information regarding status and progress was provided for ongoing projects. WLCI science projects were refined in the WLCI Data Clearinghouse with the addition of descriptive tags. These tags were used to perform query operations using Web services to selectively filter appropriate project records in the WLCI Data Clearinghouse for display in the new, developing WLCI website, which is scheduled for release in FY2012.

A collaborative virtual space was established in the myUSGS Confluence system to help the CT organize, track, and store information for annually proposed and funded conservation projects. In Confluence, the project information is organized by year and includes associated project artifacts, such as presentations, proposals, and photographs. The information for funded projects is cataloged in the WLCI Data Clearinghouse and made available in WLCI Web Site.

The USGS data management representatives initiated efforts to aid the WLCI MT in acquiring information about existing monitoring efforts conducted by partner agencies. WLCI MT representatives met with the WLCI DIMT to discuss the availability of monitoring data. Information for existing efforts sought from partners includes detailed information, locations, contacts, goals, analytical methods, monitoring protocols, and monitoring data. A Microsoft Access database was created and populated with known monitoring information. The Monitoring Project database is stored in the myUSGS Confluence system, accessible by Monitoring Team representatives. Information is being added to the monitoring database periodically, as it becomes available. Representatives from the MT requested that DIMT representatives coordinate with their respective agencies to identify monitoring activities in the WLCI region that may be added to the monitoring database.

Introduced during FY2011, new myUSGS Confluence tools enable (1) the CT to track, organize, and access habitat project information; and (2) the MT to acquire and document monitoring efforts conducted by WLCI partners. Technological advancements of the ScienceBase information-management system, which hosts the WLCI projects database, and implementation of Web services, have enabled the dynamic display of updated and enhanced project information in the new, developing WLCI Website.

Products Completed in FY2011

- Updated and current project information entered into the WLCI Data Clearinghouse.
- Established myUSGS Confluence space, allowing CT members to archive, manage, and track project information.
- Generated an Access database to document monitoring activities conducted by WLCI partners. The monitoring database is stored in the myUSGS Confluence space.
- Advanced the Web-servicing capabilities that allow use of cataloged information items, such as project information and citations, in WLCI Website.

Work Planned for FY2012

In FY2012, work will continue on (1) maintaining and updating the project database information, (2) advancing Web services to refine the display of project information on the WLCI Website and potentially other Websites, and (3) exploring methods to associate project artifacts (such as photographs, maps, datasets) in the WLCI Data Clearinghouse.

Outreach and Graphic Products

Status

Ongoing

Contacts

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Scope and Approaches

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, the USGS developed a usable and content-rich Web presence for the WLCI. The WLCI Website (*www.wlci.gov*) provides information about ongoing activities and facilitates discovery of additional resources, including publications, reports, newsletters, data products, and habitat and science projects. The WLCI CT and Communication Team manage content for the WLCI Website.

The USGS DIMT routinely communicates with the WLCI CT and Communication Team to (1) ensure that the WLCI Website displays current and accurate information; (2) determine the need for additional Website features, such as tabbed pages for special events; and (3) identify modifications needed for the WLCI Website. Authorized WLCI CT and Communication Team members routinely add and update information, including projects, photographs, and meeting notes and agendas.

The USGS DIMT personnel aid WLCI teams and participants to identify effective methods for managing and disseminating information. These methods are articulated in information articles and publications, and shared with and employed for other scientific projects. The USGS data representatives routinely attend meetings conducted by the WLCI EC, CT, and others to remain informed about WLCI activities, coordinate with team members when identifying outreach needs, and ensure that information about the WLCI is being adequately advertised and promulgated. USGS data representatives routinely participate in *ad hoc* committees to manage and coordinate information regarding special events and activities.

Objectives

- Develop and maintain a public Website providing current information about WLCI goals and activities.
- Provide and support virtual methods allowing WLCI community members to manage information for the WLCI Web site and Project Database.
- Publish information articles (such as USGS Fact Sheets), sharing methods used to provide outreach and graphic products for the WLCI.
- Identify and advertise outreach and graphic products generated for the WLCI by various WLCI participants, including the USGS Science Team, CT, MT, and others.

Study Area

Activities associated with this work apply to the entire WLCI region (fig. 1).

