USGS
science for a changing world

U.S. Geological Survey Science for the Wyoming Landscape Conservation Initiative—2010 Annual Report

Open-File Report 2011–1219

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

Front and back cover photographs: Mule Deer Herd, by Gary Zahm, U.S. Fish and Wildlife Service; Tule Butte, east of Farson, Wyo., by Spencer Schell, Ecologist, U.S. Geological Survey; Prickly Pear Cactus, west of Baggs, Wyo., by Spencer Schell, Ecologist, U.S. Geological Survey; Aspen patches in the Little Mountain area south of Rock Springs, Wyo., by Jessica Brauch, Field Technician, U.S. Geological Survey.

U.S. Geological Survey Science for the Wyoming Landscape Conservation Initiative—2010 Annual Report

By Zachary H. Bowen, Cameron L. Aldridge, Patrick J. Anderson, Timothy J. Assal, Laura R.H. Biewick, Steven W. Blecker, Gregory K. Boughton, Sky Bristol, Natasha B. Carr, Anna D. Chalfoun, Geneva W. Chong, Melanie L. Clark, Jay E. Diffendorfer, Bradley C. Fedy, Katharine Foster, Steven L. Garman, Stephen Germaine, JoAnn Holloway, Collin Homer, Matthew J. Kauffman, Douglas Keinath, Natalie Latysh, Daniel Manier, Robert R. McDougal, Cynthia P. Melcher, Kirk A. Miller, Jessica Montag, Christopher J. Potter, Spencer Schell, Sarah L. Shafer, David B. Smith, Lisa L. Stillings, Michele Tuttle, and Anna B. Wilson

Open-File Report 2011–1219

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

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia 2011

For product and ordering information:
World Wide Web: *http://www.usgs.gov/pubprod*
Telephone: 1-888-ASK-USGS

For more information on the USGS—the Federal source for science about the Earth,
its natural and living resources, natural hazards, and the environment:
World Wide Web: *http://www.usgs.gov*
Telephone: 1-888-ASK-USGS

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

Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Although this report is in the public domain, permission must be secured from the individual copyright owners to reproduce any copyrighted material contained within this report.

Contents

Figures

Tables

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.
Vertical coordinate information is referenced to the insert datum name (and abbreviation) here, for instance, "North American Vertical Datum of 1988 (NAVD 88)."
Horizontal coordinate information is referenced to the insert datum name (and abbreviation) here, for instance, "North American Datum of 1983 (NAD 83)."
Altitude, as used in this report, refers to distance above the vertical datum.

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
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
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
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
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 U.S. Geological Survey WLCI efforts by providing data and other information. The authors also wish to thank the WLCI STAC, Dan Blake (U.S. Fish and Wildlife Service), and Steve Hostetler (U.S. Geological Survey) for their careful 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.

U.S. Geological Survey Science for the Wyoming Landscape Conservation Initiative—2010 Annual Report

By Zachary H. Bowen,[1] Cameron L. Aldridge,[2] Patrick J. Anderson,[1] Timothy J. Assal,[3] Laura R.H. Biewick,[4] Steven W. Blecker,[5] Gregory K. Boughton,[6] Sky Bristol,[7] Natasha B. Carr,[1] Anna D. Chalfoun,[8] Geneva W. Chong,[9] Melanie L. Clark,[6] Jay E. Diffendorfer,[10] Bradley C. Fedy,[2] Katharine Foster,[6] Steven L. Garman,[10] Stephen Germaine,[1] JoAnn Holloway,[11] Collin Homer,[12] Matthew J. Kauffman,[8] Douglas Keinath,[13] Natalie Latysh,[7] Daniel Manier,[3] Robert R. McDougal,[11] Cynthia P. Melcher,[1] Kirk A. Miller,[6] Jessica Montag,[1] Christopher J. Potter,[4] Spencer Schell,[1] Sarah L. Shafer,[14] David B. Smith,[15] Lisa L. Stillings,[11] Michele Tuttle,[11] Anna B. Wilson[15]

Abstract

This is the third report produced by the U.S. Geological Survey (USGS) for the Wyoming Landscape Conservation Initiative (WLCI) to detail annual USGS work activities. The 2008 report described work activities for FY2007 and FY2008, and the 2009 report described work activities for FY2009; this report covers work activities conducted in FY2010. The 2008 and 2009 reports may be accessed at *http://pubs.usgs.gov/of/2009/1201/* and *http://pubs.usgs.gov/of/2010/1231/*, respectively.

In FY2010, there were 35 ongoing, completed, or new projects conducted under the five major multi-disciplinary science and technical-assistance activities: (1) Baseline Synthesis; (2) Targeted Monitoring and Research (which includes three distinct overarching projects—Long-term Monitoring [LTM], Effectiveness Monitoring [EM], and Mechanistic Studies of Wildlife [MSW]—under which numerous smaller studies are being conducted); (3) Data and Information Management; (4) Integration and Coordination; and (5) Decisionmaking and Evaluation.

[1] U.S. Geological Survey, Fort Collins Science Center, Fort Collins, Colo.
[2] Colorado State University, Natural Resource Ecology Laboratory, Fort Collins, Colo., in cooperation with U.S. Geological Survey, Fort Collins Science Center, Fort Collins, Colo.
[3] Arctic Slope Regional Corporation management services, contracted to U.S. Geological Survey, Fort Collins Science Center, Fort Collins, Colo.
[4] U.S. Geological Survey, Energy Resources Science Center, Denver, Colo.
[5] U.S. Geological Survey, Western Mineral and Environmental Resources Science Center, Reno, Nev.
[6] U.S. Geological Survey, Wyoming Water Science Center, Cheyenne, Wyo.
[7] U.S. Geological Survey, Core Science Systems, Denver, Colo.
[8] U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit, Dept. of Zoology and Physiology, Univ. of Wyoming, Laramie, Wyo.
[9] U.S. Geological Survey, Northern Rocky Mountain Science Center, Jackson, Wyo.
[10] U.S. Geological Survey, Rocky Mountain Geographic Science Center, Denver, Colo.
[11] U.S. Geological Survey, Crustal Geophysics and Geochemistry Science Center, Denver, Colo.
[12] U.S. Geological Survey, EROS Data Center, Sioux Falls, S.D.
[13] Wyoming Natural Diversity Database, Univ. of Wyoming, Laramie, Wyo.
[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.

Of the 14 baseline synthesis projects conducted in FY2010, 2 were completed, 11 were ongoing (1 had a major shift in emphasis), and 1 was new. The two completed projects were the conceptual modeling and indicator selection for monitoring resource conditions across the WLCI region, and the literature review on effects of oil and gas development in western regions of the United States. Final reports for both projects are in the last stages of publication and should be available in 2011. A major ongoing baseline synthesis task, the comprehensive assessment, included (1) continued compilation of data gathered through various projects to generate maps and other geospatial products for facilitating the ranking and prioritizing of proposed conservation projects, and for developing a WLCI 5-year Conservation Action Plan; and (2) further development of an integrated assessment that analyzes WLCI resource values based on the best available information and data, and which will support landscape-scale conservation planning and evaluation by providing data and analysis resources for addressing specific management questions.

Throughout the integrated assessment's development, USGS scientists have sought WLCI partner input to ensure that the resulting products will be of the greatest possible use to them. Ongoing baseline synthesis work also included simulation modeling of future potential changes in vegetation and wildlife habitat; compiling an energy map of southwestern Wyoming and developing a subsurface geologic database; using downscaled projected climate data to create a set of bioclimatic variables, such as growing-degree days and seasonal moisture indices; additional assessments and mapping of mineral and energy resource development or potential development; quantifying the distribution of all Wyoming Species of Greatest Conservation Need in relation to energy development and their sensitivities to disturbance; and analyzing/preparing for publication the results of a survey to assess rancher perceptions related to energy development.

Other ongoing baseline synthesis work that is not funded by WLCI entailed developing methods for assessing trace element mobilities and their biogeochemical effects on ecosystem health; using remote sensing applications for mapping geology, soils, and vegetation, including a new focus on detecting early-season invasive plants (particularly cheatgrass); and relating total organic carbon (TOC) and total nitrogen (TN) to enzyme activity to provide a soil-quality index. Although not a new baseline synthesis activity, the work of developing methods for assessing soil organic matter and mercury at various spatial scales was shifted to an evaluation of biogeochemical cycling of elements in the Muddy Creek basin; this shift was based on results of work conducted in FY2009 that indicated that selenium and arsenic levels may be elevated in the basin. New baseline synthesis work included developing regional curves (statistical models) for relating bankfull-channel geometry and discharge to drainages in the WLCI region. The term, bankfull, references the stage of streamflow during which a given stream completely fills its channel. Originally, this work was line-itemed in the budget for long-term monitoring, but the work was more in keeping with baseline information development that will eventually be used for *guiding* long-term monitoring of water resources.

Of the 17 targeted research and monitoring projects conducted in FY2010, 15 were ongoing (4 for LTM, 7 for EM, and 4 for mechanistic studies of wildlife [MSW]) and 2 were new (1 for LTM and 1 for EM). Ongoing LTM projects included testing the monitoring framework for its ability to generate simple sampling designs that adequately represent the range of variation across large, heterogeneous landscapes. The statistical properties of two potential resource condition indicators—vegetation cover and abundance of passerine birds—also were considered for their ability to detect change and adequately represent overall ecosystem condition. The ongoing LTM project to develop improved land-cover mapping methods for shrubland systems through the use of multiple remote sensing products is near completion; methods are being formalized in reports and publications; and tools are being developed for updating information on vegetation condition. Maps and data products are already being applied to planning and decisionmaking. The ongoing work of assessing soil geochemistry for LTM entailed expanding soil-sampling efforts in the area added to the WLCI region in 2009. These data were analyzed to allow further characterization of the WLCI region's soil geochemistry. The ongoing LTM of water resources continued, and a monitoring station was added in the Muddy Creek basin. The new LTM project entailed compiling existing water data for the entire WLCI region to help guide long-term water monitoring efforts, and initiating a groundwater-monitoring network for deep wells (deeper than 160 feet (ft)).

The ongoing EM work included continued development of vegetation greenness indices for monitoring sagebrush (*Artemisia* spp.) treatments with "mantis" near-surface reflectance sensors; the techniques being developed may be used by decisionmakers in a variety of contexts. Also ongoing was the EM work of assessing use of vegetation treatment areas by greater sage-grouse (hereafter sage-grouse) (*Centrocercus urophasianus*); this project was expanded to include additional treatment sites within the Moxa Arch Natural Gas Development area. The EM study that entails measuring cheatgrass (*Bromus tectorum)* occurrence in burn treatments of the Little Mountain Ecosystem continued in existing plots and was initiated in additional plots established in FY2010. The EM study to evaluate aspen (*Populus tremuloides*) responses to the mechanical removal of conifers continued with data collection, and the study evaluating relationships between ungulate herbivory and fire on aspen recruitment was expanded to evaluate relationships between aspen stand structure and the composition and herbivory of aspen at different ecological and hydrological settings. The development of methods for fine-scale mapping of aspen distribution for EM continued with the application of classification and regression tree analysis to imagery procured from the National Agriculture Imagery Project. The EM work to assess migratory bird use of isolated aspen stands and riparian habitats continued with bird surveys and characterization of stand conditions at multiple scales to determine what may influence avian use of these habitats. A new EM activity initiated in FY2010 was designed to assess the effects of energy-development activities within the Muddy Creek Basin, where significant energy exploration and development may be mobilizing selenium and other trace elements that could affect biogeochemical cycling and the overall ecology of the basin. In FY2010, this work entailed sampling stream-water chemistry, stream sediments, upland soils, and macroinvertebrates to characterize conditions in the basin.

Work on MSW continued FY2010 on the four focal species/groups: pygmy rabbit (*Brachylagus idahoensis*), sage-grouse, sagebrush-obligate songbird community, and mule deer (*Odocoileus hemionus*). The pygmy rabbit work entailed validating two existing pygmy rabbit distribution maps; initiating development of a new habitat-association model; collecting pre-treatment pygmy rabbit occupancy data in the Non-Pressurized Lands gas field; initiating a pygmy rabbit survival/demography study; and collecting vegetation, pygmy rabbit, and sagebrush songbird data in a region of the WLCI study area for which USGS acquired Light Detection and Ranging (LiDAR) imagery data. The sage-grouse study continued evaluations of long-term population trends and was expanded to include habitat use and prioritization; several manuscripts were submitted for publication. The first phase of songbird-community studies culminated in identifying several important patterns in relation to the intensity of energy development: both songbird abundance and nesting productivity were negatively influenced by increased density of well pads and increased proximity to the nearest well pad. Phase II of the mule deer study was initiated by assessing how energy development affects ungulate species' use of migration routes and their behavior (including foraging).

The ongoing work of data and information management focused on further developing and enhancing WLCI data and information resources; developing advanced data management capabilities in the WLCI Data Clearinghouse, including data visualization tools and the process for uploading and sharing data; maintaining and refining the science and projects database to ensure it is up-to-date, accurate, and complete; developing the means for more easily streaming information to the WLCI Web site using Web services; and enhancing and updating the WLCI Web site by offering new information and improved graphics and layout.

Finally, the USGS scientist liaison to the WLCI and Coordination Team (CT) member continued Integration/Coordination and Decisionmaking/Evaluation activities by collaborating with the CT to manage WLCI operations, coordinate WLCI teams and committees, and integrate science principles and concepts to support conservation planning and ensure that USGS science helps inform on-the-ground management actions and decisions. These efforts continue to focus on iteratively improving science relevance by evaluating what and how information is being used; participating in and providing leadership for numerous WLCI teams and committees designed to meet the goals and objectives of WLCI; and providing direction and oversight associated with strategic conservation planning and with developing WLCI conservation priorities and actions.

Many migratory birds use isolated patches of aspen in Southwest Wyoming.
Photo credit: Jessica Brauch, Field Technician, U.S. Geological Survey.

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. The potential effects of these changes on wildlife and wildlife habitat prompted the U.S. 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 WLCI 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 partners in the WLCI 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, 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. 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 WCLI activities, and demonstrating how to integrate research findings into on-the-ground management actions.

USGS WLCI Science Strategy Continues to Guide Science and Technical Assistance Activities in FY2010: Continued Development of the Integrated Assessment and a 5-year WLCI Conservation Action Plan

The USGS WLCI Science Strategy (Bowen and others, 2009b) 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

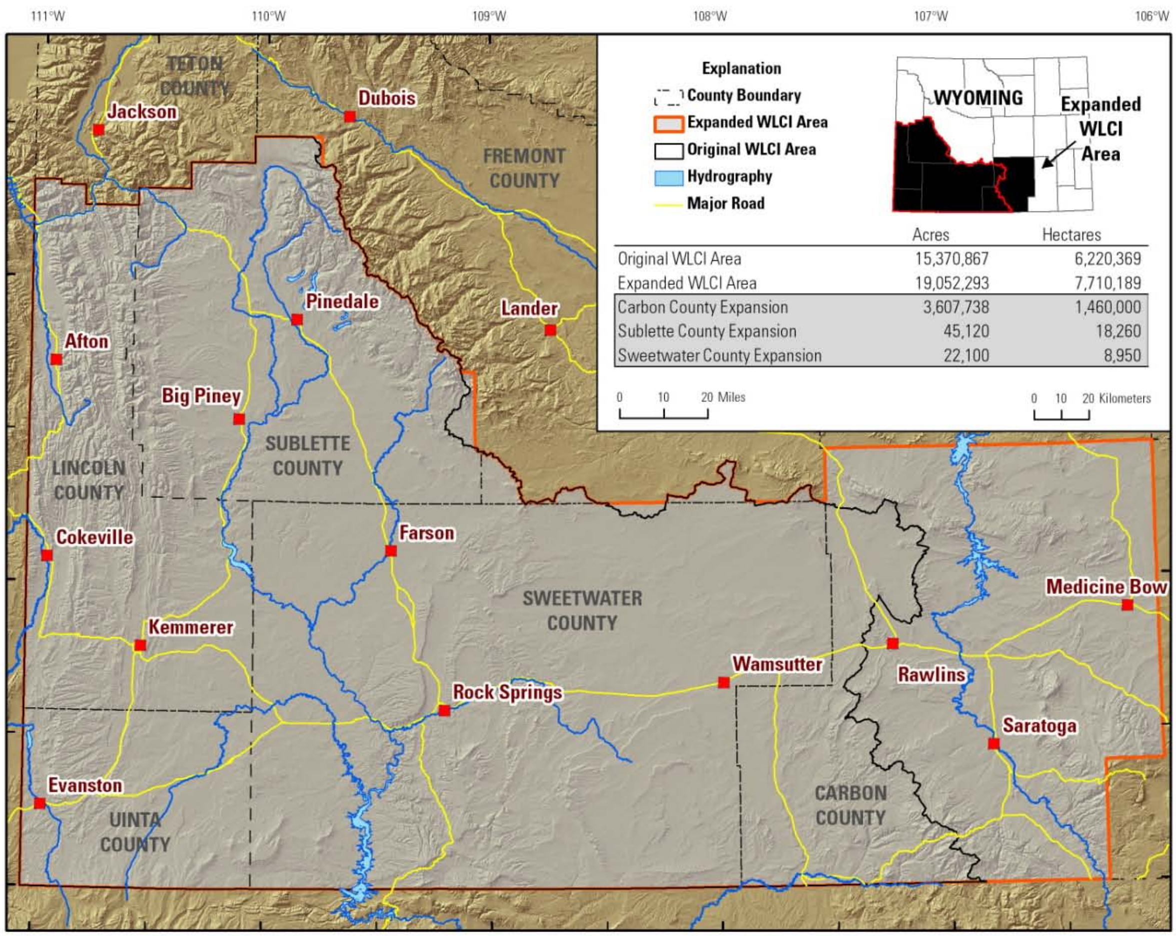


Figure 1. The Wyoming Landscape Conservation Initiative (WLCI) region, with county boundaries, major drainages, roads, and cities/towns shown. The WLCI boundary changed in 2009 to include all of Carbon, Sweetwater, and Sublette counties rather than only those portions west of the Continental Divide.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

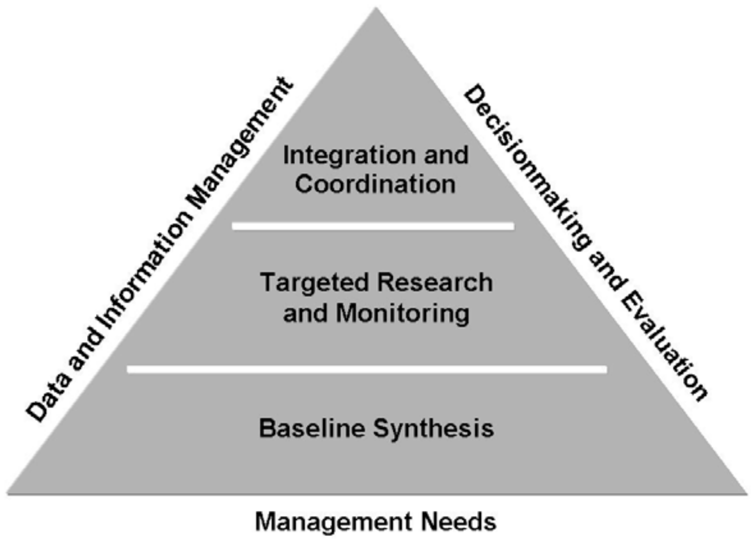
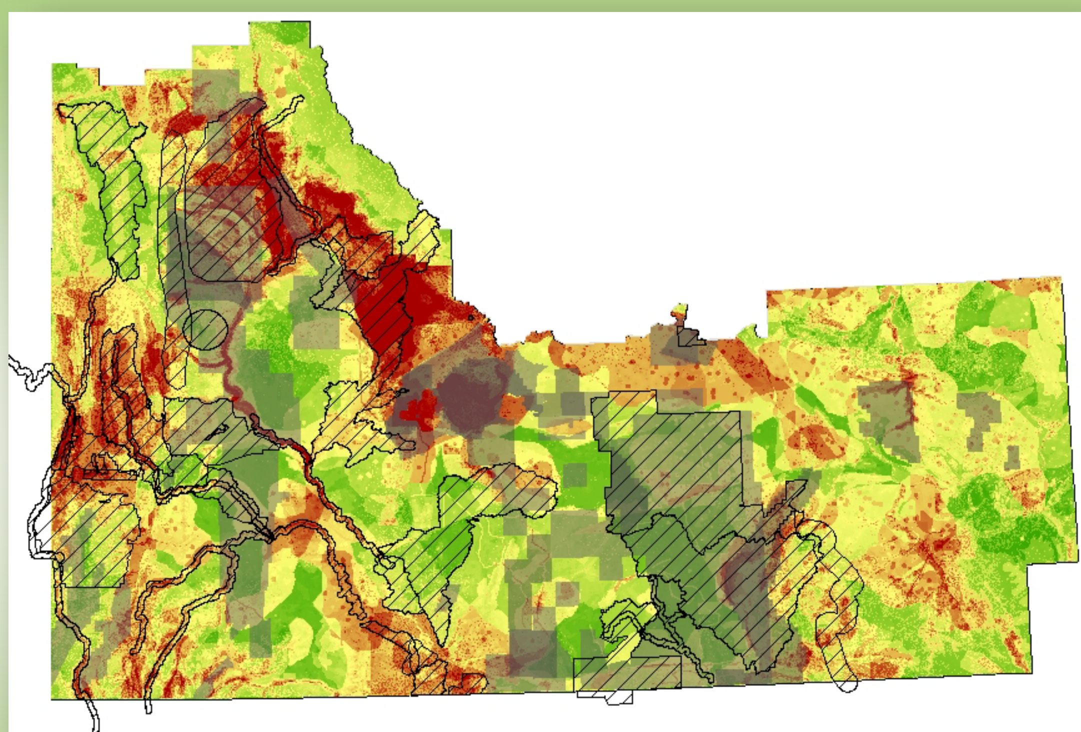


Figure 2. The U.S. Geological Survey's approach to researching and monitoring ecosystem components. The Management Needs identified by the WLCI partners form the foundation of the five major WLCI activities: (1) Baseline Synthesis, (2) Targeted Monitoring and Research, (3) Data and Information Management, (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.

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.

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 FY2010 included further development of the IA framework, data acquisition and analysis, and refinement of associated visualization tools. The IA now includes a preliminary Landscape Index of conditions across the WLCI region. 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 woodland, riparian, aquatic), and agents of change (for example, energy extraction and infrastructure, road density, distributions of invasive plants, 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 product 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.



Example map product generated from the Landscape Index developed for the Integrated Assessment .This map shows areas of high resource value (red) and low potential for oil and gas development (no gray) in regions under the jurisdiction of WLCI Local Project Development Teams (hatched areas). Map credit: Tim Assal, Application Development Platform (ADP) Application Specialist, U.S. Geological Survey.

Also underway is the WLCI 5-Year Conservation Action Plan, which will serve as a "road map" for guiding WLCI Local Project Development Team (LPDT) conservation actions and science activities during FY2012–2016. The need for a conservation plan was originally identified in the WLCI Strategic and WLCI Operation plans, and was recommended in the 2009 report from the WLCI Science and Technical Advisory Committee (STAC). In FY2010, the USGS liaison to the WLCI drafted an outline for the action plan, based on discussions and information presented at WLCI Executive Committee (EC) and LPDT meetings associated with strategic planning. The outline specifies priority accomplishments, priority conservation areas, and approaches and tools to be used. The action plan will provide a framework for how to transition from site- to landscape-level accomplishments, integrate USGS and WLCI partner science with partner priority areas and management issues, and determine (through measurable outcomes) whether objectives have been met. The plan also will provide for local input, knowledge, and expertise; enhance funding opportunities; and improve collaboration and decisionmaking between and among WLCI committees and teams. The WLCI EC and other WLCI teams and committees have reviewed the draft outline, and further development will continue in FY2011.

Throughout FY2011, 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 FY2010: Approaches and Organization

The first annual USGS WLCI report (Bowen and others, 2009a) summarized the work accomplished from FY2007 through FY2008, and it provided the necessary foundational and background information on research approaches that the USGS would use for meeting WLCI partner needs. The second annual report for FY2009 (Bowen and others, 2010), and this third annual report for FY2010, summarize the work conducted by USGS and findings of that work in FY2009 and 2010, respectively. This report builds on the first two annual reports, and it is structured in the same way that the 2009 report was structured.

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 FY2010 for that project. These summaries provide brief overviews of each major activity, including the work accomplished and findings for FY2010. 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 background scope and methods, objectives, 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 FY2010, products completed in FY2010, and, new in FY2010, a section on work to be conducted in FY2011. 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 FY2010 activity and notable results, and the products completed in FY2010 include final products, as well as interim products required for developing final products. Finally, the sections on work planned for FY2011 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 2009 report online at *http://pubs.usgs.gov/of/2009/1201/*.

Science and Technical Assistance Summaries

Baseline Synthesis

Summary of FY2010 Activities for Baseline Synthesis

As indicated in the introduction above and the overall WLCI science strategy, 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, of focal habitat types in 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 establish priorities for, and guide, conservation planning and management activities, a comprehensive integrated assessment is being developed—it incorporates much of the baseline synthesis and other WLCI science conducted to date.

There were 14 Baseline Synthesis work activities conducted in FY2010, including the completion of 2 activities, a shift in research focus for 1 activity, and a 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 Socioeconomics: Oil and Gas Development Literature Review and Case Study* (completed); (10) *Assessing Rancher Perceptions of Energy Development in Southwest Wyoming*; (11) *Assessing Wildlife Vulnerability to Energy Development*; (12) *Climate Change and Simulating Potential Future Vegetation*; (13) *Development of Conceptual Models to Inform WLCI Long-Term Monitoring and Selection of Monitoring Indicators* (completed); and (14) *Development of Regional Curves Relating Bankfull-Channel Geometry and Discharge to Drainage Area for the Rocky Mountain Hydrologic Region in Wyoming* (new).

The comprehensive assessment work in FY2010 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. In addition, the USGS has been using the compiled data to generate maps and other geospatial products for facilitating the ranking and prioritizing of proposed conservation projects and for developing and informing the WLCI 5-year Conservation Action Plan. The IA framework was developed and is already supporting assessments of resource values and how they relate to habitat integrity and agents of change. Numerous models for scoring habitat integrity, based on WLCI focal habitats and species and long-term planning needs for the WLCI region, were developed and evaluated for assessing resources. In addition, a working draft of the IA, the associated framework, and selected assessment results were prepared. Numerous meetings with WLCI partners were conducted to refine the IA framework and to prioritize data for acquisition and processing.

In addition, the status and framework of the IA were presented to the WLCI EC and other WLCI partners.

FY2010 work on the land-use/land-cover activity focused on simulation modeling of future potential changes in vegetation and wildlife habitat. This work entails modeling important drivers of change, including potential future changes in land use and patterns in climate. Results of these simulations can help resource professionals identify land-management strategies that maximize long-term persistence of habitat for wildlife species, and help to inform land-management decisions.

Mineral resources assessment work in FY2010 entailed locating numerous mineral deposits within the WLCI area, mostly within 14 mineralized areas. Areas with potential for mining base and precious metals have remained inactive in recent years. South of the Crooks Gap/Green Mountain area, however, there is interest in uranium. This element can be extracted by *in-situ*-recovery methods, which results in a much lower profile and less ground disturbance than previously used mining methods, making it possible to miss such activity during visual surveys for mining activity. Phosphate prospects are plentiful in the western part of the WLCI study area, but the largest of the historic mines have been reclaimed and there is no indication that any of the identified prospects will be developed. Trona is the only commodity for which there are visible signs of mining activity not related to energy development.

In FY2010, the energy futures work included compiling a new energy map that focuses on coal and wind sources of electrical power in southwestern Wyoming. A geospatial database of oil and gas drilling activity, including approximate dates of when drilling began and ended, was developed for Wyoming and will be made available online in the form of Geographic Information System (GIS) data (geodatabase and shapefile), a published map file, and a PowerPoint slideshow. The USGS also developed a subsurface geologic database for southwestern Wyoming that incorporates oil and gas well data; including logs of downhole geophysics); and a regional seismic reflection profile. Combined, these data will help enhance interpretations of emerging petroleum exploration concepts and help conduct integrated sciences assessments at the landscape level.

The work activity, *Developing Methods for Assessing Soil Organic Matter and Mercury at Variable Spatial Scales*, shifted in FY2010 to an evaluation of trace elements within the Muddy Creek watershed. This shift was based on results of FY2009 work on this and two other USGS WLCI studies: (1) the Long-Term Monitoring study, *Soil Geochemistry*, an ongoing project; and (2) the Effectiveness Monitoring project, *Soil Chemistry: Relationships between Energy Exploration/Development and Salinity of Soils and Water*, which was completed in FY2009. The combined results of all three studies had indicated that both selenium and arsenic occurred at elevated levels in some portions of the Muddy Creek Basin. This information prompted a closer study of the sources, transport, and bioavailabilities of these trace elements. To indicate the new emphasis and relationship to past work, the project title also shifted to *Developing Methods for Assessing Energy Exploration/Development Impacts on Biogeochemical Cycling in the Muddy Creek Watershed*. Samples of soils, rock, stream sediments, and both terrestrial and aquatic invertebrates were collected in FY2010. Subsequent geologic assays indicate that in general the marine shales and shale-derived soils in the upper watershed and tributaries (Cow, Wild Cow, and Cherokee Creeks) are enriched with trace elements, including arsenic and selenium. Overall spatial patterns in the concentrations of trace elements were similar in both soils and stream sediments, with greater concentrations being detected in the tributaries. In FY2011, analyses of soils will continue, invertebrate samples will be analyzed, and manuscripts/reports on this work will be drafted.

In FY2010, the work on developing methods for assessing element mobility in soils of the greater Green River Basin continued. When completed, resulting products 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 provide geochemical data on soils and weathering profiles of the Green River Formation that will help define the biogeochemical controls of soils on the ecological health of Wyoming sagebrush landscapes, which, in turn, will be valuable information to USGS biologists working in the WLCI region.

The development of remote sensing applications for assessing geology, soils, and vegetation continued in FY2010 with a post-review update of the mineral composite map developed in FY2009; publication of the map is anticipated for FY2011. New work entailed evaluating the use of Landsat imagery processed with USGS-developed software designed to detect early season invasives. A preliminary normalized difference vegetation index (NDVI) and a differenced normalized difference vegetation index (dNDVI) produced initial maps of cheatgrass (*Bromus tectorum*) occurrence. Initial trials of the software indicated that cheatgrass occurrence was apparently underestimated; therefore, the input parameters will be adjusted for further analysis.

The FY2010 work on developing a soil-quality index (SQI) continued to focus on an approach that may be applicable to the WLCI region. It entails relating total organic carbon (TOC) and total nitrogen (TN) to enzyme activity. Preliminary analysis of WLCI soils shows that TOC and TN correlate well with alkaline phosphatase, the total effect enzyme activity (any or all enzymes) in the alkaline pH range of these soils. This relationship will be analyzed further in FY2011 as development of an SQI for the WLCI continues.

In FY2010, the literature review and case study on socioeconomic effects of oil and gas development entailed a post-review revision of the report and preparing the report for publication early in FY2011. The review revealed that socioeconomic outcomes of energy booms are similar across communities in the western United States. Overall, the effects on local communities vary from negative to positive, and from one community to another. Potentially positive effects included increased revenue for local governments and schools, more employment opportunities, and increased income, whereas potentially negative effects included rapid population growth, increases in crime, overcrowding in schools, stressed infrastructure, and lack of affordable housing.

Progress in FY2010 on the rancher survey (completed in FY2009) entailed review and revision of the draft final report, which will be published in FY2011. Results of the survey indicated that about 42 percent of all respondents had some form of energy development on their land. Overall, respondents felt that energy development is having a negative effect on scenery/views and open space, affordability of housing, and availability of ranching supplies; they also felt that energy development is leading to increased drug activity, crime rates, and traffic congestion. More than 70 percent of respondents indicated concern about infringement on private property rights, increases in noxious weeds, human-caused losses of livestock, changes in land values, and reduced water quality. Respondents also indicated that energy development is having a positive effect on economic and small business development, employment opportunities, and salary levels in their communities. The research revealed that ranchers place greater credibility on information provided by Conservation Districts and the Natural Resources Conservation Service (NRCS), livestock and grazing associations, and the WDA than on most other sources, both government and non-government.

The work on assessing wildlife vulnerability to energy development continued in FY2010. The work entailed quantifying the distribution of Wyoming’s SGCN in relation to expanding energy development and their sensitivities to disturbance based on existing data. Statewide distribution models were completed for all terrestrial vertebrate SGCN, representing a major interim product in this analysis.

In FY2010, the climate change and vegetation simulation work entailed using downscaled projected future climate data to create a set of bioclimatic variables (for example, growing degree days, and seasonal moisture indices) for the WLCI study area. Additionally, documentation was drafted for accompanying the climate data once it is published. Using the downscaled data, simulations of potential future vegetation for the WLCI region will be completed and interpreted in FY2011.

In response to a request by the Wyoming Department of Environmental Quality (WDEQ), and funding from both the WDEQ and the Cooperative Water Program (provided to the USGS Wyoming Water Science Center), a new Comprehensive Assessment project, *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. This is part of a larger effort to develop regional bankfull curves across the Rocky Mountain Hydrologic Region, and USGS is using WLCI funds to augment the larger effort with additional sites in the WLCI area. 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, a final report will be published in early summer, and additional sites will be measured to strengthen relations in the regional curves developed in FY2010.

The WLCI Conceptual Model and Indicator Selection report has been submitted for publication as a USGS Open File Report. Across all models, 33 drivers and stressors were explicitly included, and approximately 60 degradation pathways are illustrated across the collection of conceptual models, with numerous ecological properties highlighted as potential indicators of these pathways. A total of 61 indicators were selected, which spanned 8 general categories: cover and distribution (for example, percent cover of litter), stand condition, soils/geology, hydrology, landscape pattern, animal populations, animal health, and stressors (for example, urban sprawl and energy infrastructure). Similar as well as unique indicators were selected across the focal ecosystems, and indicators specific to terrestrial and to aquatic wildlife also were determined.

These 14 Baseline Synthesis tasks are detailed in the sections that follow.

Application of Comprehensive Assessment to Support Decisionmaking and Conservation Actions

Status

Ongoing

Contacts

Zack Bowen: 970.225.9218; *bowenz@usgs.gov*, FORT Science Center
Patrick Anderson: 970-226-9488; *andersonpj@usgs.gov*, FORT Science Center
Steve Garman: 303-202-4118; *slgarman@usgs.gov*, Rocky Mountain Geographic Science Center

Scope and Methods

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 will help the WLCI Coordination Team (CT) and LPDTs 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 IA. Activities and products associated with the IA are designed to support decision making 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 and the WLCI EC uses this information to evaluate the spatial and ecological relationships between the proposed habitat projects and WLCI priorities:

- 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 sage-grouse (*Centrocercus urophasianus*), 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 support a multiple-disciplinary assessment of the effects of energy development and other land uses on resources important to WLCI partners. The IA will evaluate the natural, economic, and social context for energy development and other land uses and focus on informing landscape level conservation actions and decisions. An initial intent of the assessment is to identify areas of high conservation and restoration value, and those with high development potential, based on the current landscape. Areas with conservation and restoration potential will be evaluated with development potential and future landscape scenarios based on data-informed assumptions of land-use and climate trends. Results of these initial assessments will be used to inform immediate decisionmaking associated with landscape scale conservation planning. 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. 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 integrated assessment. 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.

Objectives

- 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 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 Comprehensive Science Catalog and Data Clearinghouse.
- Provide a data and analytical foundation for all WLCI science and technical assistance tasks.

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 2010 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 2011. Project prioritization information was provided to USGS Data and Information Management Team (DIMT) to update the WLCI internet-based conservation projects database and to update the WLCI web page. Additionally, 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 initiated. 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 also will be used to support the development of the WLCI 5-year Conservation Action Plan and with ranking and prioritizing future proposed conservation projects.

Integrated Assessment—A working draft of the IA document “Energy, Climate, and Ecosystems: U.S. Geological Survey Integrated Assessment for Southwest Wyoming” was prepared. This document provides background information on WLCI and the IA framework, and will include results of the initial integrated assessment, and descriptions of geospatial information assembled for future use by WLCI partners. A key accomplishment during 2010 was the initial development and exercising of the IA framework. The framework entails identification of resource values, condition indicators, and change agents, and the delineation of plausible rule sets and value-scoring methods for determining resource

WLCI partners are developing a 5-year conservation action plan for the WLCI effort. In FY2010, the U.S. Geological Survey liaison to the WLCI, Pat Anderson (center) drafted an outline of the plan. Photo credits: Carolyn Liedtke, WLCI Coordination Team.

condition and future risk. Methods and procedures for integrating resource values and resource conditions, and change agent effects also were initiated. Key WLCI resources were identified through collaborative efforts with the WLCI CT and WLCI partners, such as BLM, WGFD, WDA, USFS, private parties, and others. With the assistance of WLCI CT and WLCI partners, geospatial data layers were assembled for identified resources, such as big game migration corridors, guzzlers and stock trails, priority aquifers, rare plants, vertebrate species of special concern, and five key agents of change. The current list of resources will continue to be expanded through future engagements with the CT and WLCI partners. Methods for assessing resource values and condition, and for change-agent effects were also developed with the assistance of WLCI partners.

Resource values are scored in terms of presence/absence or by a relative ranking based on numbers of resource properties (for example, number of species, number of agricultural features) within a spatial unit (30- × 30-m cells). Condition values are scored based on the existing properties of a resource. Effects of change agents on integrated resource scores are ascribed based on the resource scores falling within the extent of future plausible change agents. Applications using scoring methods for values and conditions of resources, and for effects of change agents, have been conducted to determine the sensitivity of scoring methods on IA results. Fine-tuning integration approaches and analyses, and reporting of results to ensure the utility of this framework for land-management planning and decision making, will continue in FY2011, and it will involve WLCI partners directly.

Products Completed in FY2010

- Bowen, Z.H., 2010, Development and status of the WLCI Integrated Assessment, July 9, 2010, presentation to the WLCI Executive Committee, Rock Springs, Wyo.
- 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 FY2011

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 status of the IA will be presented to the WLCI EC and other WLCI teams and committees. The formulation of a landscape Index and related algorithms and scoring processes will be presented to WLCI coordinators and land management planners. Drafting of the IA report and fine-tuning of integration approaches and analyses will continue, and reporting of results to ensure the utility of this framework for land-management planning and decisionmaking will involve WLCI partners. Data and information sharing during 2011 will be structured through dedicated data stewards funded by USGS and BLM.

Assessing Land Use/Cover Change

Status

Ongoing

Contact

Steven L. Garman; 303-202-4118; *slgarman@usgs.gov*

Scope and Methods

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 soil conditions of a degraded state, 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 [*Artemisia* spp.] 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 2010 and Findings

A working prototype of the spatially-explicit, frame-based simulation model was developed. Simulation experiments were initiated to explore the potential impacts of energy development on the spread of exotic invasive plants (cheatgrass) based on given assumptions about future energy development. In concert with model development, baseline spatial information was acquired for wildlife resources and other identified resource values of the WLCI. The current distribution of surface disturbance due to oil and gas development is a critical piece of information in terms of predicting the outcomes of surface disturbance. Algorithms were developed to expedite extraction of surface disturbance from the National Agriculture Imagery Program’s 1-m-resolution imagery for the entire WLCI region. Extraction of oil and gas pads for key areas of the WLCI landscape was initiated and is ongoing.

Vegetation sampling transect in sagebrush habitat, Southwest Wyoming.
Photo credit: U.S. Geological Survey.

Products Completed in FY2010

- A working prototype of the spatially-explicit, frame-based simulation model.

Work Planned for FY2011

Extractions of oil and gas pad and related surface disturbances from 1-m National Agriculture Imagery Project (NAIP) imagery will be completed. Development and application of the frame-based model to scenarios of the most plausible future energy development across the WLCI region will continue.

Assessing Energy Futures

Status

Ongoing

Contacts

Christopher J. Potter; 303-236-1735; *cpotter@usgs.gov*
Laura R. H. Biewick; 303-236-7773; *lbiewick@usgs.gov*

Scope and Methods

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 southwestern 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 data set 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.

The Energy Map of Southwest Wyoming is being built 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 2010 and Findings

A 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 be 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.

In FY2010, this work also entailed continued compilation of a new, detailed subsurface database 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.

Both coal and wind are among the energy resources being developed in Southwest Wyoming. To further advance the objectives of the USGS and the WLCI, part A of the Energy Map of Southwest Wyoming, which primarily focuses on the electrical power sources of coal and wind, was compiled for the WLCI region. The Energy Map of Southwest Wyoming, Part A, represents decades of research by the USGS, Wyoming State Geological Survey, and others, and will facilitate a landscape-level approach to integrated science assessments, science-based resource management and science-based decisionmaking. Energy maps, data, documentation, and spatial data-processing capabilities will be available on CD-ROM and served at the USGS *Energy Program Web site* (*http://energy.cr.usgs.gov/regional_studies/wlci/*).

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. The Nature Conservancy (TNC) approach is conceptual and not based on geologically-relevant inputs.

Products Completed in FY2010

- Preliminary products developed in FY2010 will be published officially in FY2011 (see Work Planned for FY2011).

Work Planned for FY2011

Since the WLCI region has been enlarged to include Carbon County, reevaluation of oil and gas development in southwestern Wyoming will be completed and submitted for review. With updated oil and gas data, other energy resources across Southwest Wyoming, including oil shale, uranium, and solar, are planned for inclusion in Part B of the Energy Map. The two products listed below are planned:

- Biewick, Laura R.H., 2011, Energy Map of Southwestern Wyoming, Part A: Coal and Wind, U.S. Geological Survey Data Series DS (see preliminary map, fig. 3).
- Biewick, Laura R.H., 2011, Geodatabase of Wyoming statewide oil and gas drilling activity to 2010, U.S. Geological Survey Data Series Report (see preliminary map, fig. 4).

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.

Assessing Mineral Resources

Status

Ongoing

Contact

Anna Wilson; 303-236-5593; *awilson@usgs.gov*

Scope and Methods

Numerous mineral deposits are located within the WLCI area, mostly within 14 mineralized areas (fig. 5). In August 2010, visits were made to those districts not yet explored in the previous two field sessions and several areas where there are reports of mineralization but no previously defined mineral “district.” In FY2010, this work entailed focusing on phosphate deposits in the western part of the study area, historic mining districts in the eastern part of Carbon County, and on former mines outside of the major mineralized areas.

Based on information from historic maps, the geologic literature, and the new USGS mineral resources MRDS (Mineral Resources Data System) database (U.S. Geological Survey, 2010a, 2010b; Wilson and others, 2001), locations of the known mines, prospects, and occurrences (including uranium, but excluding all other energy minerals, such as coal and oil shale) were plotted on geologic and topographic maps with GIS software. From these maps, mineralized areas were identified based on clusters of similar mineral deposit types within similar geologic settings. Within each of the mineralized areas, attempts were made to visit the mines, prospects, or occurrences listed in the database. Each site visited was compared with historic records or to references of it in the literature and(or) on maps. The records of these sites in the USGS database were revised as needed. The most common correction made was to locations, which were identified with a global positioning system (GPS). The local geology, extent of mining disturbance or activity (if any), and any ore minerals or commodities present were noted. Rock and mine dump samples were collected at several locations and submitted for geochemical analysis. Results are pending. New overview records were created for each of the mineralized areas in the MRDS database.

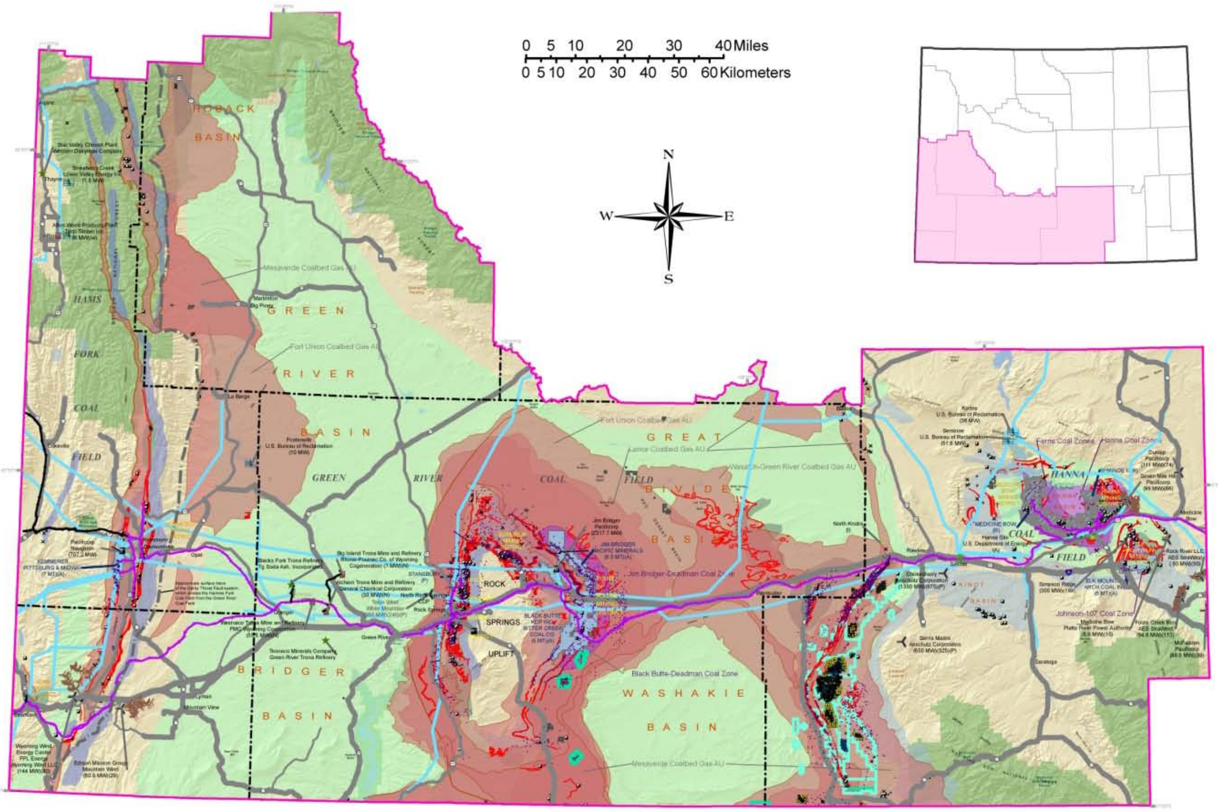


Figure 3. Thumbnail graphic of the preliminary U.S. Geological Survey Energy Map of southwestern Wyoming, Part A: Coal and wind. Surface coal mines are shown as light blue polygons near Kemmerer in southern Lincoln County, on the east side of the Rock Springs Uplift in central Sweetwater County, and 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 WLCI region and include the Greater Green River Basin and the Hanna-Carbon Basin.

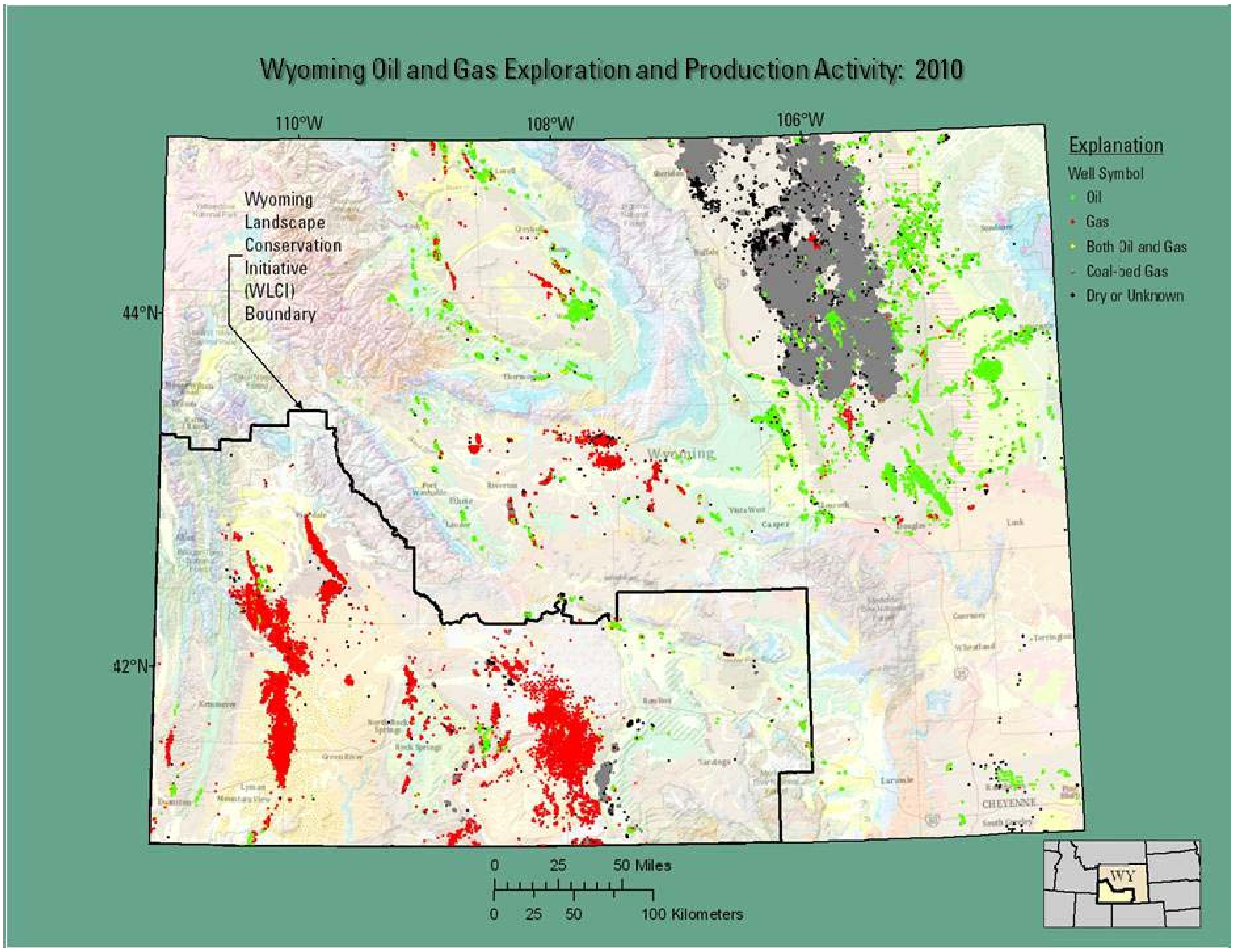


Figure 4. Preliminary thumbnail graphic of 2010 oil and gas drilling activity in Wyoming.