Work Accomplished in 2011 and Findings

The WLCI Website requires regular maintenance and refinement. In FY2011, the USGS DIMT began developing a new WLCI Website using the Drupal open source content management system. The Drupal system is powerful and flexible, providing advanced capabilities for managing information intended for WLCI Website display, enabling CT and Communication Team members to remotely augment the WLCI Website, and allowing use of Web services to display information dynamically in the WLCI Website. Working with the WLCI CT and Communication Teams, the new Website was constructed to differ significantly from the existing WLCI Website, as requested by various WLCI partner agency and public participants. The new WLCI Website was designed to more readily engage and relate synoptic information to public users, ensconcing technical jargon and details in auxiliary pages on the Website. While important technical details and documents remain available on the new WLCI Website, they are less conspicuous than they were previosuly, with aesthetically pleasing photographs and short information bits being more prominent. The new Website uses Web services to dynamically display project information and publication citations cataloged in the WLCI Data Clearinghouse, providing comprehensive and versatile connectedness among various WLCI information resources.

The WLCI bibliography was improved. Citations for agency reports, USGS scientific publications, and publications for topics relevant to WLCI were cataloged in the WLCI Data Clearinghouse for display in the new, developing WLCI Website. Finally, a USGS fact sheet focusing on data management and development for the WLCI was published.

Products Completed in FY2011

- Latysh, N., and Bristol, S., 2011, Wyoming Landscape Conservation Initiative Data Management and Integration: U.S. Geological Survey, WLCI Fact Sheet 1, online at *http://pubs.usgs.gov/wlci/fs/1/WLCI_FS_1.pdf*.
- For the WLCI Website, Web service capabilities were developed to dynamically display science project information and publication citations cataloged in WLCI Data Clearinghouse.
- The WLCI bibliography was improved, and additional publication citations relevant to WLCI were documented and cataloged in WLCI Data Clearinghouse.

Work Planned for FY2012

Work to further refine the WLCI Website, including advancement of its information-handling capabilities and publicly releasing it, will extend into FY2012. Detailed information about USGS science projects and other scientific studies conducted in Southwest Wyoming will be added to the Website. Cataloging, relating, and managing project artifacts, such as photographs and documents, in WLCI Data Clearinghouse for dynamic display in WLCI Website will continue. USGS data personnel will work with the WLCI CT and Communication Team to refine the WLCI Website, using stories and rich content, including graphics and maps, to add to the public's understanding of the WLCI mission and activities. Information-mining activities will seek relevant WLCI information resources for cataloging in WLCI Data Clearinghouse. The WLCI bibliography of scientific publications, agency reports, and other relevant citations will be maintained and updated.

WLCI Coordination, Science Integration, Decisionmaking, and Evaluation

Summary of FY2011 Activities for WLCI Coordination, Science Integration, Decisionmaking, and Evaluation Activities

A USGS scientist, who is a member of the WLCI CT, continues to work full-time with the WLCI CT to manage WLCI operations, coordinate WLCI teams and committees, and integrate science principles and concepts into WLCI activities. These tasks are intended to support conservation planning and to ensure that USGS science helps inform on-the-ground management actions and decisions. This individual serves as a direct connection between local managers, project developers, and administrators, and as a liaison to the WLCI for the scientific information and technical capabilities available through The USGS and partners. In addition to the CT, the USGS also supports and(or) provides leadership (representation) for other WLCI teams and committees, including the WLCI EC, MT, DIMT, and STAC.

During 2011, the USGS continued to participate in and provide leadership for numerous WLCI teams and committees necessary to meet the goals and objectives of WLCI. The USGS coordinator continued to provide direction and oversight associated with strategic conservation planning and with developing WLCI conservation priorities and actions. The coordinator also participated with other CT members to carry out the operational and logistical activities associated with the WLCI, including planning and logistics associated with the Ruby Conservation Fund. Investigators with the USGS presented science information to the WLCI EC and WLCI partners and met with many WLCI partners to discuss USGS science activities and related findings as a way to integrate science into WLCI. Details of this work are provided in the section that follows.

WLCI Coordination, Science Integration, Decisionmaking, and Evaluation

Status

Ongoing

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Scope and Approaches

A program as large and complex as the WLCI requires significant coordination and management, as well as the integration of what is learned from science with the decisionmaking and program-evaluation processes. For the WLCI, coordination and integration are accomplished through the WLCI CT, which is composed of one member each from the USGS, BLM, FWS, WGFD, and WDA. There is also a USGS member on the Science and Technical Advisory Committee. Under the direction of the WLCI EC, the CT manages the fiscal and logistical operations necessary to meet the goals and objectives of the WLCI. The CT also is responsible for conservation planning and implementing adaptive management strategies to guide future conservation actions. Decisionmaking and evaluation are achieved by iteratively improving the overall knowledge base as new knowledge is acquired and products are completed. The knowledge and products are then used to inform decisions made about habitat projects and other conservation activities and to inform evaluations of the overall effectiveness of habitat projects in meeting WLCI goals.