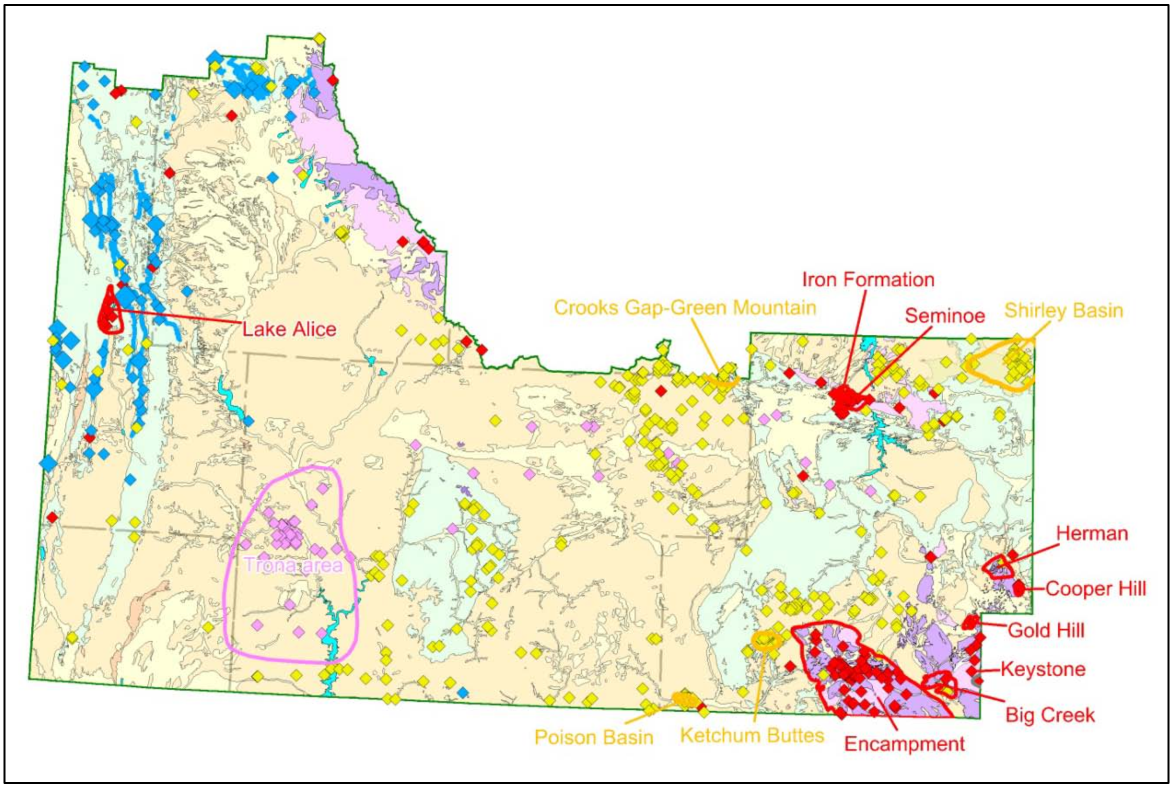


Figure 5. Locations of mineralized areas in and immediately adjacent to the Wyoming Landscape Conservation Initiative's expanded study area (see fig. 1 for locations context). Areas primarily containing base- and precious-metals are shown in red, uranium in yellow, trona in pink, phosphate in blue. Base- 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.

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

Most of the locally significant mineral deposits (excluding oil, gas, and coal) in the WLCI study area are confined to 14 mineralized areas (see fig. 5). 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 outlined as the Wyoming Phosphate area. The largest trona deposit in the world covers almost 3600 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 of *in-situ*-recovery (ISR) methods for uranium have widely expanded the area in which uranium is sought. 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 2010 and Findings

During FY2010, database entries were completed for sites visited in late FY2009, many errors in the older MRDS database (U.S. Geological Survey, 2010a, 2010b) were corrected, and hundreds of duplicate entries (caused by overlap of several different agency's databases when the databases were merged) were eliminated. During the course of field work in late FY2010, the remaining mineralized areas were visited, and attempts were made to find some of the outlying mines that appeared, from their descriptions, to be of potential local significance. Additionally, areas that have been completely reclaimed were identified.

At all the visited sites, the latitude and longitude coordinates were recorded by GPS and the locations were corrected in the new MRDS database (*http://mrds.cr.usgs.gov:7777/mrds/f?p=130:1*) as needed. In addition, the geology and mineralogy of the ores were noted and dump samples often were collected for geochemical analysis. Hundreds of duplicate MRDS records were consolidated and eliminated.

At the start of the WLCI project, records for about 800 known base- and precious-metal mines and prospects pulled from the USGS databases (*http://mrds.cr.usgs.gov:7777/mrds/f?p=130:1* and Wilson and others, 2001) were plotted on simplified geologic base maps. Over the course of three field seasons, two USGS scientists visited as many of these sites as they could, mostly within the nine major mineralized areas (Lake Alice, Seminoe, Encampment, Big Creek, Copper Hill, Gold Hill, Herman, Iron Formation, Keystone). In addition to amending the records for the visited sites, summaries of each of these nine mineralized areas were added to the MRDS database as "district" or "deposit" records. None of the sites visited is currently active. It is possible that some relatively small sites (mostly in the Encampment area) are currently active, but there was no access to those private properties. Overall, access to some sites was problematic due to road closures, locked gates, or private property, or because the sites have been reclaimed. Other sites could not be located due to insufficient information on maps or in the literature.

Hundreds of uranium mines and prospects cover the study area. The exploration of these properties was confined to the four defined areas: Ketchum Buttes, Poison Basin, Shirley Basin, and Crooks Gap/Green Mountain. Although not observed directly, the only current uranium activity seems to be in the Great Divide Basin from Crooks Gap/Green Mountain southward. The newest mining activity, however, entails *in-situ*-recovery, which has a much lower profile and less ground disturbance than previously used mining methods. Therefore, it is difficult to observe such activity. Summary records of each of these four areas have been added to the MRDS database.

Many former phosphate properties dot the western part of the study area. None appears to be currently active. The largest of these, the former mines at Leefe (fig. 6) and South Mountain (fig. 7), have been reclaimed. A few small abandoned mines, such as those at Cokeville (fig. 8) and in Raymond Canyon (fig. 9), are still visible. Currently, only trona mining seems to be active. These properties were not visited in FY2010.

There are 986 records for the expanded WLCI study area in the MRDS database (as of January, 2011). Of these, 145 records are for base- and precious-metal deposits (down from nearly 800 when the project began), such as gold, silver, copper, lead, zinc, molybdenum, iron, titanium, and manganese. There are 454 uranium records, and 44 sodium records, which are mostly trona (see fig. 5). Another 73 records are phosphate, 142 sand and gravel (construction material), 18 potassium, 16 gypsum-anhydrite, 16 crushed stone (stone, crushed/broken), and fewer than a dozen each (ordered alphabetically, by abundance) of geothermal (3), dimension stone (8), graphite (1), bentonite (10), clay (5), vermiculite (3), garnet, abrasive (2), asbestos (2), rare-earths (4), kyanite (5), gemstone (3), pumice (6), calcium (1), mica (4), beryllium (2), barite (1), stone(1), silica (2), corundum (1), and aluminum (2). Of these, some may be duplicate or unverifiable records.

Products Completed in FY2010

- Update of the U.S. Geological Survey, 2010, Mineral Resources Program—New Mineral Resources Data System (MRDS): U.S. Geological Survey master database, online at *http://mrds.cr.usgs.gov:7777/mrds/f?p=130:1* (access for internal users only).
- Update of the U.S. Geological Survey, 2010, Mineral Resources Data System (MRDS): U.S. Geological Survey public access database, online at *http://tin.er.usgs.gov/mrds/* (access for general public).

Work Planned for FY2011

FY2011 is likely the final year for this portion of the project. Large scale maps and qualitative mineral resource potential maps for the major commodity groups will be prepared and a final mineral resource potential report will be written.

Figure 6. Site of the former Leefe mine.

Figure 7. The reclaimed site of the South Mountain Mine.

Figure 8. The former Cokeville Mine.

Figure 9. The abandoned Raymond Canyon Mine.

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

Status

Ongoing. This project's focus has shifted 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.

Contacts

Robert McDougal; 303-236-1854; *rmcdouga@usgs.gov*
JoAnn Holloway; 303-236-2449; *jholloway@usgs.gov*
Travis Schmidt, 970-226-9470; *tschmidt@usgs.gov*

Scope and Methods

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 Wyo., 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 mountains (fig. 10).

Work Accomplished in 2010 and Findings

Samples of soil, rock, and stream sediments were collected in FY2010 to evaluate potential source areas within the Muddy Creek watershed for metals that have negative impacts on ecological health. Alluvial soils were collected along stream banks, and soils forming on shale bedrock were collected from upland areas in the tributary watersheds (fig. 10). Stream sediments were collected directly from the streambed as water samples were taken (fig. 10). Terrestrial and aquatic invertebrates also were collected at sampling sites.

Geologic units in the Muddy Creek watershed include mudstone and sandstone of the Wasatch Formation, and marine shales, including the Lewis, Fort Union and Steele Shales. Alluvium that dominates the drainage area is derived from these units of sedimentary rock, with eroded soils contributing to the sediment load of Muddy Creek and its tributaries, including Cow Creek, Wild Cow Creek and Cherokee Creek. Marine shales and the soils forming from the shales in the upper watershed and tributaries generally were found to be enriched in trace metals, including arsenic (fig. 11). Patterns in the concentrations of trace metals in stream sediments were similar to those observed in soils, whereby greater concentrations were associated with the tributaries; Figure 12 shows the concentrations of selenium that were detected.

Compared to baseline levels or arsenic and selenium throughout Southwest Wyoming, concentrations of both elements (which originate from the Lewis, Fort Union, and Steele shales) in the Muddy Creek drainage are relatively elevated. The stream sediment and alluvium in the main channel of Muddy Creek are derived from a much larger area than the sub-catchments of Cow, Wild Cow, and Cherokee creeks. Since the proportion of trace element-bearing shales is larger in these tributaries than it is across the entire watershed, there is a greater likelihood that soil disturbance through grazing, road building, and other surface disturbances in these tributary watersheds would result in mobilization of trace elements.

Products Completed in FY2010

- McDougal, R., Grauch, R., Holloway, J., Plumlee, G., Stillings, L., and Tuttle, L. 2010. Development of Assessment Methods in Support of U.S. Geological Survey Integrated Science—Wyoming Landscape Conservation Initiative, presented at the Energy Resources and Produced Waters Conference—Water Quality, Management, Treatment, and Use, Laramie, Wyo., May 25-26, 2010, Laramie, Wyo., University of Wyoming [presented by R. McDougal].

Work Planned for FY2011

Analyses of soil and invertebrate samples collected in 2010 will continue in 2011. The initial results of the 2010 samples will determine the need for and extent of further field work and sample collection. Preparation of reports and manuscripts will begin in 2011.

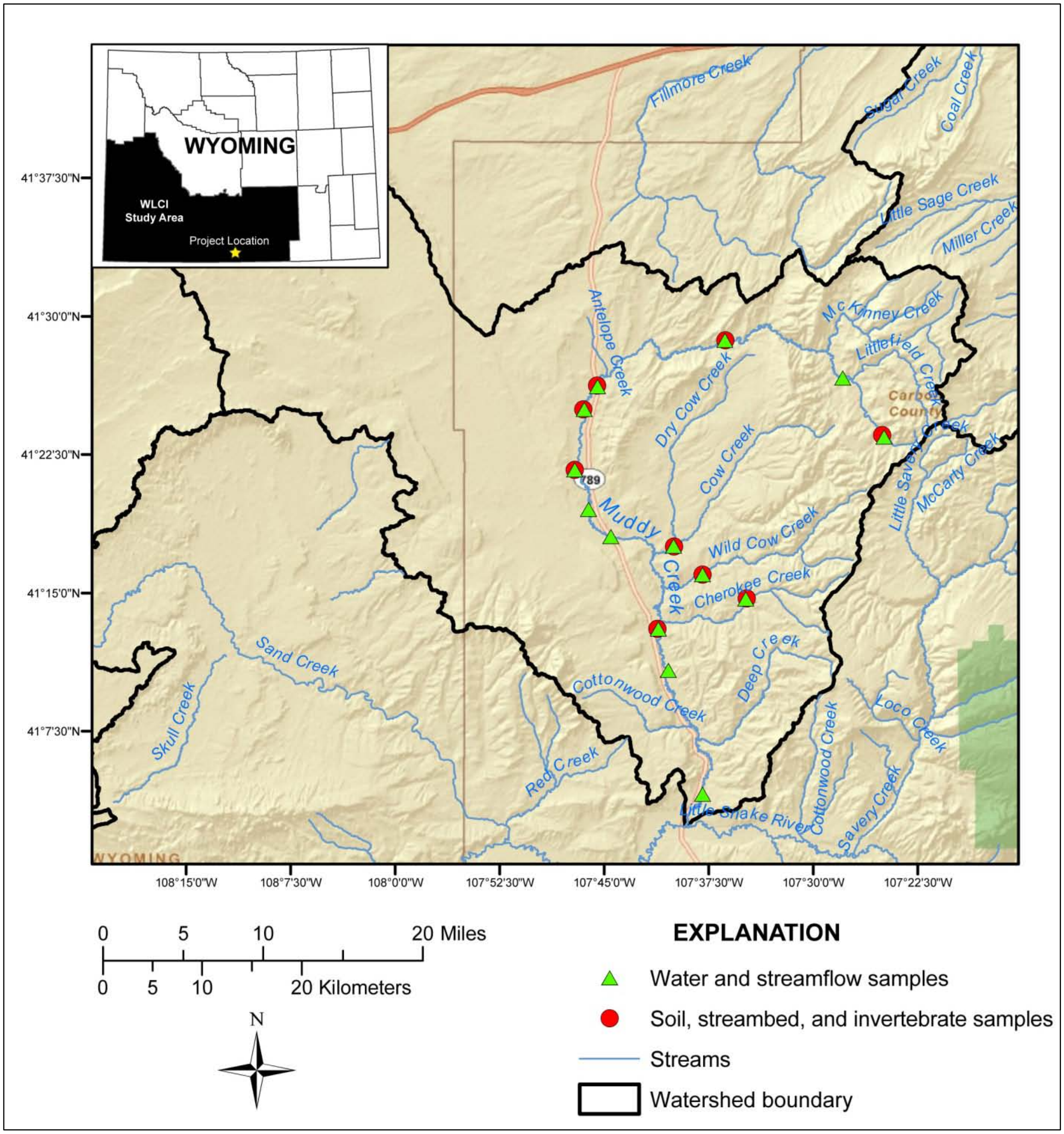


Figure 10. Locations of Muddy Creek watershed sampling sites, Carbon County, Wyo. The town of Baggs, Wyo., is situated at the southern apex of the Muddy Creek watershed (outlined in black), just south of the southern-most green triangle.

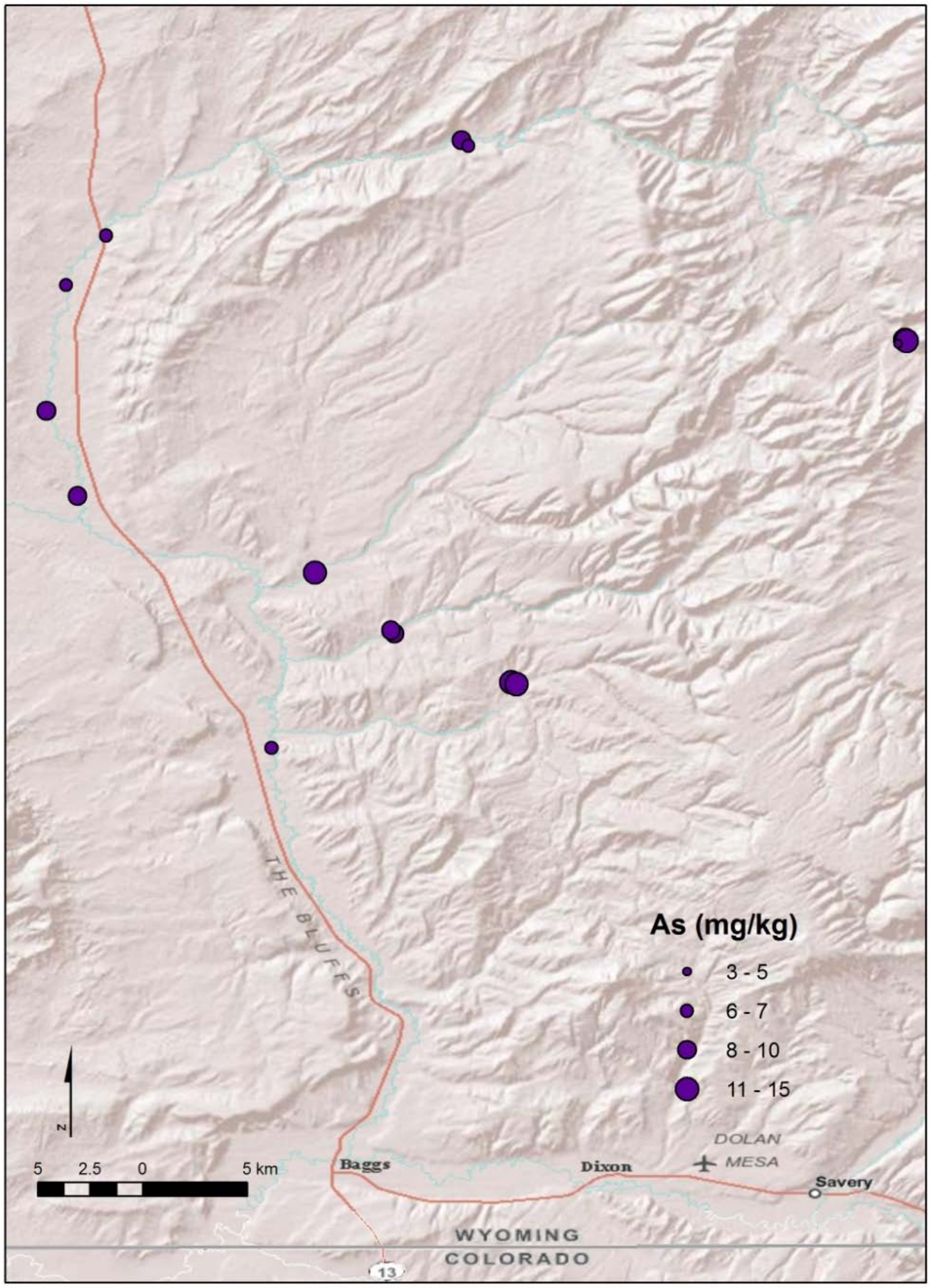


Figure 11. Arsenic (As) concentrations (milligrams per kilogram, or (mg/kg) detected in A-horizon soil samples collected from the Muddy Creek watershed in Carbon County, Wyoming.

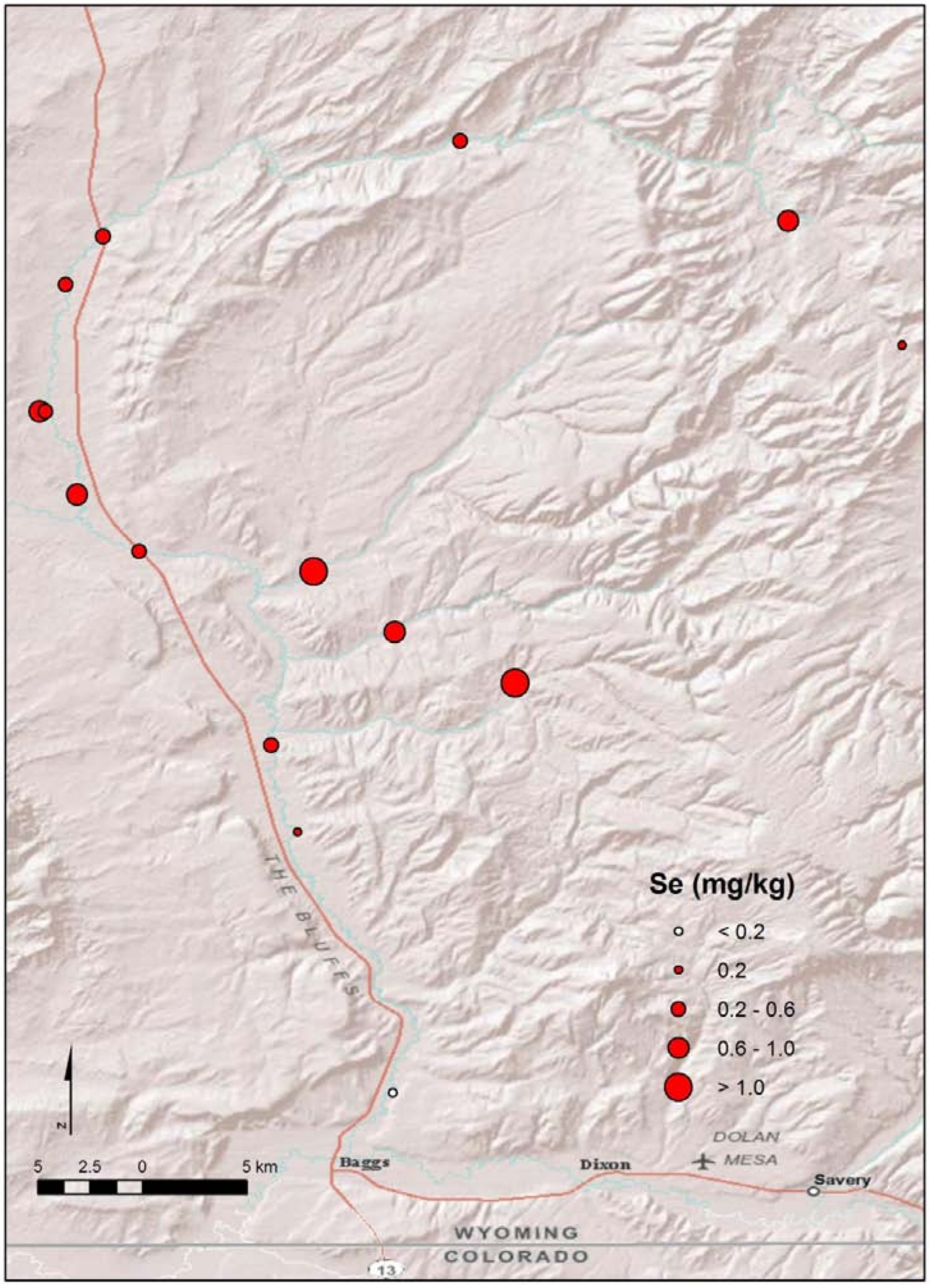


Figure 12. Selenium (Se) concentrations (milligrams per kilogram, or mg/kg) detected in stream bed sediment samples collected from Muddy Creek and tributaries in Carbon County, Wyoming.

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

Status

Ongoing

Contacts

Michele Tuttle; 303-236-1944; *mtuttle@usgs.gov*
Robert McDougal; 303-236-1854; *rmcdouga@usgs.gov*

Scope and Methods

The Tipton Shale Member of the Green River Formation. Photo taken during summer 2010 while collecting weathering profiles at White Mountain in the Green River Basin of Wyoming. Photo credit: Michele Tuttle, Research Geochemist, U.S. Geological Survey.

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 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 second 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. 13).

Work Accomplished in 2010 and Findings

In FY2010, soil samples collected in FY2009 were prepared and submitted to XRAL for analyses. Bulk samples are being analyzed for elemental composition and water extracts to allow for measurements of salinity, pH, and extractable elements. Findings from sample analyses will be reported in the WLCI annual report for FY2011.

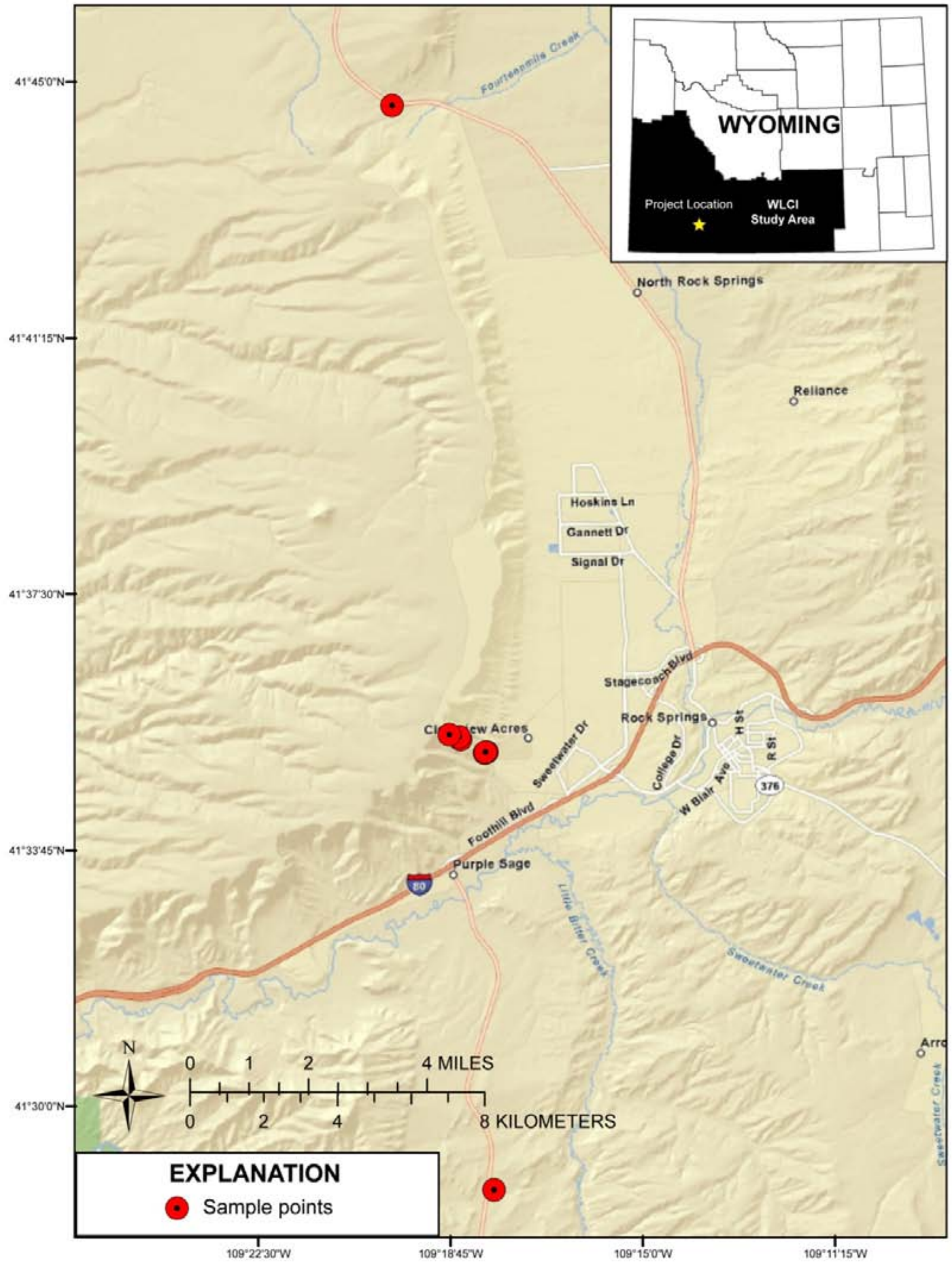


Figure 13. Locations of sampling sites (red circles) for assessing soil profiles and rocks in the three members of the Green River Formation (Laney Shale, Wilkins Peak, and Tipton Shale).

Products Completed in FY2010

- Initial sample preparations and analyses; products to follow in FY2011.

Work Planned for FY2011

Analyses of samples will be completed and preparation of manuscripts will be initiated to report the chemical composition of soils and rocks in the Green River Formation.

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

Status

Ongoing

Contact

Robert McDougal; 303-236-1854; *rmcdouga@usgs.gov*

Scope and Methods

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 data sets 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 WCLI 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.

---

[1] DESI (Detection of Early Season Invasives) software 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.

- Derive an NDVI, showing relative 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).

Work Accomplished in 2010 and Findings

The mineral composite map was updated after internal review, and is planned to have Director's approval in FY2011. Preliminary NDVI and dNDVI analysis was conducted and initial maps were produced showing the probability of the occurrence of cheatgrass. The DESI software worked well at converting the raw Landsat data to radiance and finally to reflectance; however, the mapping results are currently unverified and initial mapping results appear to underestimate the presence of cheatgrass in the test area.

Products Completed in FY2010

- McDougal, R., Grauch, R., Holloway, J., Plumlee, G., Stillings, L., and Tuttle, L. 2010, Development of Assessment Methods in Support of U.S. Geological Survey Integrated Science—Wyoming Landscape Conservation Initiative, presented at the Energy Resources and Produced Waters Conference—Water Quality, Management, Treatment, and Use, Laramie, Wyo., May 25-26, 2010, Laramie, Wyoming, University of Wyoming [presented by R. McDougal].

Work Planned for FY2011

Work in FY2011 will entail conducting field verification of invasive species mapping. In addition, invasive species mapping will continue, using DESI software, and input parameters will be adjusted to improve apparent underestimation of occurrences predicted for cheatgrass.

Developing a Soil-Quality Index

Status

Ongoing

Contacts

Lisa Stillings; 775-784-5803; *stilling@usgs.gov*
Steven W. Blecker; 775-784-5036; *sblecker@usgs.gov*

Scope and Methods

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

U.S. Geological Survey's Research Geologist, Lisa Stillings (foreground), and Volunteer, Lisa Blecker (background), measure vegetation in sagebrush-steppe habitat during summer 2010. Photo credit: Steve Blecker, Research Soil Scientist, U.S. Geological Survey.

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 14 indicates where sampling occurred in FY2010.

Work Accomplished in 2010 and Findings

FY2010 field efforts focused on the major soil/land types found in the WLCI region, represented by the light brown areas (fig. 14). In total, 72 samples of soil and vegetation were collected. This number includes three replicates of samples collected under shrub canopies and three replicates of samples collected between shrub canopies, at each of the 12 sample locations.

Chemical analyses were received from the laboratory in December, 2010; thus, interpretations are preliminary. The data first were compared to soils data collected previously, to verify that FY2010 sample and analytical methods returned similar findings. It was concluded that the datasets were similar, although the pH and electrical conductivity in the FY2010 data were lower and higher, respectively, than they were in the samples collected previously. This difference might be explained by the sampling depth: the previous samples were collected from the top 5 centimeters (cm) of the soil surface, whereas the samples collected in FY2010 were taken from the top 15 cm. The difference also may have been an effect of shrub canopy: previous samples were collected from interspaces between plants, but the replicate samples collected in FY2010 were collected from under the shrub canopy, possibly causing the difference in pH and electrical conductivity.

Previous SQI analyses of Great Basin soils from Nevada have shown an apparent relationship between microbial biomass and enzyme activity, and between TOC and TN (Blecker and others, 2010); thus, efforts were initiated to determine whether similar relationships exist in the WLCI region. Initial analysis shows that in the WLCI region, TOC and TN correlate with the activity of alkaline phosphatase, an enzyme more active in alkaline environments (the pH range of WLCI soils) (fig. 15). The high values of TOC and TN, plotting between 3,000 and 4,000 milligrams per kilogram per hour (mg/kg/hr) of enzyme activity, were from soils collected at sample sites 1 and 2 (fig. 14), which had highest TOC and TN values in the dataset.

Another preliminary finding is the correlation of the concentration of metals (copper, nickel, lead, and zinc; Cu+Ni+Pb+Zn, mg/kg) in the soil with total phosphorus (milligrams per kilogram, or mg/kg) (fig. 16). This relationship may be due to the chemistry of the underlying, soil parent material, and will receive further investigation.

Products Completed in FY2010

- Chemical analyses of soil samples and preliminary results.
- Blecker, S., Stillings, L.L., Amacher, M.C., Ippolito, J.A., Gough, L., and DeCrappeo, N., 2010, Indicators of ecosystem health and the impact of mineralized terrane, *in* Briggs, K.M., ed., Proceedings of the U.S. Geological Survey Interdisciplinary Microbiology Workshop, Estes Park, Colorado, October 15-17, 2008: U.S. Geological Survey Scientific Investigations Report 2010-5146.
- Blecker, S.W., Stillings, L.L., Amacher, M.C., Ippolito, J.A., and DeCrappeo, N., Development of vegetation-based soil-quality indices for mineralized terrane in arid and semi-arid ecosystems: Ecological Indicators (in review).

Work Planned for FY2011

The data and interpretations presented above are preliminary, and work will continue in FY2011 to develop an SQI for the soil/landtype characterized by these 12 sample locations. In addition, the USGS geologists working on this project are collaborating with USGS biologists to apply the SQI work associated with this project to WLCI lands impacted by invasive species. Because this collaborative effort is of great interest and potential use to WLCI partners, further work in this realm will be pursued as funding permits.

Assessing Socioeconomics: Oil and Gas Development Literature Review and Case Study

Status

Completed

Contact

Jessica Montag; 970-226-9137; *montagj@usgs.gov*

Scope and Methods

Understanding the socio-political and economic context of energy development is crucial for an accurate portrayal of the true tradeoffs of energy development. In addition to the bio-physical effects, development of oil and gas has an effect on and is affected by the surrounding communities and the region as a whole. Synthetic literature reviews can elucidate what is already known about these effects, create a common understanding of the social and economic context for energy development and habitat conservation, and provide a basis for dialogue with the public through the entire adaptive management process. For this task, literature produced prior to and during the current energy-development booms in Southwest Wyoming was reviewed to identify trends in socioeconomic effects and how the effects and perceptions of those effects have changed. The results of this effort can be used to inform further research and assist communities affected by energy development. A concomitant case study of the WLCI area will use baseline data provided by the U.S. Bureaus of the Census, Labor Statistics, and Economic Analysis.

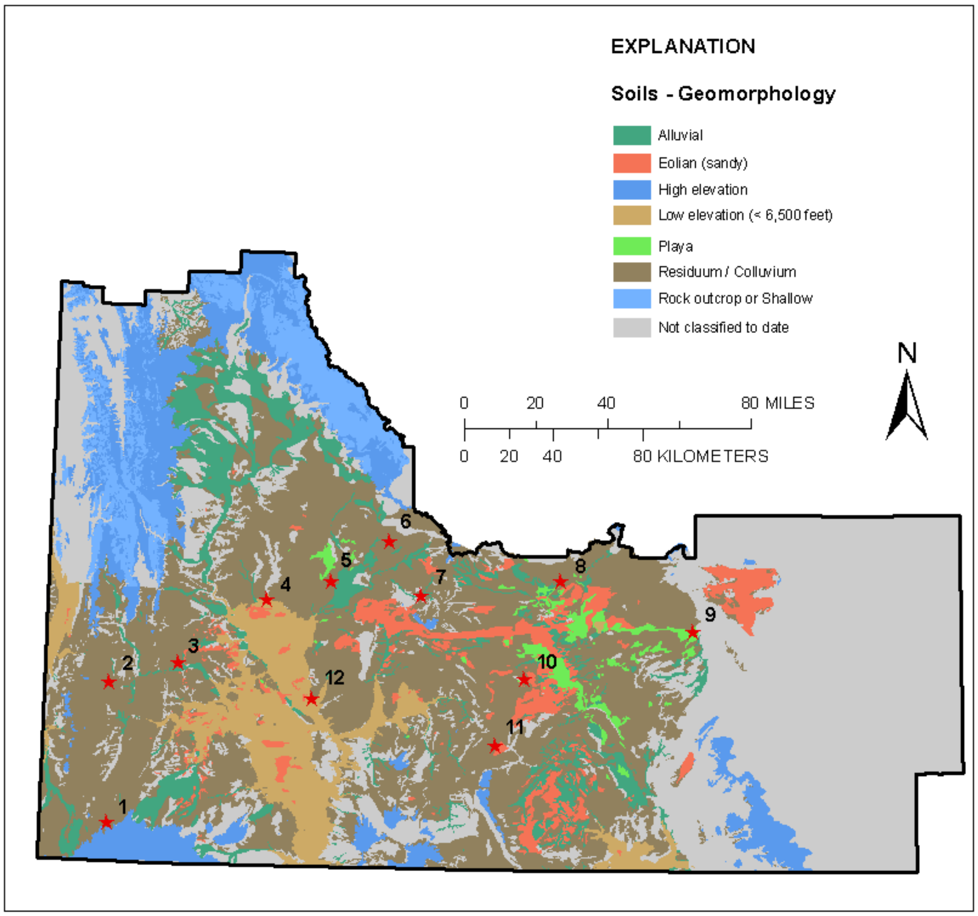


Figure 14. Locations (red stars) where soil and vegetation samples were collected in FY2010.

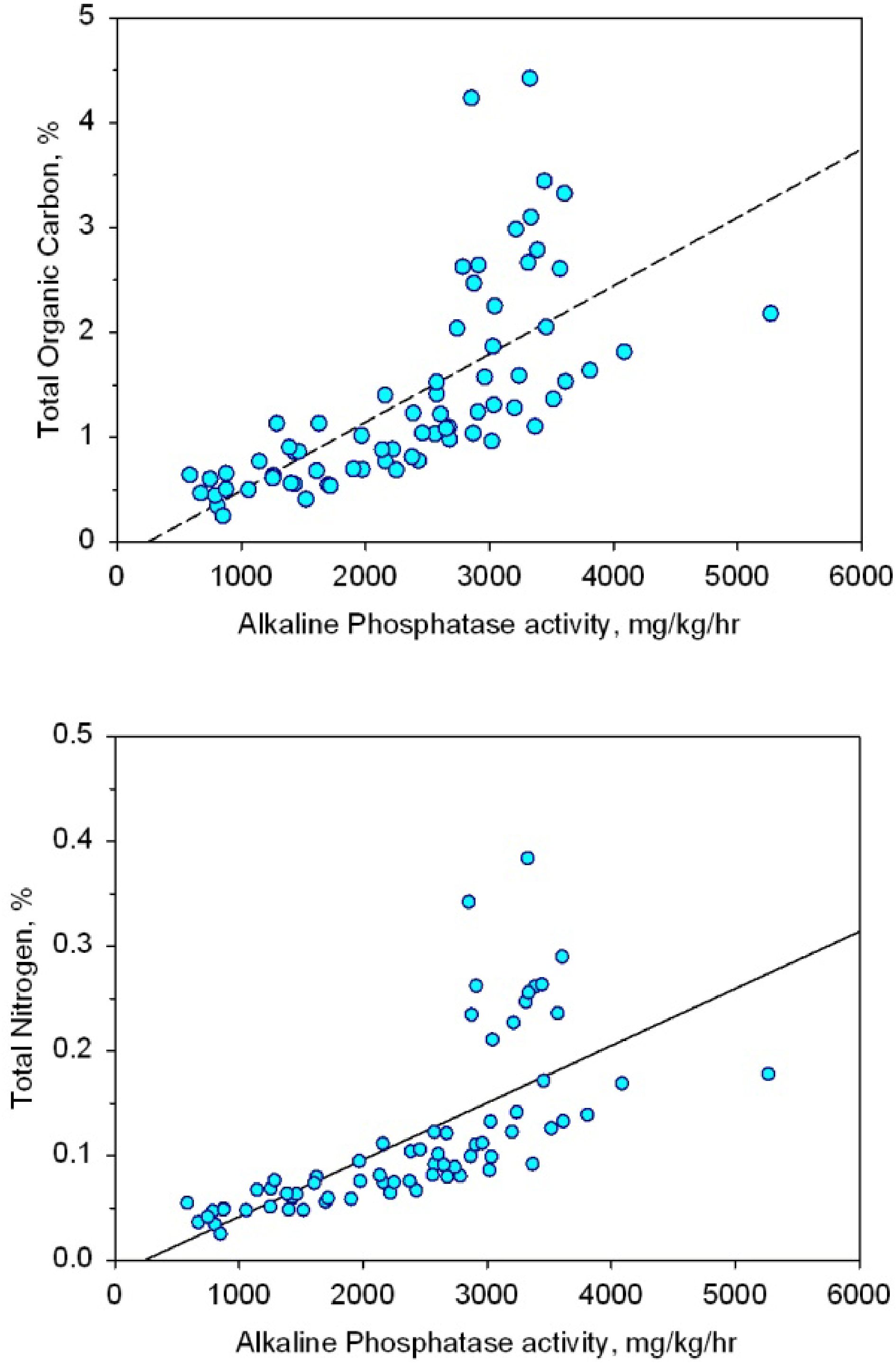


Figure 15. Correlation of total organic carbon (TOC) and total nitrogen (TN) in soils from the Wyoming Conservation Landscape Initiative study area, with microbial enzyme activity of alkaline phosphatase.

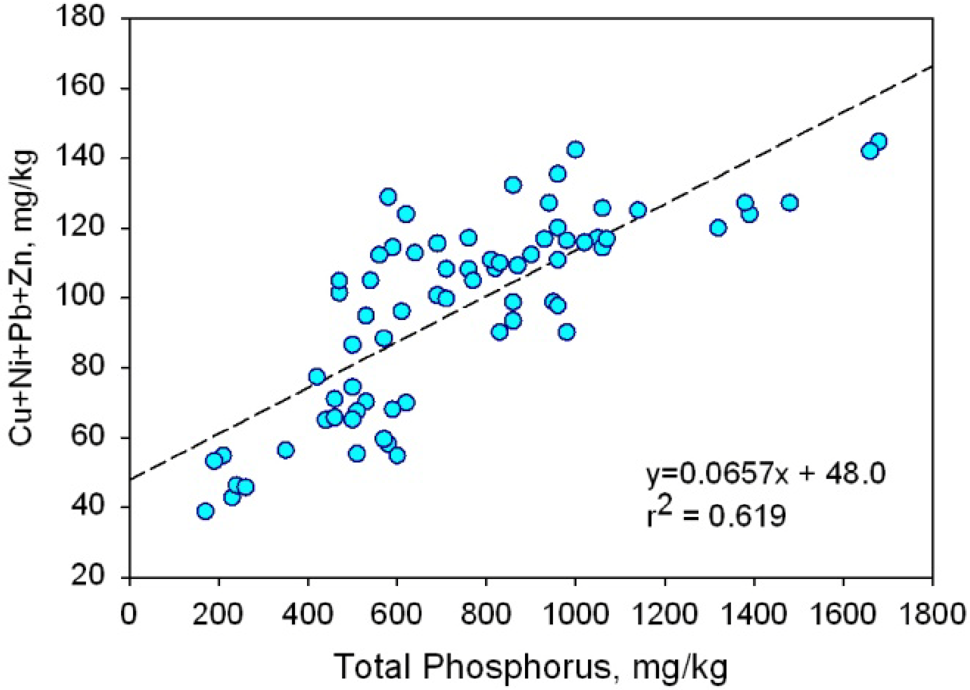


Figure 16. Correlation of metals concentrations with total phosphorus concentrations (milligrams per kilogram, or mg/kg) in soils from the Wyoming Landscape Conservation Initiative study area (y = the model estimate and r^2 = the coefficient of determination, or how the model estimate represents the data—in this case, with an r^2 of less than 1, not all the variation in the sum of Cu,Ni,Pb,Zn concentrations can be explained by Total P concentration).

Objectives

- Compile a basic social and economic assessment to provide a common context for the other issues addressed in the WLCI.
- Compile a complementary literature review on the social and economic research.

Study Area

The WLCI boundaries overlap six counties in Southwest Wyoming; however, when this project was initiated in FY2009, only four counties fell completely or almost completely within the original WLCI boundaries: Lincoln and Uinta (completely), and Sweetwater and Sublette (almost completely). Because the data were collected and summarized at the county level, the study area for this task effectively included only the four counties that fall completely or almost completely within the original WLCI boundary (fig. 1).

Work Accomplished in 2010 and Findings

The Open-File Report culminating this research went out for review in 2009 and received valuable substantial review comments; the report was subsequently revised and completed. The literature review revealed that the mix and extent of negative and positive effects on affected communities were influenced by characteristics of both the development and the communities themselves and did not appear to be the same from place to place. Review of the literature indicates that some of the socioeconomic effects of energy-development booms, including those seen in Sweetwater County in the 1970s and in Sublette County in the 2000s, are similar. Previous literature focused on economic issues while social or quality-of-life components received little attention. In the case of rapid rural energy development, however, there were many potentially positive effects across differing communities and types of development, including increased revenue for local governments and schools, more employment opportunities, and increased income. Potentially negative effects included rapid population growth, increases in crime, overcrowding in schools, stressed infrastructure, and lack of affordable housing. Many of these effects were felt in the Green River Basin during the 2000s boom. Specifically, Sublette County experienced the majority of the effects due to the development of major natural gas fields in the county.

Products Completed in FY2010

- Miller, H., Montag, J.M., Essen, M., Ponds, P., and Willis, C., in press, Socioeconomic effects of oil and gas development in the western United States—A literature review: U.S. Geological Survey Open-File Report 2011.

Work Planned for FY2011

N/A; project completed.

Assessing Rancher Perceptions of Energy Development in Southwest Wyoming

Status

Ongoing

Contact

Jessica Montag; 970-226-9137; *montagj@usgs.gov*

Scope and Methods

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 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 2010 and Findings

In FY2010, reviews were solicited and received for the draft report of this project, and the incorporation of comments into the report was initiated. Findings of this study indicate that approximately 42 percent of respondents currently had some form of energy development on their land, the majority of which was for oil or gas. They also were asked to indicate whether any of 28 components associated with quality of life has been affected by energy development in their communities. Respondents indicated that energy development is having a negative effect on scenery/views and open space, affordability of housing, and availability of ranching supplies; they also indicated that energy development is leading to increased drug activity, crime rates, and traffic congestion. On the other hand, respondents indicated that energy development is having a positive effect on community economic development, small business development, employment opportunities, and salary level (fig. 17).

The respondents were also concerned about the potential impacts of energy development on the lands that they use or own. Out of the seventeen potential impacts that covered all energy types, fourteen were a concern for a majority of the respondents (50 percent or more) (fig. 18). Over 70 percent of the respondents indicated concern about six potential impacts: private property rights infringement, increases in noxious weeds, increased number of roads, human-caused losses of livestock, decreasing land values, and reduced water quality.

When asked about the WLCI effort, approximately 55 percent of the respondents said that the survey was the first they had heard about the WLCI; less than 10 percent of the respondents are participating on a WLCI project or a local project team; and 90 percent are not sure that the science generated by the WLCI will be credible. When asked about specific organizations/agencies as a source of credible information, a majority of respondents indicated that Conservation Districts (for assessing opinions of local-level NRCS administration), Livestock Association, Wyoming Department of Agriculture, Grazing Associations, and Natural Resources Conservation Service (for assessing opinions of higher-level NRCS administration), were credible sources of information on energy development and its potential impacts (fig. 19). Additionally, a higher percentage of respondents agreed than disagreed that Wyoming Game and Fish, Wyoming Oil and Gas Conservation Commission, and the USGS were credible sources of information. Other federal/state agencies, trade associations, and conservation groups, saw a higher percentage of respondents disagree than agree that they were credible sources of information about energy development and its potential impacts.

Products Completed in FY2010

- Montag, J.M., and Lyon, K., 2010, Rancher perspectives towards energy development in Southwest Wyoming, presented at the International Symposium of Society and Resource Management, Corpus Christi, Tex., June 2010: University Park, Pa., International Association for Society and Natural Resources [presented by J.M. Montag].
- Lyon, K., and Montag, J.M, 2011, in review, Ranching community perceptions toward energy development in Southwest Wyoming: U.S. Geological Survey, Open-File Report.

Work Planned for FY2011

FY2011 work on this project will entail developing a fact sheet about the project and writing an article for publication in a peer-reviewed journal.

Assessing Wildlife Vulnerability to Energy Development

Status

Ongoing

Contacts

Douglas Keinath; 307-766-3013; *dkeinath@uwyo.edu*
Matthew Kauffman; 307-766-6404; *mkauffm1@uwyo.edu*

Scope and Methods

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, 2005). 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 was to develop detailed distribution models for all species that refine where they are most likely to occur within their ranges, which was completed in FY2010. 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.

In May 2008, representatives of State and Federal entities met to coordinate range mapping and developed by the Wyoming Natural Diversity Database (WYNDD) as the standard. Distribution models were generated by statistically extrapolating the environmental characteristics of locations where species have been documented to occur to other areas potentially suitable for occupation (for example, Elith and others, 2006; Greaves and others, 2006; Phillips and others, 2006; Guisan and Thuiller, 2007).

The basic components of creating these “environmental niche models” are occurrence data collection and processing, environmental data collection and processing, and model generation and validation.