Objectives

- Provide coordination and science integration for planning and work among multiple research and management projects and activities to meet the WLCI's goals and objectives.
- Provide coordination and direction to WLCI teams and committees.
- Participate as team leads for the USGS Science Team, Data and Information Management Team, and the MT.
- Ensure that the interdisciplinary knowledge, expertise, and work of scientists with the USGS and other organizations are available to support the work of WLCI managers and decisionmakers.

Study Area

Activities associated with this task apply to the entire WLCI region (fig. 1).

Pat Anderson gets some field assistance from Bonnie Cannon, Congressional District Representative, while conducting an outreach meeting on Little Mountain, Wyoming. Photo credit: Tim Assal, Ecologist, U.S. Geological Survey.

Work Accomplished in 2011 and Findings

During FY2011, the USGS continued to participate in numerous activities designed to inform WLCI partners about USGS science activities, improve collaboration, and integrate science with decisionmaking during FY2012. These activities included (1) participating on WLCI teams and committees (the EC, CT, STAC, MT, DIMT, and USGS Science Team) and serving as a WLCI liaison and steering team member for the GNLCC; (2) providing direction and oversight of WLCI strategic conservation planning, and presenting science activities and science findings at WLCI meetings and field tours; and (3) organizing or participating in meetings to better integrate science information among partners and conservation activities.

The USGS WLCI coordinator was involved with numerous coordination and integration activities. The primary activities continued to focus on defining WLCI conservation priorities, issues, and priority conservation areas. Some of the activities included working with the WLCI CT to meet with project leads, conduct site visits, photograph and map areas of interest and related issues. In addition to conservation planning, some of these 2011 coordination activities included

- providing direction and coordination between the DIMT, STAC, MT, and USGS Science Team;
- presenting information about USGS science activities and products at numerous at LPDT meetings and with staff from WGFD and BLM field offices;
- participating in the evaluation and selection of WLCI habitat projects for 2011;
- initial planning for the 2012 WLCI Science Workshop, which included developing a questionnaire;
- participating with the CT to make recommendations and to complete the 2011 WLCI Program Review;
- working with WLCI partners to acquire data to support science studies, conservation planning and integrated assessments;
- planning activities associated with the Ruby Conservation Fund; and
- meeting with WLCI partners to plan aspen monitoring for 2011.

Products Completed in FY2011

The USGS continued to provide the WLCI EC information about USGS science activities and their application to the WLCI during FY2011. The list of products below provides a full description of each presentation made by USGS investigators to the WLCI executive leadership during executive meetings and affiliated tours.

- Robert McDougal of the Crustal Geophysics and Geochemistry Science Center presented information about the development of assessment methods in support of USGS Integrated Science.
- Chris Potter provided an overview of the Energy Resources of Southwest Wyoming (WLCI Study Area).
- Dave Mott of Wyoming Water Science Center provided an overview of the formation of the Green River Basin and discussed drivers associated with groundwater.
- Zack Bowen of the USGS Fort Collins Science Center discussed WLCI management needs and priorities for the USGS Energy and Minerals Mission.
- Zack Bowen presented an overview of WLCI Long-Term Monitoring: USGS Activities.
- Zack Bowen discussed the completion of Phase I of the IA and initial development of the associated IA web application.
- Steve Germaine of the USGS Fort Collins Science Center provided an update of his study using LiDAR technology to map vegetation.

Work Planned for FY2012

The USGS WLCI Coordinator will continue to support completion of the WLCI Conservation Plan. In addition, the Coordinator will work with other CT members to initiate the 2011 WLCI Program Review recommendations. This will include revising the Science strategy and developing a WLCI meeting with all WLCI-related teams and committees. The USGS will continue to work with WLCI partners to plan the 2012 WLCI Science Workshop and provide updates of specific USGS science activities to the WLCI EC. The USGS will continue to work with the WGFD as liaisons for WLCI with the GNLCC and other Landscape Conservation Cooperatives. Finally, USGS investigators will continue to meet with land management agencies to discuss interim and final assessment and map products associated with the IA.

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