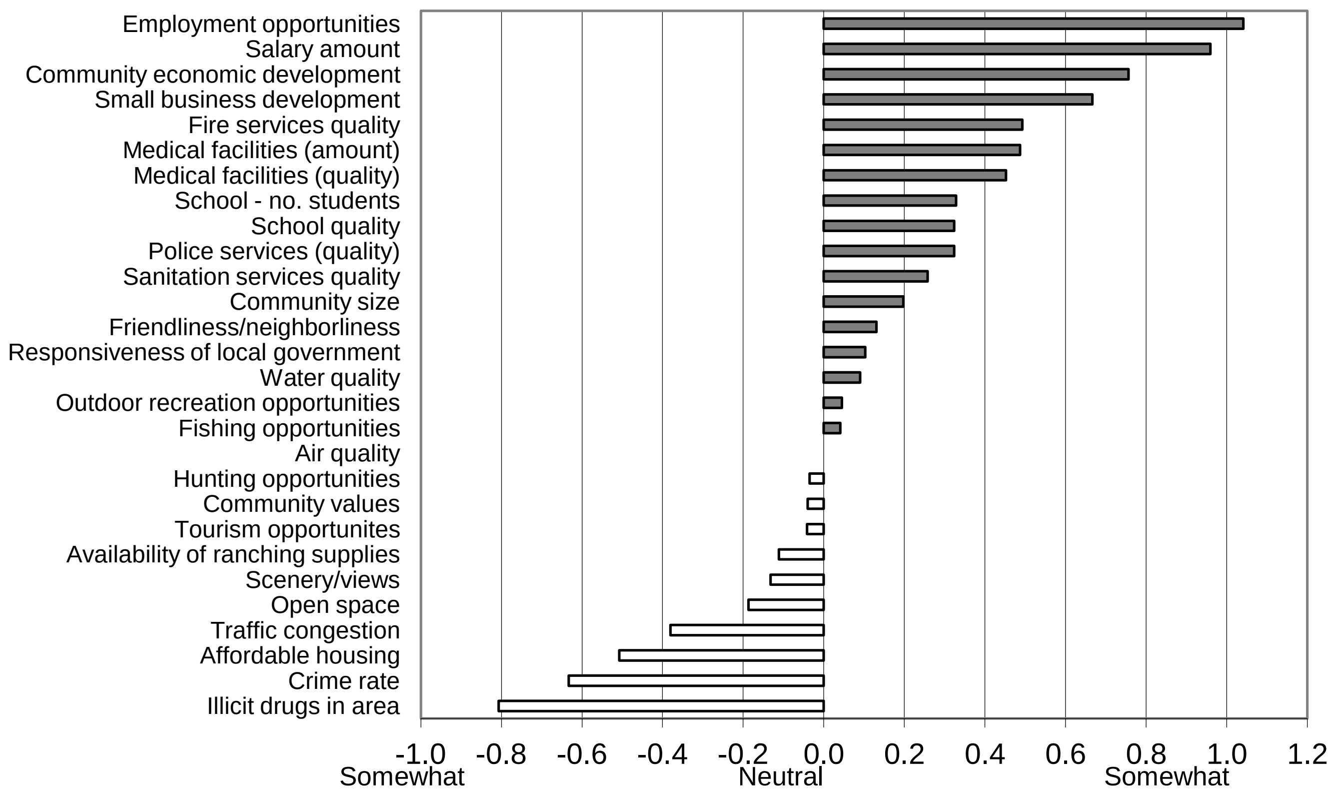


Figure 17. Rancher responses to perceived effects of energy development on their quality of life. Ranchers were asked to indicate (positive or negative) whether any of 28 components associated with quality of life has been affected by energy development in their communities.

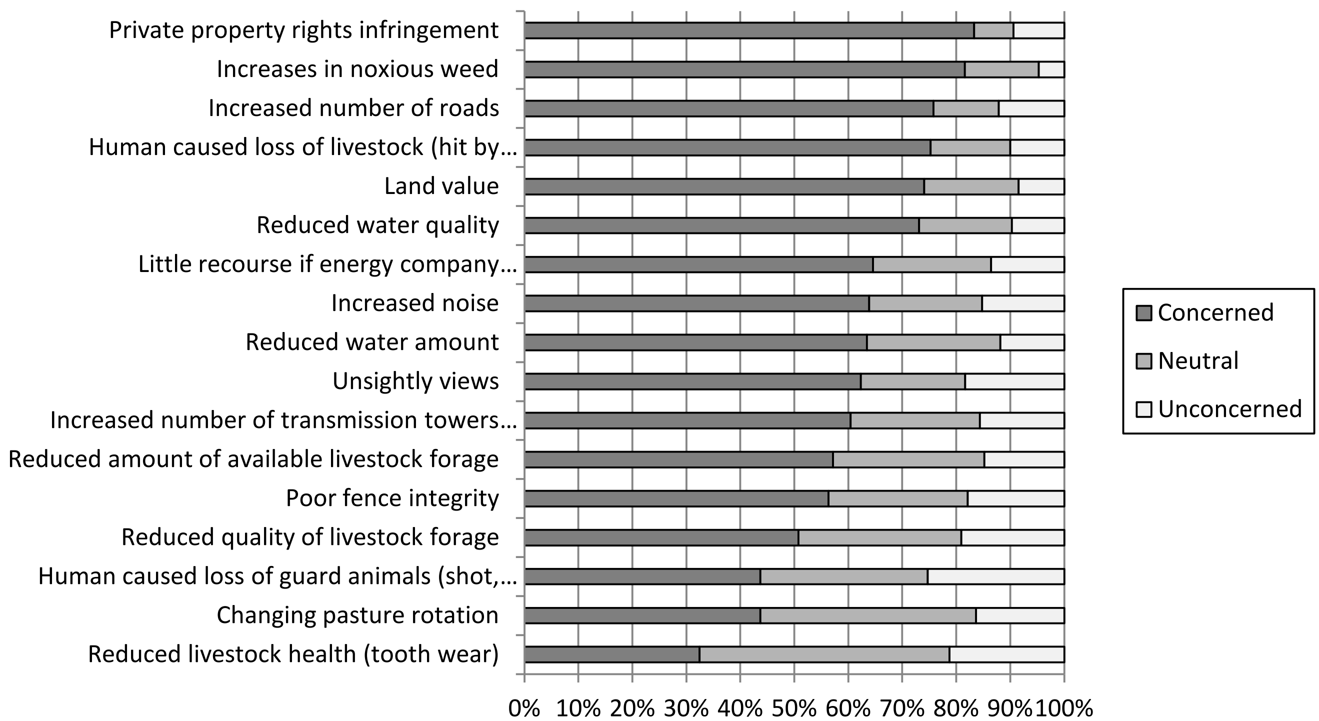


Figure 18. Percent of ranchers expressing concern about potential impacts from energy development.

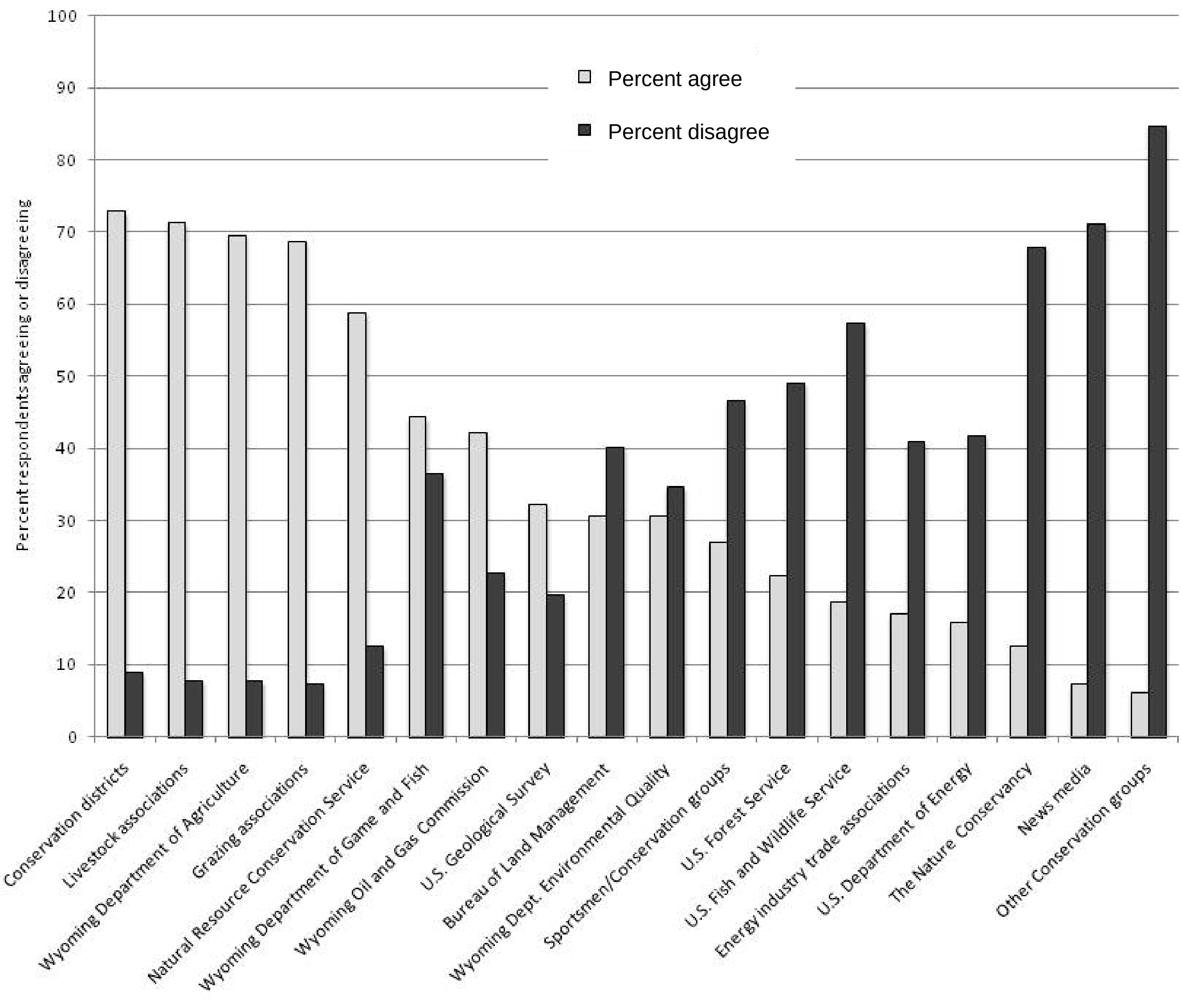


Figure 19. Rancher responses (agreement or disagreement) regarding credible sources of information on energy development and its impacts.

A dataset of approximately 260,000 individual records for 159 species was compiled and stored in a geodatabase, which was queried as needed for analysis and modeling. Observations varied greatly in their quality, and were not of equal value for constructing niche models; thus, a point quality index was computed for each record (see Keinath and others, 2010), which was used to filter data prior to modeling. The impact of autocorrelation artifacts arising from non-uniform sampling across the area of interest (Jimenez-Valverde and Lobo, 2006; Johnson and Gillingham, 2008) was minimized by using target-group background data for model building (Phillips and others, 2009), and a multi-pass filtering technique was used to construct a minimally-biased modeling dataset for each species (Keinath and others, 2010). Environmental data layers used in modeling generally fell within six categories: climate, hydrology, land cover, landscape structure, substrate, and terrain (see Appendix 2 in Keinath and others, 2010, for explanation variables). Maximum Entropy methods were used to identify pertinent predictor variables for each species and to generate distribution models (for example, Phillips and others, 2006; Phillips and Dudik, 2008), as they have been consistently shown to be among the most accurate and robust algorithms for constructing niche models from opportunistically collected data, particularly with small sample sizes (Graham and Elith, 2005; Hijmans and Graham, 2006; Graham and others, 2008; Wisz and others, 2008). To avoid biases associated with any one validation technique, models were evaluated quantitatively and qualitatively by using multiple methods, including prediction accuracy based on ten-fold cross-validation, statistics derived from receiver operating characteristic analyses, evaluations of input data quality, and the expert opinion of biologists regarding how well final models reflected their understanding of species' distributions (for example, Fielding and Bell, 1997; Freeman and Moisen, 2008).

Prairie rattlesnake photographed south of Rock Springs, Wyoming, during summer 2010. Photo credit: U.S. Geological Survey field staff.

Objective

- Focus conservation attention on the most vulnerable species before they become imperiled. To accomplish this, assess relative risks from energy related disturbances based on geospatial estimates of exposure and evaluation of biological sensitivities.

Study Area

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

Work Accomplished in 2010 and Findings

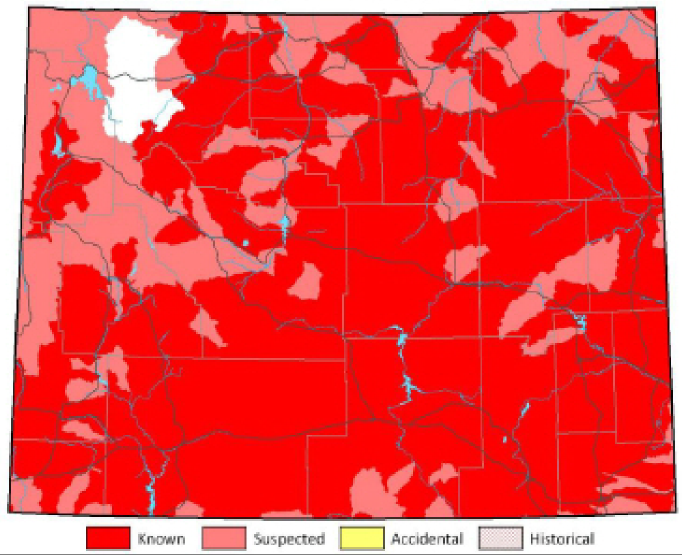
In FY2010, distribution models were completed for all terrestrial vertebrate SGCN. A report (Keinath and others, 2010) and geodatabase containing these models has been disseminated to cooperators and is available to all interested parties by contacting WYNDD (*http://uwadmnweb.uwyo.edu/wyndd/*). In addition to the main report, a 4-page model summary is available for every SGCN (examples of the report for a given species are shown in figs. 20–23, respectively).

Ferruginous Hawk (*Buteo regalis*)
Range Map and Distribution Model Summary

August 20, 2010

This report presents range and distribution of Ferruginous Hawk (ABNKC19120) in Wyoming (see Keinath et al. 2010b). Similar reports were developed by the Wyoming Natural Diversity Database for terrestrial vertebrate species of conservation need in Wyoming's State Wildlife Action Plan. This effort was supported by the Wyoming Game and Fish Department and the U.S. Geological Survey.

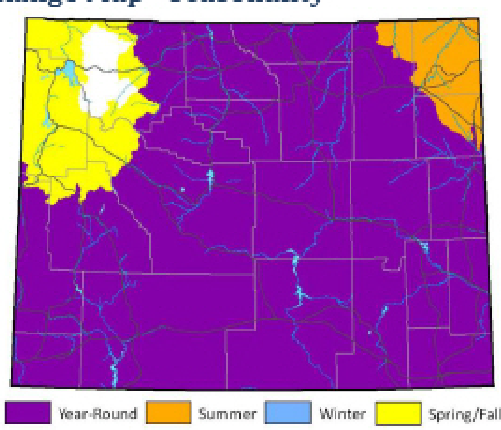
Range Map - Occupancy



Range Notes

- Version: 2010-01-19
- Proportion of range deemed known based on documented occurrences: 0.710
- Details of range map creation noted in Keinath et al. (2010a).

Range Map - Seasonality



Maps, models and report were created by and are available from the Wyoming Natural Diversity Database. (http://uwadmnweb.uwyo.edu/wyndd/).

Doug Keinath, Senior Zoologist

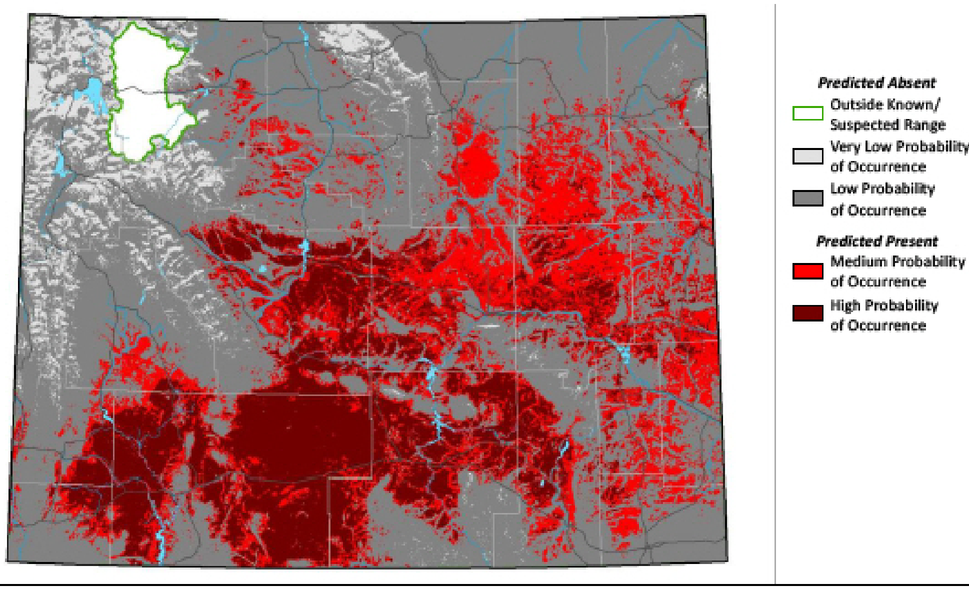
Mark Andersen, GIS Specialist

© 2010, WYNDD

Figure 20. Example of page 1 for a given species (in this case, the ferruginous hawk [*Buteo regalis*]) in the Wyoming Diversity Database summary report on range mapping and modeling efforts associated with refining species' distributions for the Assessing Wildlife Vulnerability to Energy Development project. Page 1 presents occupancy and seasonal range maps and associated statistics for the species. Four-page summary reports are available online (see Keinath and others, 2010) for all terrestrial vertebrate Species of Greatest Conservation Need identified in Wyoming's State Wildlife Action Plan (Wyoming Game and Fish Department, 2010). See Figures 21–23 for pages 2–4, respectively, of the example report.

Distribution Model (Version: Mon Jan 04 18:36:30 MST 2010)

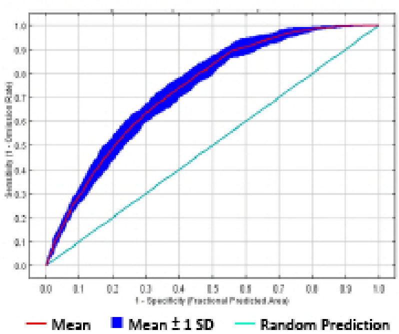
Details of distribution model creation are presented in Keinath et al. (2010b)



Model Parameters

- Season Modeled: Breeding (1-Apr- 15-Aug)
- Algorithm: Maxent version 3.3.1
- Feature Types: Linear, Product, Quadratic, Hinge, Threshold
- Binary Threshold Rule: Maximum training sensitivity plus specificity
- Binary Threshold Value: 0.4379630
- High-Probability Threshold Value: 0.5423713
- Low-Probability Threshold Value: 0.0194921

Model Evaluation - ROC Plot



Model Quality Summary

Overall Assessment of Model Quality: MEDIUM

Expert Assessment: Medium
Occurrence Sample Size: High
Quality of Occurrences: Medium
Positive Success Rate: Medium
Test AUC and Model Gain: Low

Model Evaluation Statistics

Final Model Statistics

Training AUC: 0.749
Regularized Training Gain: 0.383

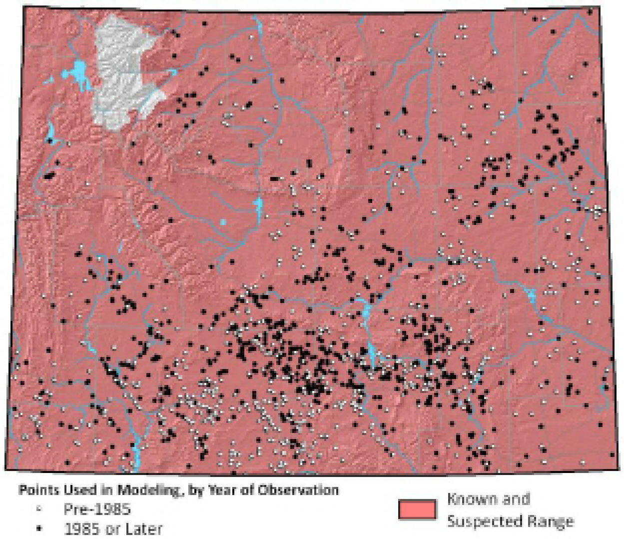
Cross-Validation Statistics

- Average Test AUC: 0.737 ± 0.023
- Upper Bound on Test AUC: 0.737
- Average Test Gain: 0.373 ± 0.070
- Omission Error (fraction of test points omitted during 10-fold cross validation): 0.24± 0.10

Figure 21. Example of page 2 for a given species in the Wyoming Diversity Database summary report on range mapping and modeling efforts associated with refining species' distributions for the Assessing Wildlife Vulnerability to Energy Development project. Page 2 presents a map of the distribution model and its evaluation statistics for the species.

Occurrence Data for Distribution Model

Occurrence Map



Occurrence Summary Statistics

- Number of Occurrences in AWVED master dataset: 4,914
- Number of Occurrences used to create distribution model: 1,443
- Average Point Quality Index (highest quality is 12.00): 6.12 ± 1.92
- Most recent occurrence used: 2008
- Oldest occurrence used: 1876
- Occurrence File: LARGE_AREA_SAMPLE_POINTS_ALL.CS V

Comments

There are no additional comments specific to this species range map or distribution model.

References

Keinath, D.A., M.D. Andersen, and G.P Beauvais. 2010a. Range maps for Wyoming's species of greatest conservation need. Report prepared for the Wyoming Game and Fish Department by the Wyoming Natural Diversity Database, Laramie, Wyoming. January 19, 2010.

Keinath, D.A., M.D. Andersen, and G.P. Beauvais. 2010b. Range and modeled distribution of Wyoming's species of greatest conservation need. Report prepared by the Wyoming Natural Diversity Database, Laramie Wyoming for the Wyoming Game and Fish Department, Cheyenne, Wyoming and the U.S. Geological Survey, Fort Collins, Colorado. August 20, 2010.

Figure 22. Example of page 3 for a given species in the Wyoming Diversity Database summary report on range mapping and modeling efforts associated with refining species' distributions for the Assessing Wildlife Vulnerability to Energy Development project. Page 3 presents an occurrence map and summary for the species.

Predictor Variables used in the Distribution Model

Percent Contribution (PC) to final model

Environmental Variable	*PC*
Forest Cover Index	37
Variation in monthly radiation	17
Conifer Index	15
Warmest quarter mean temperature	15
Bare Ground Index	11
Vector Ruggedness Measure	5

Response Curves

Each curve shows dependence of predicted suitability on input values of a single predictor variable considering correlations with others. Suitability is on the vertical axis (units: probability). Variable values are on the horizontal axis (units based on inputs; see Keinath et al 2010b for details).

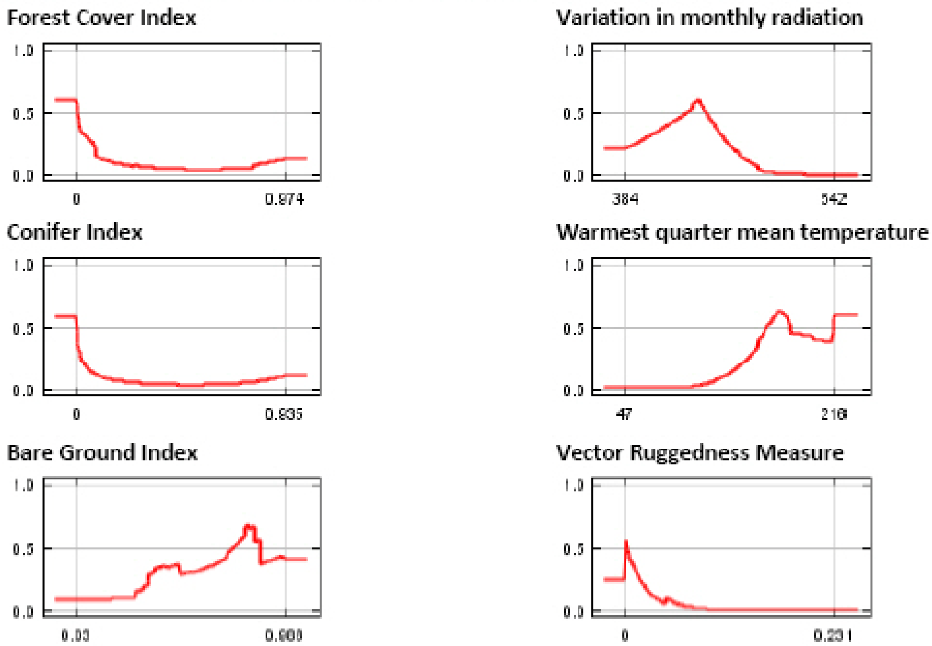


Figure 23. Example of page 4 for a given species in the Wyoming Diversity Database summary report on range mapping and modeling efforts associated with refining species' distributions for the Assessing Wildlife Vulnerability to Energy Development project. Page 4 presents predictor variables used in constructing the distribution model for the species.

The distribution models and previously generated range maps were officially incorporated into Wyoming's revised State Wildlife Action Plan (Wyoming Game and Fish Department, 2010), wherein the products will be used to help track statewide status of SGCN.

Distribution models identify areas where species are most likely to occur based on currently available observations and environmental data layers. On the whole, distribution models seemed to perform well. Species-specific evaluations of distribution model quality suggested that 35 species had high-quality models, 75 had medium-quality models (see an example (for ferruginous hawk) of model-quality ranking in fig. 21), and 49 had low-quality models, based on both quantitative evaluation statistics and qualitative expert opinion (Keinath and others, 2010). Models classified as high- or medium-quality are apt to be reliable depictions of true distribution. In many cases, low-quality models also can be reasonable depictions of distribution, but they often have notable shortcomings (for example, very low sample size or low validation statistics) and should therefore be used with some caution. Models of all quality levels can offer useful insights into the distribution of otherwise poorly-understood species.

A lack of adequate occurrence data impacted model quality for numerous species. In general, small mammals and reptiles (particularly lizards) were poorly sampled (fig. 24). Game species and species receiving attention under the U.S. Endangered Species Act had more documented occurrences than other non-game species, although the quality of their occurrences was not necessarily any better. A lack of suitable occurrence data translated into poor model quality, as small mammals and reptiles with poor datasets also demonstrated a disproportionate number of species with low-quality models (for example, fig. 25a). In contrast, for species receiving attention under the Endangered Species Act, generally there were better datasets and a relatively large proportion of high-quality models (fig. 25b).

Products Completed in FY2010

- Main Report and Appendix 1: *http://www.uwyo.edu/wynddsupport/docs/Reports/WYNDDReports/U10KEI01WYUS.pdf*
- Appendix 2, Environmental Data: *http://www.uwyo.edu/wynddsupport/docs/Reports/WYNDDReports/U10KEI01WYUS_Appendix2.pdf*
- Appendix 3, Species Summary and Index: *http://www.uwyo.edu/wynddsupport/docs/Reports/WYNDDReports/U10KEI01WYUS_Appendix3.pdf*
- Appendix 4, Amphibian Reports: *http://www.uwyo.edu/wynddsupport/docs/Reports/WYNDDReports/U10KEI01WYUS_Appendix4.pdf*
- Appendix 5, Bird Reports: *http://www.uwyo.edu/wynddsupport/docs/Reports/WYNDDReports/U10KEI01WYUS_Appendix4.pdf*
- Appendix 6, Mammal Reports: *http://www.uwyo.edu/wynddsupport/docs/Reports/WYNDDReports/U10KEI01WYUS_Appendix6.pdf*
- Appendix 7, Reptile Reports: *http://www.uwyo.edu/wynddsupport/docs/Reports/WYNDDReports/U10KEI01WYUS_Appendix7.pdf*
- Keinath, D.A., Andersen, M.D., Beauvais, G.P., and Kauffman, M.J., 2010, Mapping the distribution of Wyoming's Species of Greatest Conservation Need; presentation by D. Keinath.
- Wyoming Natural Diversity Database, University of Wyoming, Laramie, Wyo., presented at the annual conference of the Wyoming Chapter of The Wildlife Society, Lander, Wyoming, November 17, 2009 [presented by D. Keinath].
- Keinath, D.A., Andersen, M.D., and Beauvais, G.P., 2010, Distribution models for Wyoming's Species of Greatest Conservation Need, ver. 1.0 geodatabase: Laramie, Wyo., Wyoming Natural Diversity Database, University of Wyoming.

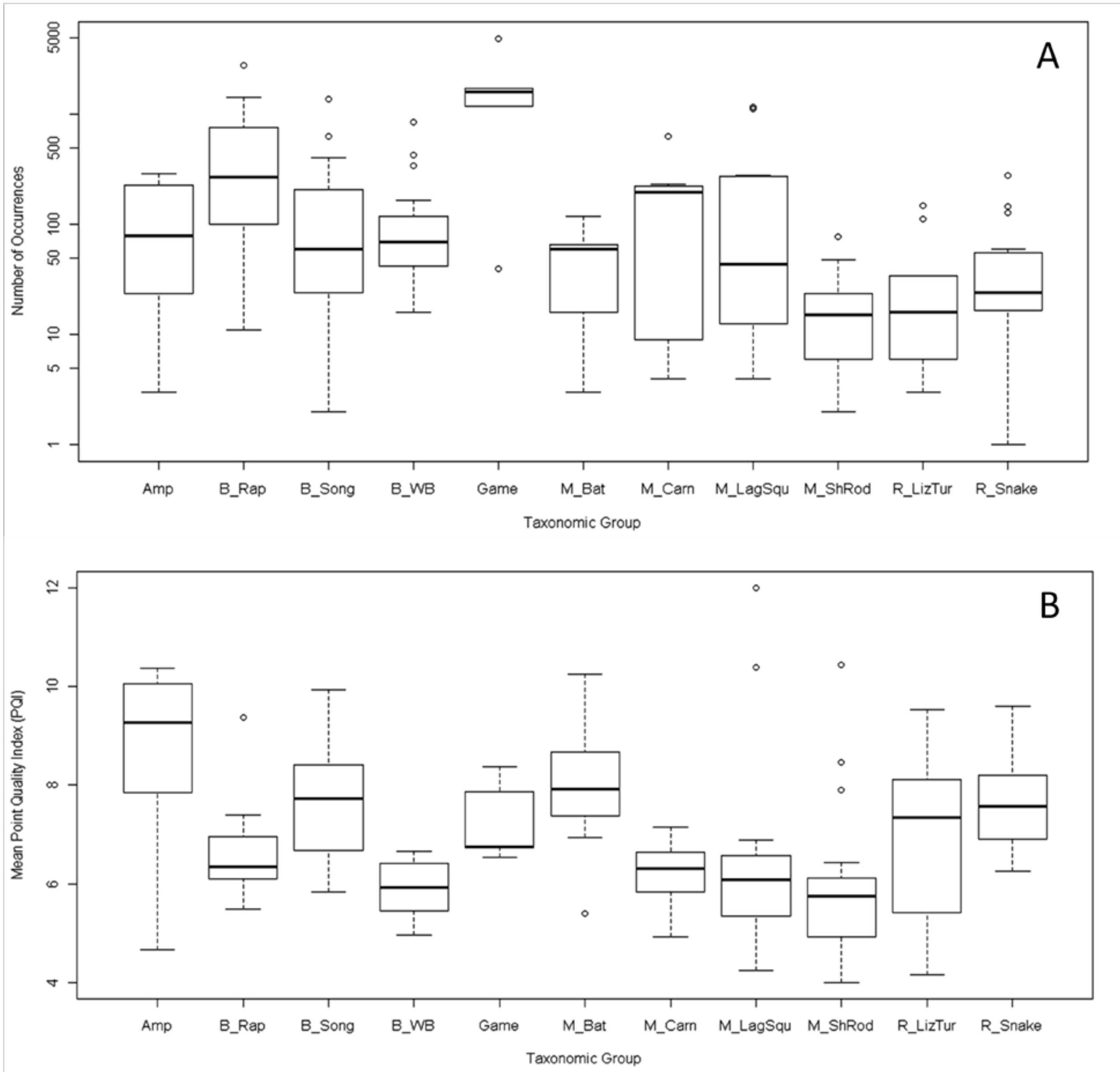


Figure 24. *A*, Number of species occurrences and *B,* mean point quality of species occurrences, plotted as a function of taxonomic grouping. Game species were addressed separately as they were generally outliers within their taxonomic groups. Game species had many more occurrences than other groups, but not higher point quality. Amphibians have the highest mean point quality of any group. Taxonomic groups are as follows: Amp = amphibians; B_Rap = raptors; B_Song = songbirds; B_WB = waterbirds; Game = game species; M_Bat = bats; M_Carn = carnivores; M_LagSqu = diurnal small mammals (lagomorphs and squirrels); M_ShRod = cryptic small mammals (shrews and rodents); R_LizTur = lizards and turtles; and R_Snake = snakes. The point-quality index (PQI) ranges from 0 to 12, with higher values representing higher-quality occurrences (see Keinath and others, 2010 for explanation).

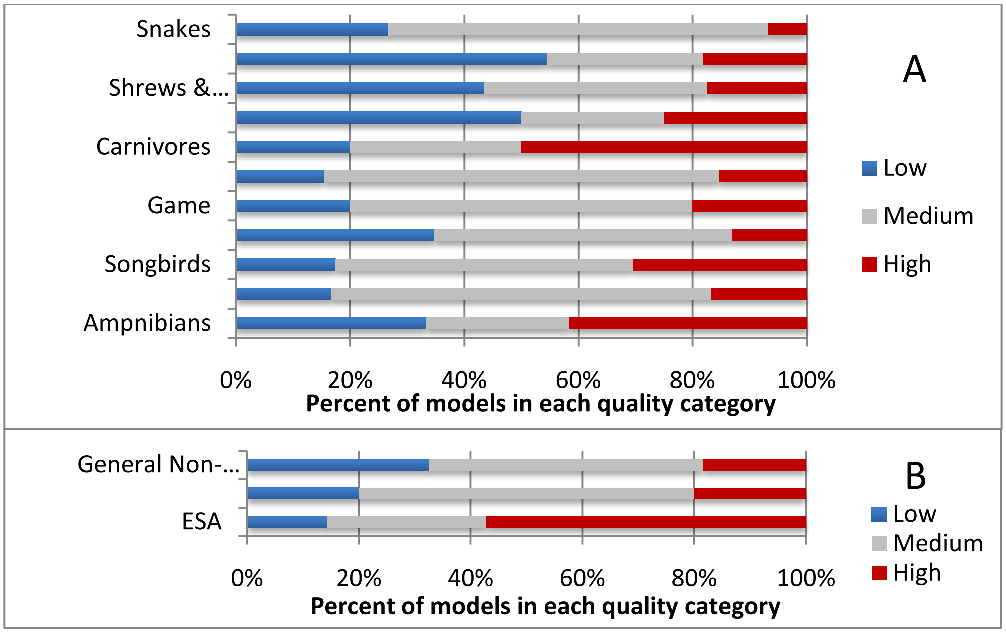


Figure 25. Proportion of models in each quality category (low, medium, or high) plotted as a function of *A*, taxonomic grouping and *B*, management grouping. Game species were addressed separately to agree with presentation in Figure 25, where they were generally outliers within their taxonomic groups (ESA = species listed under the Endangered Species Act).

Work Planned for FY2011

In FY2011, spatially-explicit projections of energy development for Wyoming will be developed in cooperation with TNC. Subsequently, estimates of SGCN exposure to development will be made by quantitatively linking species distribution models and energy development projections (for example, Copeland and others, 2009). The species will be ranked according their magnitude of exposure, and the spatial distribution of impacts will be evaluated for its potential to indicate which areas are likely to benefit from conservation action.

Climate Change and Simulating Potential Future Vegetation

Status

Ongoing

Contact

Sarah Shafer; 541-750-0946; *sshafer@usgs.gov*

Scope and Methods

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 LPJ (Lund-Potsdam-Jena), 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.

Afternoon clouds building over the Red Desert in Wyoming, summer 2010.
Photo credit: Spencer Schell, Ecologist, U.S. Geological Survey.

Study Area

The study area, which extends beyond the WCLI region to encompass all of Wyoming and portions of surrounding states (fig. 26), 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 2010 and Findings

The downscaled climate data produced in FY2009 was used to begin creating a set of more than 30 bioclimatic variables for the study area (for example, growing degree days, seasonal moisture indices) (fig. 26). In addition, the documentation that will accompany the publication and release of the climate data for the study area was initiated. Other work planned for FY2010 was significantly delayed due to a series of computer hardware failures between October 2009 and June 2010.

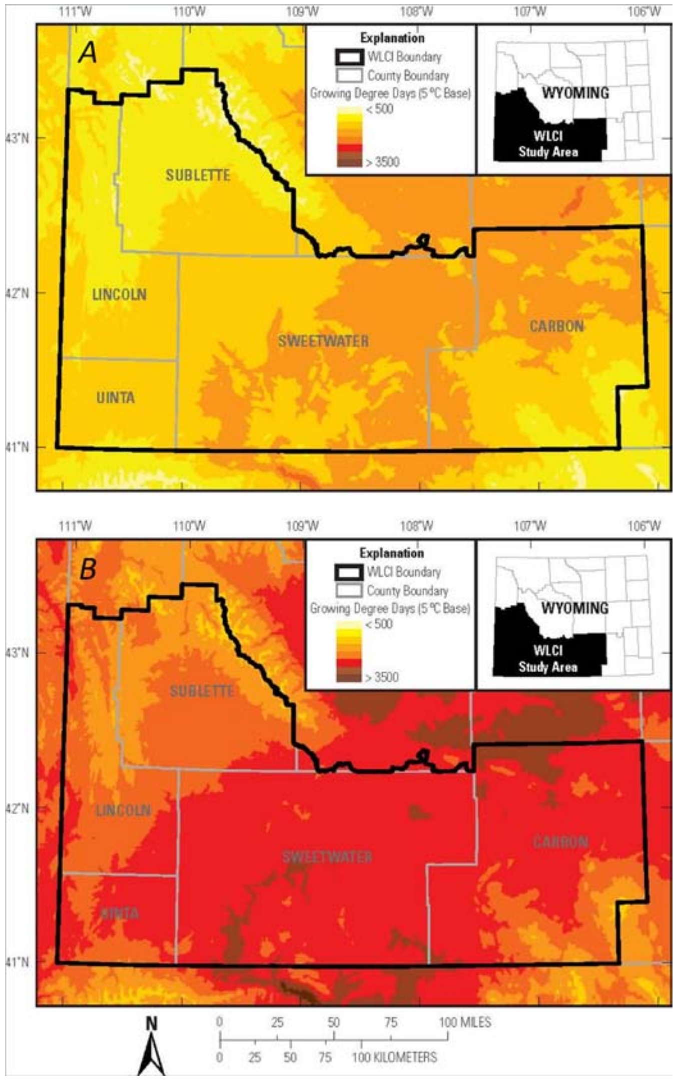


Figure 26. Mean annual growing degree days on a 5 °C base for 1961–1990 and 2070–2099. *A*, 1961–1990 30-year mean calculated from the University of East Anglia's Climatic Research Unit CL 2.0 data set (New and others, 2002). *B*, 2070–2099 30-year mean calculated from data simulated by CCSM3 (Collins and others, 2006), a coupled atmosphere-ocean general circulation model, using the Special Report on Emissions Scenarios A2 emissions scenario (Nakicenovic and others, 2000). The Climatic Research Unit CL 2.0 data were downscaled to a 30-arc-second grid of the study area using an interpolation method developed by P.J. Bartlein (University of Oregon, written commun., 2009). (Figure by R.T. Pelltier, U.S. Geological Survey.)

Products Completed in FY2010

- A set of bioclimatic variables for the study area.

Work Planned for FY2011

Development of the bioclimatic data will be completed and the climate and bioclimate data sets for the study area will be published. The downscaled climate data will be used to complete the simulations of potential future vegetation changes for the study area. The results will be interpreted in terms of potential future habitat changes for the WLCI region.

Developing Conceptual Models to Inform Long-Term Monitoring and Selection of Monitoring Indicators

Status

Completed

Contacts

Steven L. Garman; 303-202-4118; *slgarman@usgs.gov*
Jay Diffendorfer; 303-202-4070; *jediffendorfer@usgs.gov*

Scope and Methods

Initial conceptual models were developed to organize and document current knowledge about key ecosystems in Southwest Wyoming. The goal of this work was to provide a scientific means for identifying potential indicators of ecosystem change to be used in a long-term monitoring program. Models pertain to the atmospheric systems and human systems, and the focal ecosystems identified by WLCI partners: aspen foothill woodlands, mixed mountain shrubs, sagebrush steppe, riparian, and aquatic. Additional models were developed to illustrate the effects of disturbances on wildlife habitat and populations. A hierarchy of models was used to illustrate key components and processes of native systems and how systems respond to human-mediated stressors. Models were developed based on literature reviews, or were extracted from the literature and enhanced to accommodate the drivers and stressors of the WLCI study area. Individual system models were organized into an integrative model that additionally considers the interactions among systems and across scales.

In 2008, preliminary conceptual models for terrestrial systems were developed and then reviewed by USGS Science Team members during a Conceptual Model Workshop. In 2009, these models were refined and additional models were developed and reviewed. A draft conceptual model and indicator report was developed in 2009 and a final report will be published in 2010 along with a report on indicators for use in monitoring ecosystem change. The workshop and a subsequent report documenting prioritized indicators were drafted to provide direction in planning monitoring efforts for FY2010.

Objectives

- Create a useful set of conceptual models that organize and document current knowledge of key ecosystems and processes in Southwest Wyoming and that can be used to help identify indictors for monitoring ecosystem change.
- Use conceptual models and other information developed for the WLCI to identify indicators for monitoring ecosystem change. Indicators will include properties of habitat (for example, vegetation and soil attributes and landscape pattern) and wildlife species.
- Based on documented criteria, prioritize the monitoring indicators identified for immediate consideration in operational monitoring efforts.

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 2010 and Findings

Conceptual models for the WLCI effort were completed in 2009. A hierarchy of models showing very general to specific degradation pathways was assembled, and supporting narratives were completed. Models spanned the focal ecosystems (aspen foothills, mixed mountain shrubs, shrub-steppe, riparian, and aquatic), as well as atmospheric and human systems. Conceptual models related to the effects of stressors on wildlife species and populations also were produced to explicitly delineate potential impacts and causal pathways. Across all models, a total of 33 drivers and stressors were explicitly included. Approximately 60+ degradation pathways are illustrated across the collection of conceptual models, with numerous ecological properties highlighted as potential indicators of these pathways. The final Conceptual Model report is being combined with the final report on Indicator Selection to provide a more comprehensive document. A draft report was produced in 2009 and is being finalized for submission to the USGS Report Series review process as an Open-File Report.

Using the WLCI conceptual models, WLCI Science Team Members identified key indicators that could provide early warning of system change in response to land-use actions (for example, oil/gas development) and other potential ecosystem stressors (for example, climatic change). A total of 61 indicators were selected, which spanned 8 general categories: cover and distribution (for example, percent cover of litter), stand condition, soils/geology, hydrology, landscape pattern, animal populations, animal health, and stressors (for example, urban sprawl and energy infrastructure). Similar as well as unique indicators were selected across the focal ecosystems, and indicators specific to terrestrial and to aquatic wildlife also were determined. As indicated above, the results of the Indicator Selection workshop are being combined with the Conceptual Model report to provide a more cohesive and comprehensive document.

Products Completed in FY2010

- Garman, S.L., Diffendorfer, J.E., Foster, K., Germaine, S., Manier, D., Sweat, M.J., McDougal, R.R., Assal, T.J., Bowen, Z.H., Aldridge, C.L., Anderson, P.J., Biewick, L.R.H., Blecker, S.W., Boughton, G.K., Bristol, S., Carr, N.B., Chalfoun, A.D., Chong, G.W., Clark, M.L., Fedy, B.C., Holloway, J., Homer, C., Kauffman, M.J., Keinath, D., Latysh, N., Miller, K.A., Montag, J., Potter, C.J., Shafer, S.L., Smith, D.B., Stillings, L.L., Tuttle, M., and Wilson, A.B., in press, WLCI conceptual models & indicator selection for long-term monitoring: U.S. Geological Survey Scientific Investigations Report

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

Status

New in FY2010

Contact

Katharine Foster; 307-775-9166; *kafoster@usgs.gov*

Scope and Methods

This new work activity 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 drainage area to 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, WDEQ had funding ($158,000) to pilot 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 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 WGFD are implementing 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 Region 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 27 shows the sampling sites with the WLCI area.

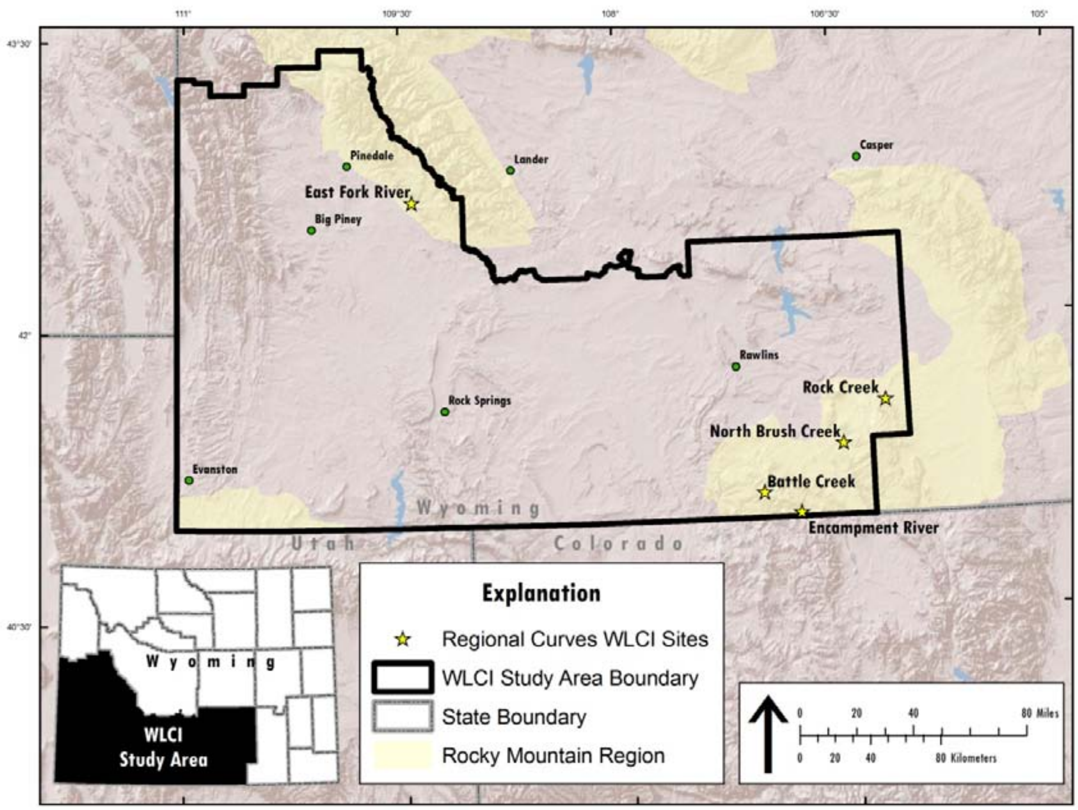


Figure 27. Locations of survey sites for the bankfull curves study in FY2010 (WLCI = Wyoming Landscape Conservation Initiative).

Work Accomplished in 2010 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, a determination of using 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, the most recent rating table (stage-discharge relationship) was obtained, and corresponding 9-207 forms (Discharge Summary Notes) that included records of moderate to high flows were compiled. The USGS tabulated the (1) station name and USGS station number (note if active or discontinued); (2) station location (lat-long, 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). Also for each gaging station, USGS (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 $Q_{1.5}$) and 2.3-year recurrence interval (mean annual flood, identified as $Q_{2.3}$); and (5) identified width, depth, cross-sectional area and velocity associated with $Q_{1.5}$ and $Q_{2.3.}$

Field surveys were completed for 25 streamflow-gaging sites. A draft report has been initiated and will be ready for peer review by mid-February 2011.

Products Completed in FY2010

- Regional curve dataset.
- Preliminary regional Curves.
- Foster, K., in review, development of regional curves relating bankfull-channel geometry and discharge to drainage area for the Rocky Mountain Hydrologic Region in Wyoming: U.S. Geological Survey Scientific Investigations Report

Work Planned for FY2011

In FY2011, field measurements will be collected at 20–25 additional streamflow-gaging sites and a final project report will be published.

Targeted Monitoring and Research

Targeted Monitoring and Research for the WLCI is composed of three major activities: Long-Term Monitoring, Effectiveness Monitoring, and Mechanistic Research of Wildlife. The long-term monitoring work entails not only conducting long-term measurements of change, but also designing the framework (process, sampling design) and selecting the most suitable indicators 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 (for example, greater sage-grouse and elk [*Cervus elaphus*]) 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; additionally, it is essential 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 FY2010 Activities for Inventory and Long-Term Monitoring

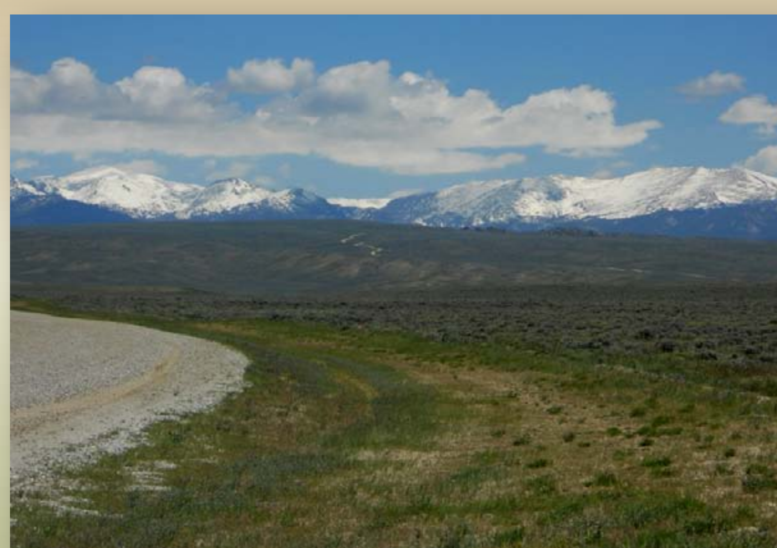
There were five Inventory and Long-term Monitoring work activities conducted in FY2010, including a new activity and some additional work and a shift in focus in another: (1) *Framework and Indicators for Long-Term Monitoring*; (2) *Remote Sensing for Vegetation Inventory and Monitoring*; (3) *Long-Term Monitoring of Soil Geochemistry*; (4) *Long-Term Monitoring of Surface Water and Groundwater*, including *Water Data Compilation* (new work budgeted for FY2010 under the Comprehensive Assessment project, but reported here because the work is designed to guide long-term monitoring of water resources); and (5) *Wyoming Groundwater-Quality Monitoring Network* (new).

An oil derrick in an area of energy development west of Big Piney/Marbleton in Sublette County, Wyo., in the area surrounding groundwater-quality monitoring station number 422804110152301. Photo credit: Greg Boughton, Hydrologist, U.S. Geological Survey.

In FY2010, work on the long-term monitoring framework entailed testing the framework for its ability to generate simple sampling designs for adequately representing the range of variation across large, heterogeneous landscapes. In practice, the framework will generate accurate assessments of trends in resource conditions, such as land use, vegetation cover type, priority habitats, populations of priority species, and soil geochemistry. The statistical properties of two potential resource condition indicators—vegetation cover and the abundance of passerine birds—have been tested for their ability to detect change and adequately represent overall ecosystem condition. Pilot data collected for both indicators have been subjected to sampling simulations and statistical analyses to optimize monitoring designs and minimize sampling efforts. The results provide guidance for designing and implementing long-term monitoring programs and surveys of current conditions. Implementing a multi-disciplinary, landscape-scale resource assessment and monitoring program that crosses administrative boundaries requires a cooperative effort held together by a common purpose and design. To that end, USGS scientists are including stakeholders in developing the tools for moving this project towards implementation. This work also entails ongoing assessments of current and historic monitoring projects and protocols; analyses of the pilot monitoring data being gathered at four sites in the WLCI study area; and working with WLCI partners to develop the cooperative framework and effort required for implementing a regional assessment and monitoring program for the WLCI region.

The current phase of research and development on the remote sensing for inventorying and monitoring vegetation work is nearing its conclusion. Methods are being formalized in reports and publications, and details of future implementations are being discussed. Efforts of USGS scientists demonstrate that continuous land-cover estimates are possible for semi-arid shrubland systems. Products of this work are currently being applied in multi-agency (federal, state, and non-governmental organizations) efforts to conserve and manage endangered species (such as the sage-grouse) and manage for healthy rangelands. Current research and development associated with this work activity also entails developing tools and data (GIS layers) for conducting annual updates of, and detecting meaningful changes in, resource conditions across the WLCI region.

Work conducted in FY2010 for long-term monitoring of soil geochemistry involved collecting soil samples at 36 sites in the portion of Carbon County that was added to the original WLCI study area in 2009. These samples were collected in August 2010 and subsequently they were prepared and submitted to USGS laboratories for analysis of 44 elements, total carbon, and carbonate carbon. Splits of the samples were submitted to the Colorado State University's



A gravel roadside near the Wind River Range (summer 2010) illustrating the profound change in vegetation that typically occurs along roadsides. The depth of disturbance was 10 meters on each side of this road, and the new vegetation was composed of largely exotic species, both of which significantly increase the road's habitat-fragmenting effects. Photo credit: Steve Blecker, Research Soil Scientists, U.S. Geological Survey.

Soil, Water, Plant Testing Laboratory for analysis of total nitrogen, soil pH, electrical conductivity, and sodium adsorption ratio.

In FY2010, the work associated with characterizing baseline conditions of surface water and groundwater resources continued, but there were some shifts in emphasis and some new work added. As in FY2009, monitoring of surface water quality was ongoing at the streamgage located near Rock Springs, Wyo., on the upper Green River and at the streamgage near Baggs, Wyo., on Muddy Creek. Likewise, groundwater-level data collection continued at the well on the upper Green River. In addition, a second streamgage was added for monitoring water quality in the upper Muddy Creek Basin because the results of work conducted on Muddy Creek in FY2009 indicated possible mobilization of selenium in that drainage. Also new in FY2010 was the task of compiling all water data for the entire WLCI region. These data were then used to guide the selection of wells for long-term monitoring of groundwater. Rudimentary statistics from these data were compiled and presented to the BLM's Rawlins Field Office, and USGS will work with BLM to determine the next step in using these data. The other new work initiated in FY2010—establishing a Wyoming groundwater monitoring network—involved collecting groundwater samples from four new deep wells (greater than160 feet deep) north and south of Big Piney in the Green River watershed. 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.

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

Framework and Indicators for Long-Term Monitoring

Status

Ongoing

Contacts

Natasha Carr; 970-226-9446; *carn@usgs.gov*
Cameron Aldridge; 970-226-9433; *aldridgec@usgs.gov*
Steve Germaine; 970-226-9107; *germaines@usgs.gov*
Collin Homer; 605-594-2714; *homer@usgs.gov*
Dan Manier; 970-226-9466; *manierd@usgs.gov*

Scope and Methods

Long-term monitoring in the WLCI area is necessary for assessing cumulative effects at landscape scales and detecting trends for key indicators (for example, species, habitat, and land use) in response to development activities and other stressors (for example, climate change). When long-term monitoring is coupled with mechanistic research, modeling (as discussed throughout this document), and management, it has the potential to serve as a warning system that can alert managers to deteriorating population or habitat trends before they reach critical levels that could require costly actions (for example, habitat protection versus reconstruction). Designing an effective and efficient long-term monitoring program that meets stated objectives requires finding a balance between extensive sampling across a heterogeneous resource and the power to detect significant changes in priority indicators. To meet these requirements, this work entails using a spatially balanced, random sampling framework that has proven to be powerful for making inferences across large, heterogeneous resource targets, such as the WLCI area. These designs may be combined with a variety of sampling protocols and objectives to provide a comprehensive, extensive picture of the current status and, if continued through time, a perspective on ongoing changes in the WLCI study area. Provided impetus and funding, the USGS is developing approaches for regional condition assessment and monitoring of land use, vegetation, priority habitats, and populations of priority species.

For monitoring priority terrestrial habitats (sagebrush, aspen, riparian, and mixed mountain shrub communities within WLCI), a spatially balanced design provides a representative but random distribution of samples across the region, thus providing the capacity for comprehensive status estimates and a framework for long-term monitoring. The approach currently being developed by the USGS incorporates the use of multiscale sampling by linking field measurements of vegetation to remotely sensed data (QuickBird, Landsat, and Advanced Wide Field Sensor [AWiFS]) at several scales of resolution and extent. Work is underway to maximize change-detection accuracy and resolution while minimizing the costs of repeated sampling across the region. The resulting maps will facilitate analyses of land use and habitat changes at multiple scales, which are needed for evaluating cumulative impacts and potential management decisions. In addition, the USGS is evaluating several different potential monitoring frameworks for determining condition of vegetation, wildlife, and a range of management and monitoring targets. Comparing and evaluating the cost, information effectiveness, implementation feasibility, and objectives of each alternative will help identify which program(s) will meet stakeholder needs. The alternative programs will be presented to stakeholders for evaluation and further development. Implementation of selected monitoring programs is contingent upon the availability of funding.

Objectives

- 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.
- Evaluate the success of the baseline and pilot monitoring efforts developed in FY2008–2009, 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.
- Draft a monitoring-plan report documenting approach, process, and alternatives for designs and implementation options.

Study Area

Sampling for this work will take 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. Additionally, some long-term monitoring sites based on four QuickBird images (scenes) have been established 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”).

Work Accomplished in 2010 and Findings

The USGS continued to investigate and develop data and models initiated in 2009, and is engaged with colleagues and stakeholders in ongoing review and evaluation of monitoring objectives and potential designs. Clear objectives and funding commitments are important for determining the sampling allocation across the landscape and through time. In support of these discussions, previous work is being used and formalized to assess (1) the statistical power required for trend detection (fig.

28) and (2) the potential precision of range-wide condition estimates for two potential indicators of resource conditions across the WCLI region: vegetation cover and passerine birds. Pilot data for vegetation were derived from the field samples associated with sagebrush mapping (see the Remote Sensing for and Vegetation Inventory and Monitoring section below); pilot data for passerine birds were compiled through cooperative efforts between the USGS, Wyoming Cooperative Wildlife Research Unit, and Rocky Mountain Bird Observatory (RMBO). A combination of sampling simulations (boot-strap) and statistical analyses (simple and multivariate models) was used to determine optimal designs for a monitoring framework.

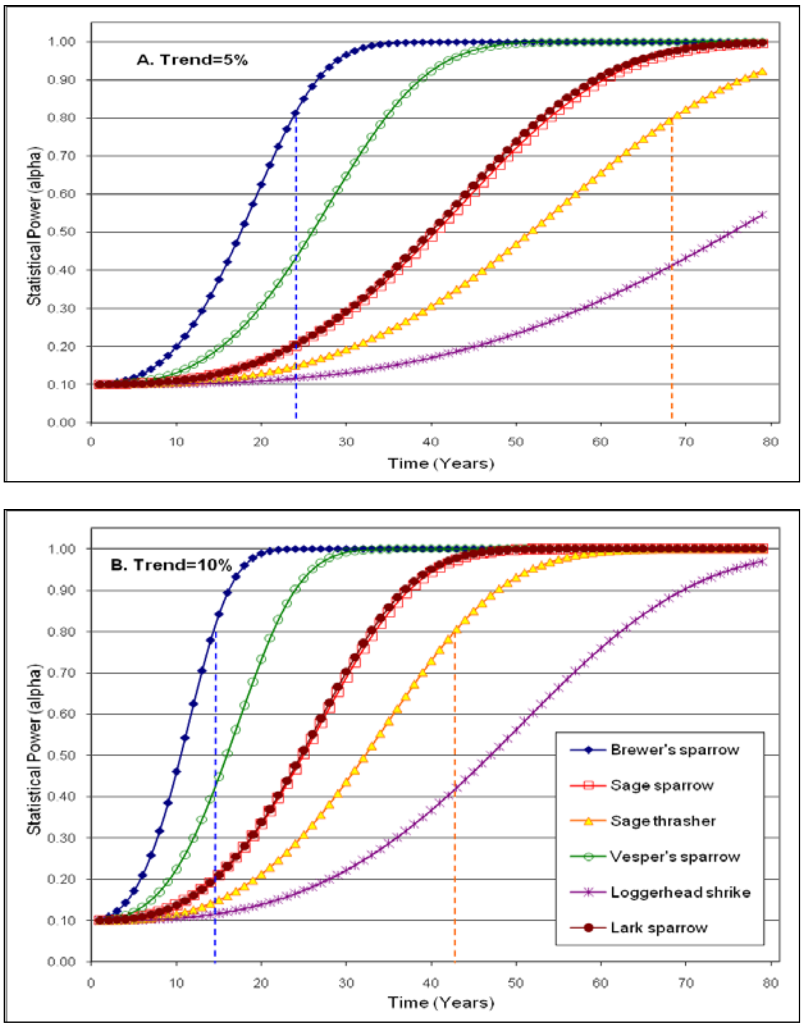


Figure 28. Examples of predicted statistical power for trend based on population parameters derived from pilot data and a split-plot, rotating panel sample design for passerine birds. This design includes 28 plots currently sampled annually by the Rocky Mountain Bird Observatory and a rotating panel of 30 additional plots. The accumulation of statistical power to detect abundance trends for six sagebrush bird species is shown with, *A* a 5 percent trend and *B* a 10 percent trend. Dashed vertical lines indicate the number of years it takes to achieve 80 percent power for Brewer's sparrow (*Spizella breweri*; blue dashed line) and sage thrasher (*Oreoscoptes montanus*; orange dashed line). Factors such as number of samples and rotation duration can decrease the time it takes to achieve desired statistical power for trend detection.

Minimum sampling requirements for assessing dominant community types across the WLCI area were determined by using mapped dominant vegetation to represent community types. Results indicate that existing long-term monitoring conducted by RMBO meets the design criteria that the USGS established in the sampling framework and will contribute to the long-term monitoring goals for sagebrush-obligate birds in the WLCI. Monitoring designs (for birds and vegetation) that can augment RMBO's monitoring program to support WLCI monitoring objectives are being evaluated, and options for local- and regional-scale resource monitoring are being offered. In 2011, efforts to evaluate existing data for monitoring objectives that still need to be addressed will continue. In addition, USGS scientists will continue to sample and assess a set of pilot vegetation monitoring sites, including field sites nested within Quickbird and Landsat imagery (see "Remote Sensing for Vegetation Inventory and Monitoring" section below for details).

Products Completed in FY2010

- Manier, D.J., Aldridge, C.L., Anderson, P.J., Chong, G., Homer, C.G., O'Donnell, M., and Schell, S., in press, Land use and habitat conditions across the southwestern Wyoming sagebrush steppe—Development impacts, management effectiveness and the distribution of invasive plants, *in* Monaco, T.A., Schupp, E.W., Kitchen, S.G., and Pendleton, R.L., compilers, Threats to shrubland ecosystem integrity: Linking research and management, *in* Wildland Shrub Symposium, 16th, May 18-20, 2010, Proceedings: Logan, Ut., Utah State University Press; and S.J. and the Jessie E. Quinney Natural Resources Research Library, Natural Resources and Environmental Issues, v. 17, p. xx–xx.
- Interim data products and analyses were developed for presentation to stakeholders.

Work Planned for FY2011

A Fact Sheet (2–4 pages) will be developed to explain approaches and concepts associated with assessing changes in the status and trends of the indicators used for monitoring. The fact sheet will target a semi-technical audience of natural resource executives and field office staff. In addition, a technical discussion of the modeling and assessment processes for assessing status and trends across the WLCI region will be developed and published in a peer-reviewed journal. Finally, contact with stakeholders will be re-established through meetings with the WLCI STAC, EC, MT, and/or LPDTs.

Remote Sensing and Vegetation Inventory and Monitoring

Status

Ongoing

Contacts

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

Scope and Methods

This subtask focuses on developing remote-sensing protocols to allow spatial projections of continuous cover estimates for sagebrush habitat components (Homer and others, 2009; Homer and others, in review) to support affordable, repeated assessment of the entire region. This work extends beyond traditional category-based, cover-type mapping, with efforts directed at making continuous cover predictions for shrubs, big sagebrush (*A. tridentata*), Wyoming big sagebrush (*A. t. wyomingensis*), all sagebrush species combined, herbs, litter, and bare ground, as well as an estimate of overall shrub height, at multiple spatial scales. Based on samples collected both in the field and from remotely sensed imagery, the USGS is evaluating the distribution of variability in these habitat measures and the amount they are changing over time. This information is critical for understanding current and future distribution of sagebrush habitats.

Objectives

- Ground sample six permanently marked QuickBird vegetation sampling sites.
- Ground sample and permanently mark two new QuickBird vegetation sampling sites.
- Acquire additional 2010 QuickBird and Landsat imagery required to support the 2010 monitoring effort.
- Publish initial paper that describes the remote-sensing protocol being used for WLCI and outline the relationship with the monitoring goals.
- Complete analyses of long-term trends in sagebrush habitat components in southwestern Wyoming.

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.

QuickBird vegetation monitoring site northeast of Cedar Mountain, Sweetwater County, Wyo., for the Remote Sensing and Vegetation Inventory and Monitoring project. Photo credit: Spencer Schell, Ecologist, U.S. Geological Survey.

Work Accomplished in 2010 and Findings

In the summer of 2010, vegetation data were collected from over 7,200 individual plots within eight QuickBird scenes distributed across the WLCI study area. These data will be used to assess and to enhance the ability to detect long-term changes in vegetation across the WLCI region, at local-to-regional scales, by using current sampling approaches. In addition, spatial models were developed for trend analyses of eight sagebrush components based on two Quickbird scenes and for five primary sagebrush components based on Landsat path 37/row 31 (southwestern Wyoming) for every other year from 1985–2006.

Several manuscripts related to this research and long-term monitoring of vegetation and remote sensing within the WLCI were completed. A revised version of the initial manuscript on the methodology for these novel approaches is currently in review, and two additional manuscripts that assess (1) long-term changes in vegetation of the WLCI region (Xian and others, in press) and (2) potential drivers of those changes (Xian and others, unpubl. data) have been developed.

Products Completed in FY2010

- Data from re-sampling permanent monitoring plots at 422 locations distributed across six QuickBird scenes.
- Data from sampling plots at 125 newly established permanent monitoring locations distributed across two additional QuickBird scenes.
- Updated coordinates for more than 400 permanently marked sites.
- Trend analysis to detect change in sagebrush components across four years of permanent plot sampling. Trend analysis incorporated field plot data, QuickBird imagery, and Landsat imagery.
- Analyses of change in vegetation components (and variability in cover) with environmental variables/ecosystem drivers (for example, precipitation and temperature) across the WLCI region, based on field sampling.
- Developed eight spatial models for sagebrush components based on two Quickbird scenes and for the five primary sagebrush components based on Landsat path 37/row 31 (southwestern Wyoming) for every other year, beginning with 2006 back to 1985, for use in trend analyses.
- Xian, G., Homer, C.G., and Aldridge, C.L., in review, Effects of land cover and regional climate variations on long-term spatiotemporal changes in sagebrush ecosystems: Global Ecology and Biography, v. xx, p. xx.
- Homer, C.G., Aldridge, C.L., Meyer, D.K., and S. Schell, in review, 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. xx, p. xx.
- Xian, G., Homer, C.G., and Aldridge, C.L., 2011, Assessing long-term variations of sagebrush habitat – Characterization of spatial extents and distribution patterns using multi-temporal satellite remote sensing data: Journal of Geophysical Research—Biogeosciences: v. xx, p. xx.
- Manier, D.J., Aldridge, C.L., Anderson, P.J., Chong, G., Homer, C.G., O'Donnell, M., and Schell, S., in press, Land use and habitat conditions across the southwestern Wyoming sagebrush steppe—Development impacts, management effectiveness and the distribution of invasive plants, *in* Monaco, T.A., Schupp, E.W., Kitchen, S.G., and Pendleton, R.L., compilers, Threats to shrubland ecosystem integrity: Linking research and management, in Wildland Shrub Symposium, 16th, May 18-20, 2010, Proceedings: Logan, Ut.: Logan, Ut., Utah State University

Press; and S.J. and Jessie E. Quinney Natural Resources Research Library, Natural Resources and Environmental Issues, v. 17, p. xx–xx.

Work Planned for FY2011

Because the supplementary funding support for the project ended in FY2010, long-term monitoring data will be collected only at permanently marked field transects for three Quickbird sites (8 × 8 km). More sites are required to detect on-the-ground, WLCI-wide changes with any precision, but that additional scope of work is currently unfunded; however, it is important to maintain monitoring of some long-term sites to enable future assessment of trends. Additionally, Landsat will be used to update (to 2010) predictions for five vegetation components over the WLCI study area. Regression-tree models developed in 2006 for the WLCI study area (Homer and others, pers. commun.) will be updated to extrapolate existing, base-line models by using change-vector analysis from 2010 Landsat imagery. Work on implementing and integrating these methods for monitoring trends in resource conditions across the WLCI region will continue.

Long-Term Monitoring of Soil Geochemistry

Status

Ongoing

Contact

David B. Smith; 303-236-1849; *dsmith@usgs.gov*

Scope and Methods

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. To meet this baseline need, soil samples were collected in 2008 from 139 relatively undisturbed sites in the original WLCI study area (prior to the study area expansion in 2009) and in 2010 from an additional 36 relatively undisturbed 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 (fig. 29). This sampling scheme represents the same approach used in a continent-wide soil geochemistry program being conducted by the USGS in collaboration with the Geological Survey of Canada and the Mexican Geological Survey (Servicio Geológico Mexicano) (Smith and others, 2009).

Surface soil is considered the material most likely to be affected by human activities in the study area, such as energy development; thus, the primary sample medium for this work 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 data set for the samples collected in 2008, were published by Smith and Ellefsen (2010).

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 1 site per 440 km^2.

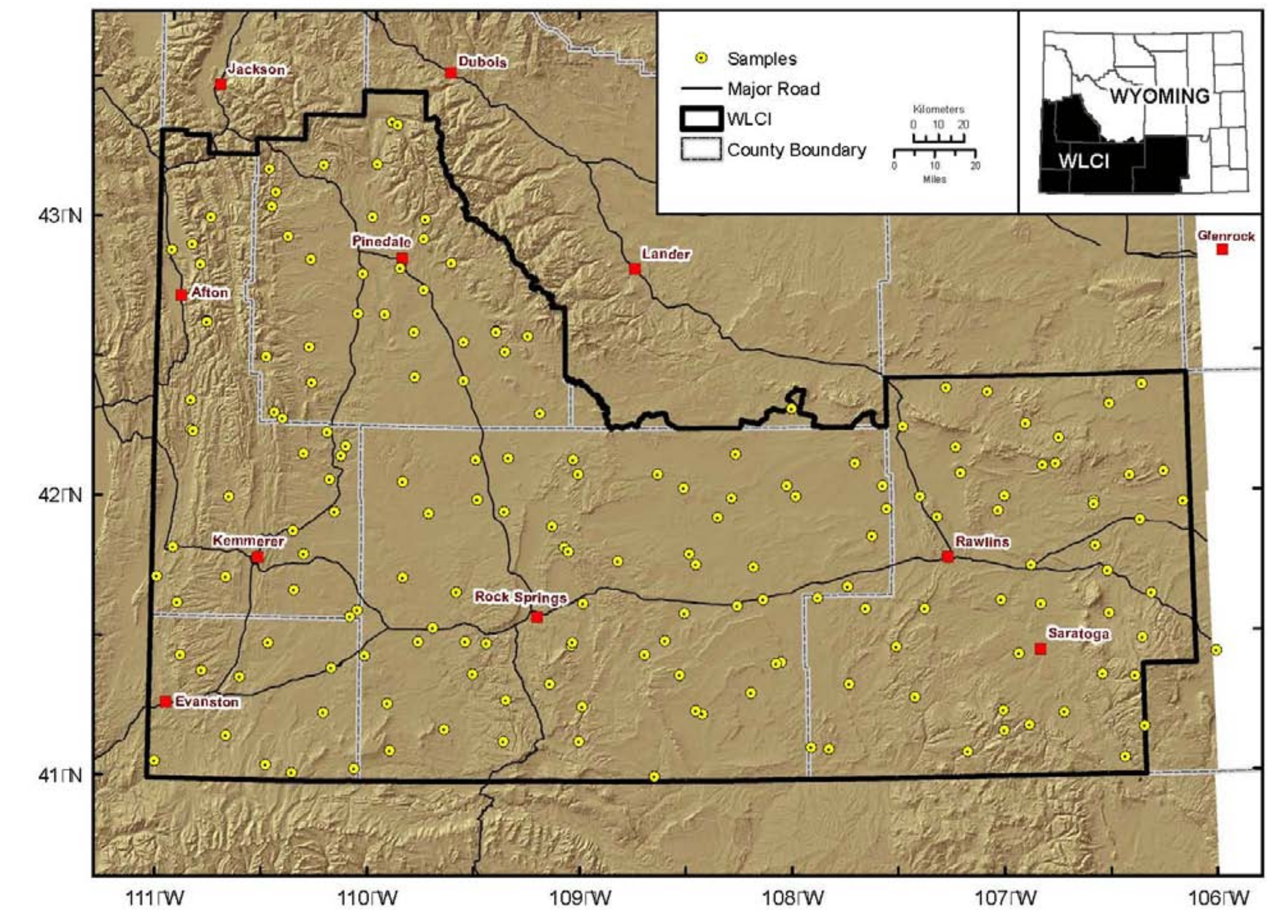


Figure 29. Soil geochemistry sampling locations for the Wyoming Landscape Conservation Initiative's long-term monitoring program.

Study Area

This soil geochemical investigation involved the entire WLCI study area with sampling sites selected using a generalized random tessellation stratified design (fig. 29).

Work Accomplished in 2010 and Findings

Soil samples were collected from 36 sites during August, 2010. These samples were air-dried, disaggregated, and sieved to less than 2 millimeters (mm). The less-than 2-mm material was crushed to less than150 micrometers (µm) in a ceramic mill and thoroughly mixed to ensure homogeneity prior to analysis by the USGS laboratories for (in order of prevalence) 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. Splits of the less-than 2-mm material were also submitted to the Colorado State University's Soil, Water, Plant Testing Laboratory for analysis of total nitrogen (N), soil pH, electrical conductivity, and sodium adsorption ratio. Rigorous quality control protocols were used throughout the analytical process. Chemical analyses of the samples collected during FY2010 were initiated and will be completed in FY2011.

Lindsay Shirk (Delaware Valley College) and Shawn Koltes (North Dakota State University) collecting soil samples in Wyoming during summer 2008. Photo credits: Shawn Koltes (photo of Shirk) and Lindsey Shirk (photo of Shawn Koltes), both U.S. Geological Survey summer student interns.

Products Completed in FY2010

- 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, 10 p., available online at: *http://pubs.usgs.gov/ds/510/downloads/DS-510.pdf*.
- Map showing location of all 175 soil sampling sites within the WLCI study area.

Work Planned for FY2011

The geochemical data from the soil samples collected in 2010 will be combined with the data from the 2008 sampling. Exploratory data analysis, including preparation of histograms, Tukey boxplots, plots of empirical cumulative distribution functions, and quantile-quantile plots, will be performed on the complete data set. Geochemical maps will be prepared to show the abundance and spatial distribution of each analyzed chemical element or parameter. A new version of USGS Data Series 510 (Smith and Ellefsen, 2010) will be prepared showing data for the expanded WLCI study area.

Long-Term Monitoring of Surface Water and Groundwater Hydrology

Status

Ongoing; as in prior years, the report for this work rolls together the two separately line-itemed long-term monitoring studies on "Green River Flow and Water Quality," and "Groundwater Quality in the Green River Basin;" it also includes a new component of work added for FY2010, "Water Data Compilation." (This work was budgeted as a Comprehensive Assessment activity, but it is reported here under long-term monitoring because the new water data compilation work was conducted to inform and guide the long-term monitoring of water resources in the Green River Basin.)

Contact

Kirk Miller; 307-775-9168; *kmiller@usgs.gov*

Scope and Methods

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 three sites; this monitoring is partially funded by the WLCI. Groundwater levels are being monitored at one site; this monitoring also is 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 monthly water-quality samples for 09217000 Green River near Green River, Wyo., and for 09258980 Muddy Creek below Young Draw near Baggs, Wyo.; publish the results at USGS NWISWeb (U.S. Geological Survey, various years).

- Provide publicly accessible seasonal real-time water temperature, specific conductance, and computed total dissolved solids (TDS) concentrations for 09217000 Green River near Green River, Wyoming, and 09258050 Muddy Creek above Olson Draw near Dad, Wyo., and computed TDS concentrations for 09258980 Muddy Creek below Young Draw near Baggs, Wyo. (U.S. Geological Survey, various years).
- Publish seasonal daily water temperature and specific conductance for 09217000 Green River near Green River, Wyo., and 09258050 Muddy Creek above Olson Draw near Dad, Wyo. (U.S. Geological Survey, various years).
- Provide publicly accessible real-time water-level data for the 413850109150601 19-105-10bbb01 Rock Springs site, Rock Springs, Wyo. (U.S. Geological Survey, various years).

Study Area

The focus of this work is water quality and quantity in the Green River Basin and the Muddy Creek Watershed (fig. 30).

Work Accomplished in 2010 and Findings

Surface-water quality data were collected at three sites in the upper Green River Basin and Muddy Creek Watershed, and 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.* In addition, two comprehensive efforts to compile all known water data for the WLCI study area were completed. Groundwater data were published in a Wyoming Geological Survey report coauthored by USGS Wyoming Water Science Center hydrologists (Clarey and others, 2010). Surface-water data from various agencies were compiled, organized, and assessed by using rudimentary statistical methods to better characterize these data and to explore how they might be of use in helping to meet WLCI goals. These surface-water data and analyses have been provided to the BLM Rawlins Field Office and discussion is ongoing about how to further use this information.

Products Completed in FY2010

- Preliminary data for water year 2010 (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=09258980
  http://waterdata.usgs.gov/wy/nwis/nwisman/?site_no=413850109150601

- Final data for water year 2009 were published in the USGS Annual Water-Data Report (U.S. Geological Survey, 2010c). Individual site data sheets are available online:
- *http://wdr.water.usgs.gov/wy2009/pdfs/09217000.2009.pdf*
  http://wdr.water.usgs.gov/wy2009/pdfs/09258980.2009.pdf
  http://wdr.water.usgs.gov/wy2009/pdfs/413850109150601.2009.pdf
- Clarey, K.E., Bartos, T., Copeland, D., Hallberg, L.L., Clark, M.L., and Thompson, M.L., 2010, Available groundwater determination: Technical memorandum, WWDC Green River Basin Water Plan II—Groundwater study, Level I (2007-2009): Lar amie, Wyo., Wyoming Geological Survey, variously paginated.

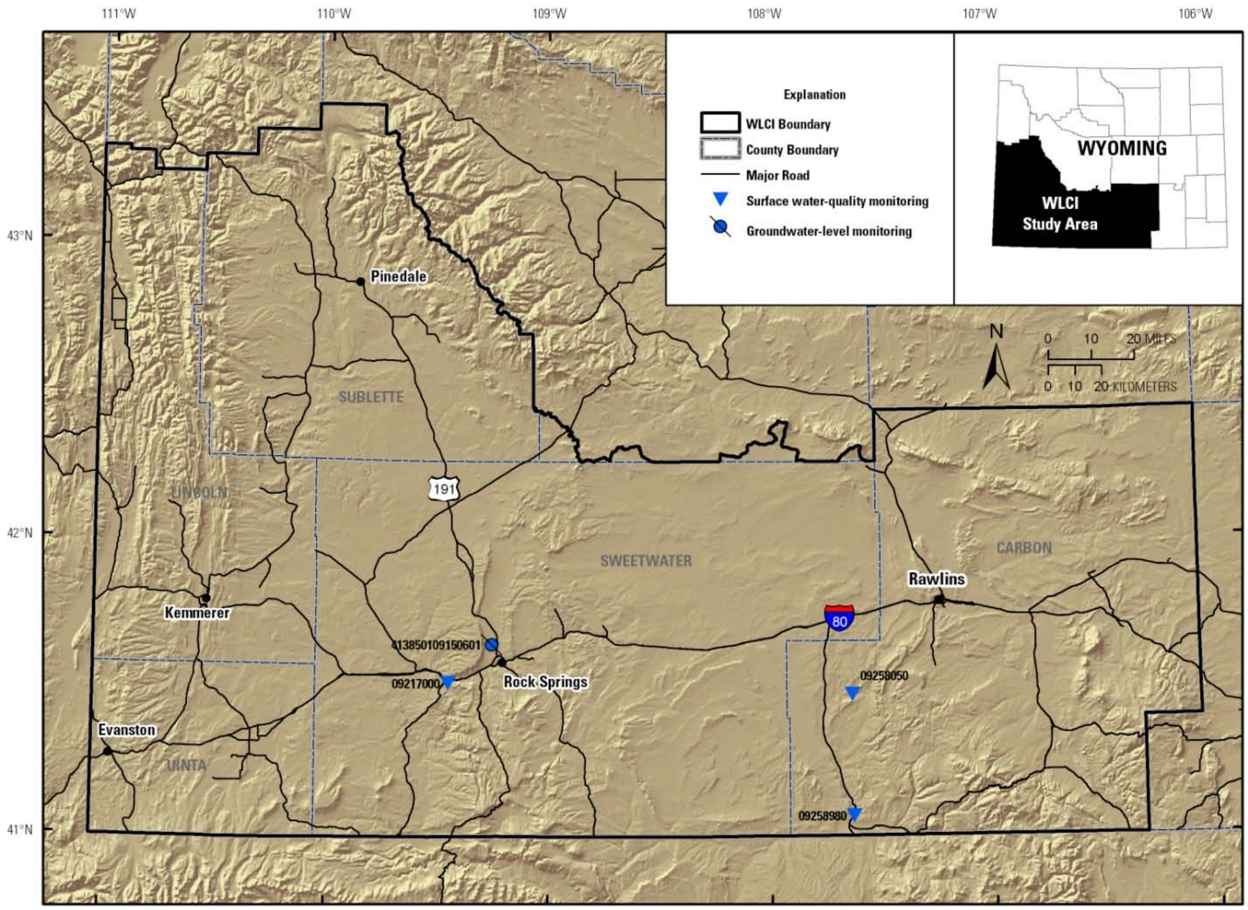


Figure 30. Locations of stations and gages for long-term monitoring of surface water quality and groundwater levels in the Wyoming Landscape Conservation Initiative study area.

Work Planned for FY2011

Water year 2010 data will be reviewed and published in the 2011 USGS Annual Water Data Report. Monitoring of surface-water quality and groundwater levels will continue in water year 2011 at the same sites. Additional monthly water-quality data will be collected at 09205000 New Fork River near Big Piney, Wyo., in water year 2011. Two new groundwater monitoring sites will be added, collocated at site 09205000, for the long-term monitoring of groundwater levels.

Wyoming Groundwater-Quality Monitoring Network

Status

New in FY2010

Contact

Gregory K. Boughton; 307-775-9161; *gkbought@usgs.gov*

Scope and Methods

USGS Hydrologist, Peter Wright, processes groundwater-quality samples collected at groundwater station number 422804110152301, which is located in an energy-development area west of Big Piney/Marbleton in Sublette County, Wyoming. Photo credit: Greg Boughton, Hydrologist, U.S. Geological Survey.

The Wyoming Groundwater-Quality Monitoring Network samples existing shallow wells (less than 160 ft deep) to evaluate groundwater in priority areas where groundwater represents an important source of drinking water to public and private water supplies, is susceptible to contamination, and is overlain by one or multiple land-use activities, including energy development, that could negatively impact groundwater resources (Hamerlinck and Arneson, 1998) (fig. 31). The USGS, in cooperation with the WDEQ, began groundwater sampling in the Green River watershed of the WLCI region in December 2009. WLCI funds allowed four intermediate-depth wells (160–500 ft deep) to be sampled in priority areas within the Green River Watershed (fig. 32).

Samples from randomly selected wells were collected in accordance with specific USGS sampling protocols (USGS, 1997–2010) to ensure a quality sample. Samples were containerized and preserved according to methods required for target analyses and shipped to either the Environmental Protection Agency’s Region 8 Laboratory or the USGS National Water Quality Lab, depending on the analysis to be performed. All samples were analyzed for major ions, trace elements, nutrients, volatile organic compounds, $^{2}H/^{1}H$ and $^{18}O/^{16}O$ 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.

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/*.

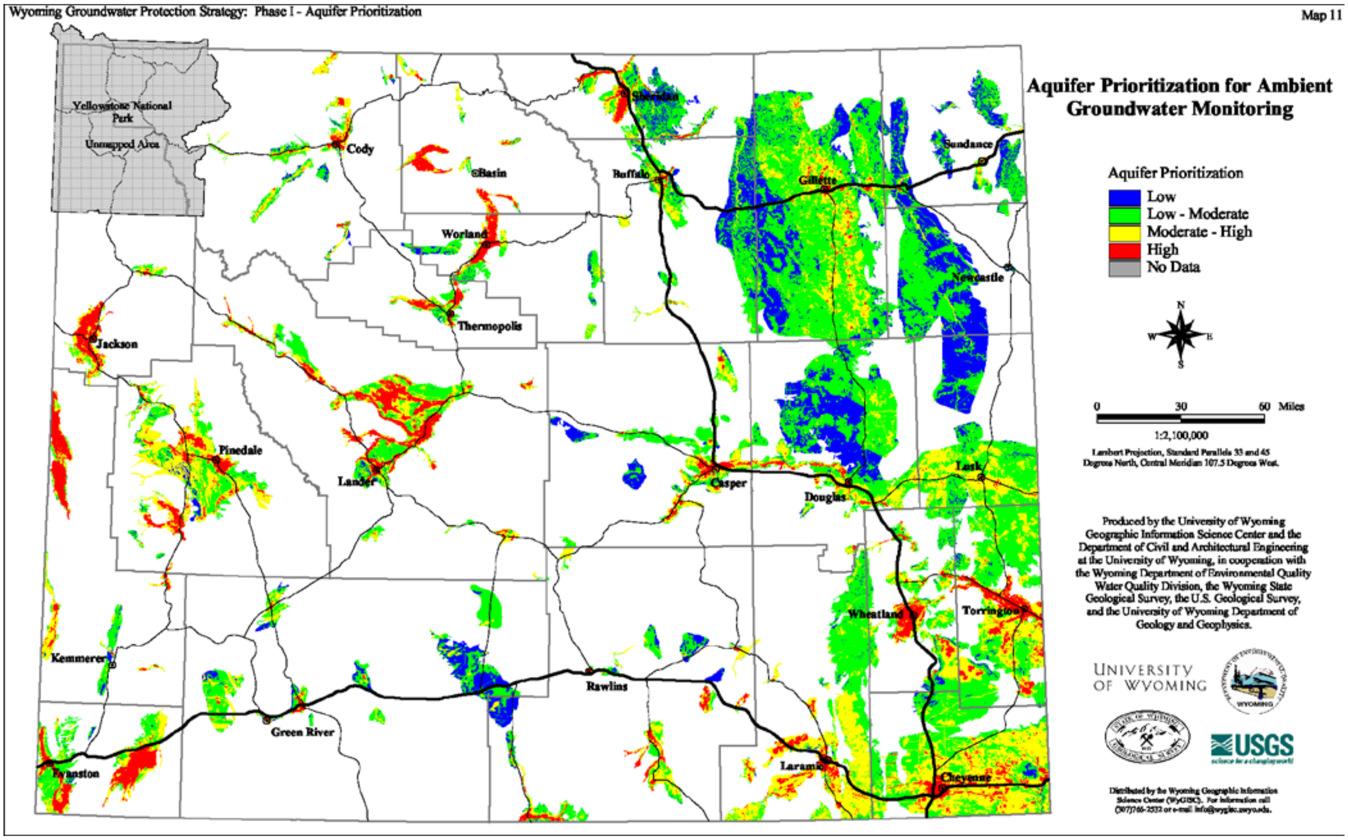


Figure 31. Aquifer prioritization for ambient groundwater monitoring across Wyoming (Hamerlinck and Arneson, 1998). Red and yellow indicate the moderate to high and high priority areas for monitoring.

Study Area

The overall work associated with this study applies to aquifers considered "susceptible" throughout the entire state of Wyoming (fig. 31). The four intermediate-depth wells (160–500 feet deep) for sampling groundwater selected in FY2010 within the WLCI region and funded by WLCI are depicted in Figure 32.

Work Accomplished in 2010 and Findings

Groundwater samples were collected from four intermediate-depth wells in the Green River watershed. Groundwater-quality data were made available online in real-time (USGS NWISWeb). Drinking water standards were exceeded for iron (four samples), manganese (two samples), TDS (two samples), sulfate (one sample), and aluminum (one sample). Methane was detected in all 4 samples, with concentrations ranging from 1.3E to 310 micrograms per liter (µg/L). 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 (5.6E µg/L), but diesel-range organics were not detected in any samples. (The drinking water standards are 5 µg/L for benzene, 1,000 µg/L for toluene; 700 µg/L for ethylbenzene; and 10,000 µg/L for xylene.)

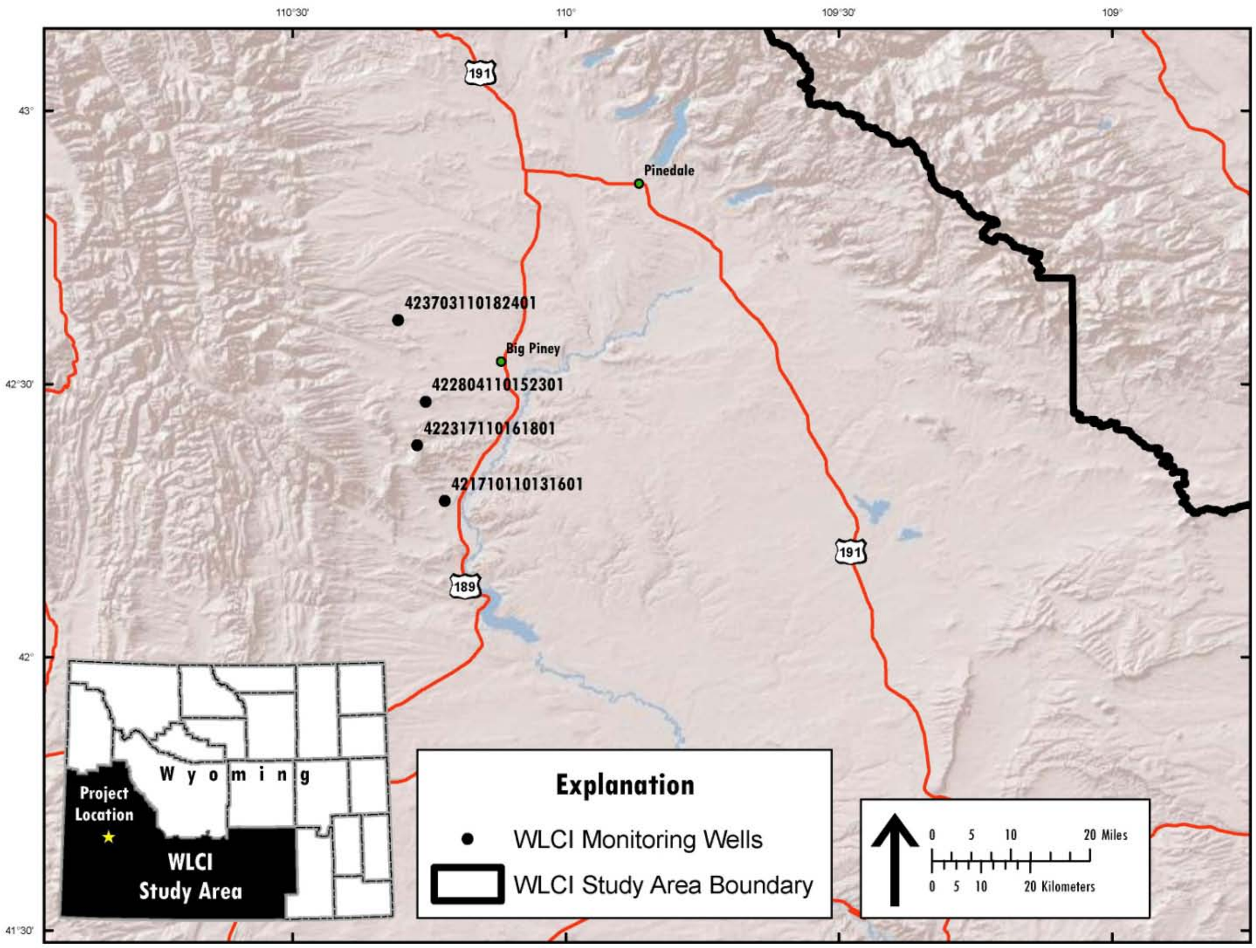


Figure 32. Locations of four intermediate-depth wells (160–500 feet deep) for sampling groundwater in the Green River Basin portion of the Wyoming Landscape Conservation Initiative study area.

Products Completed in FY2010

- 2010 groundwater-quality data were made available online at USGS NWISWeb.

Work Planned for FY2011

Two Fact Sheets are in preparation and will be published in 2011. One Fact Sheet will cover the statewide project, including the WLCI area; the other Fact Sheet will be specific to the WLCI project. In addition, more deep wells (160–500 feet) will be sampled in priority areas in the Green River Basin.

Groundwater-quality monitoring station number 423703110184012, a well used by one of the natural gas producers in the WLCI, northwest of Big Piney, Wyoming. Photo credit: Greg Boughton, Hydrologist, U.S. Geological Survey.

Summary of FY2010 Activities for Effectiveness Monitoring of Habitat Treatments

Effectiveness Monitoring for the WLCI in FY2010 included eight work activities, seven of which were ongoing from previous years: (1) *Applying Greenness Indices to Evaluate Sagebrush Treatments in the WLCI Region*; (2) *Greater Sage-Grouse Use of Vegetation Treatment Sites*; (3) *Occurrence of Cheatgrass Associated with Habitat Projects in the Little Mountain Ecosystem* (the mountainous region south of Rock Springs, Wyo.); (4) *Application and Feasibility of Mapping Aspen Stands and Conifer Encroachment Using Classification and Regression Tree (CART) Analysis for Effectiveness Monitoring*; (5) *Aspen Regeneration Associated with Mechanical Removal of Subalpine Fir*; (6) *Herbivory, Stand Condition, and Regeneration Rates of Aspen on Burned and Unburned Plots For Effectiveness Monitoring*; and (7) *Use of Aspen Stands by Migrant Birds for Effectiveness Monitoring*. The new work activity initiated in FY2010, (8) *Muddy Creek Synoptic Study* (in southwestern Carbon County and southeastern Sweetwater County, Wyo.) is not a follow-up of a habitat treatment, per se; rather, it is a follow-up of energy-development activities within the Muddy Creek Basin. This area has been undergoing significant energy exploration and development that may be mobilizing sediments and elements that could affect the Basin's water and soil quality as well as the ecology of organisms that inhabit the Basin. This synoptic study was designed to simultaneously evaluate stream-water chemistry, stream sediments, upland soils, and macroinvertebrates in the eastern part of the Muddy Creek drainage during summer 2010 to characterize conditions in the Basin.

The work to develop greenness indicators for monitoring vegetation continued in FY2010 through use of near-surface reflectance ("mantis") platforms. The results of this technique may assist managers in making resource-management decisions ranging in scope from the design, application, and monitoring of habitat treatments and restoration activities to the timing of when to provide supplemental feed for elk. Monitoring the long-term effects of historic sagebrush-reduction treatments at a landscape scale also will help with developing guidelines for future vegetation treatments, including invasive species control and restoration.

In FY2010, the sage-grouse habitat treatment work entailed continued monitoring of sage-grouse habitat use in the areas encompassed by the Moxa Arch Natural Gas Development Project Area (an area overlapping the region where Sweetwater, Uninta, and Lincoln counties meet in Wyoming) that were treated with tebuthiuron herbicide and mowing. Relative seasonal use by sage-grouse was estimated by counting pellet types and distribution in treated and nearby untreated areas. The area monitored in 2009 was expanded in 2010 to include additional treatments areas within the Moxa Arch Project Area. Preliminary results indicate that relative use by sage-grouse of treated and nearby untreated habitats varied among treatment locations and types. Monitoring and analysis of sage-grouse use along transects will continue in FY2011.


Dave Kesonie, U.S. Geological Survey Science Technician (left), prepares a "mantis" near-surface sensing platform for use, Wyoming, and U.S. Geological Survey Ecologist, Geneva Chong (right), carries another mantis platform for deployment on native sage-brush vegetation, both near the Fall Creek Feedground, Pinedale, Wyoming. The mantis sensors are used to detect changes in plant phenology (see Effectiveness Monitoring section below). Photo credits . Photo: Geneva Chong (left photo) and Dave Kesonie (right).

In FY2010, the study of cheatgrass occurrence associated with habitat treatments (prescribed burns and wildfires), in the Little Mountain Ecosystem (just south of Rock Springs, Wyo.) continued with a preliminary assessment of the vegetation data collected in 2009. The distribution and frequency of occurrence of cheatgrass and other invasive species varied by burn size and with the number of years since the burn occurred. Eighteen invasive species were observed in transects located in burned areas. Of these, cheatgrass and desert alyssum (*Alyssum desertorum*) have been identified by LPDTs as a priority for the WLCI. Cheatgrass was observed at all 23 locations that were sampled and desert alyssum was observed at 7 locations. African mustard (*Malcomia africana)*, a previously undocumented invasive plant in the Little Mountain area, also was observed at one location. These data will be compared with additional invasive species data collected by USGS during 2011 to evaluate the variation in distributions of invasive species across southwestern Wyoming. During FY2010, seven additional plots were established to augment the six plots established during FY2009 to monitor the distribution, percent cover, and frequency of occurrence of cheatgrass, other invasive species, and native species in the Firehole Canyon area of the Little Mountain Ecosystem. Percent cover and frequency of occurrence of native and introduced species were recorded and soil samples were collected at all 13 plots; soil samples also were collected at the location nearest each plot where cheatgrass was not present. In FY2011, the collection of vegetation data will continue and soil analysis will be conducted.

The aspen-mapping work entailed evaluating Classification and Regression Tree (CART) analysis for its usefulness in this study and applying it to imagery from the NAIP to draft a fine-scale map of aspen distribution on Little Mountain. This methodology, which can be applied to other areas of the WLCI, fills a critical data gap regarding aspen distribution and is being used to support other projects for effectiveness monitoring.

For the study on aspen regeneration associated with mechanical removal of conifers, post-treatment vegetation sampling continued in previously established plots located in pure aspen stands and in conifer stands of varying density and canopy cover. Preliminary data analyses indicate that aspen regeneration is meeting management objectives; they also indicate that responses of both aspen and herbaceous plant species have varied with pre-treatment conifer presence and density, and with the extent of disturbance to soil and litter that occurred during conifer removal.

The study to evaluate the influence of ungulate herbivory on aspen recruitment and growth rates on burned and unburned plots in the Little Mountain Ecosystem area was expanded to evaluate relationships between stand structure and composition of aspen woodlands and herbivory on aspen at different ecological and hydrological settings. This entailed taking a suite of vegetation and terrain measurements in pure aspen stands and at locations with varying densities of aspen and conifer species across a gradient of ecological and hydrologic settings. Data collected during FY2010 will be analyzed in FY2011 to compare the abundance, growth rate, and herbivory of aspen ramets (shoots) in different ecological and hydrological settings and conifer densities. In addition, data will be collected to determine the age structure of each of sampled aspen stand.

The study on migratory bird use of isolated aspen stands and riparian areas as migration stopovers continued with bird surveys conducted in the Little Mountain Ecosystem, Fossil Butte National Monument (southwestern Lincoln County, Wyo.), and Seedskadee National Wildlife Refuge (northwestern Sweetwater County, Wyo.). Data describing habitat characteristics at the stand, landscape, and regional scales also were collected to evaluate how these characteristics influence habitat use by *en route* migratory birds. Initial results indicate that at least 130 bird species use aspen and riparian woodlands in the Green River Basin area. At least four of these species do not breed in Wyoming, which indicates that aspen stands in the WLCI region are of regional-scale importance.

Seth Davidson, U.S. Geological Survey Hydrologic Technician, measures water quality in Muddy Creek's mid-basin, during summer 2010 field sampling for a new work activity, Muddy Creek Synoptic Study, initiated in FY2010.
Photo credit: Melanie Clark, Hydrologist, U.S. Geological Survey.

The Muddy Creek synoptic study initiated in FY2010 entailed sampling water, upland soils, streambed sediments, and terrestrial and aquatic invertebrates. Preliminary results indicate that selenium levels, the primary constituent of concern, are spatially variable within the basin, but greatest in the upper basin. Levels of TDS were greater in the tributaries than they were in Muddy Creek.

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

Applying Greenness Indices to Evaluate Sagebrush Treatments in the WLCI Region

Status

Ongoing

Contacts

Geneva W. Chong; 307-733-9212 x5; *geneva_chong@usgs.gov*

Scope and Methods

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 plant species identity, and phenology in turn 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.

The circular, multi-scale vegetation plot method (Barnett and others, 2007) was used to assess composition of plant species; canopy cover; and the cover of bare soil, rock, and litter in historic sagebrush treatments and controls, and in anomalous green areas and controls (native vegetation) on the Jonah Field (Jonah areas identified on a September 2009 SPOT satellite image). Mantis near-surface sensing platforms (fig. 33; Heidi Steltzer, Asst. Professor, Ft. Lewis College, Durango, Colo., unpubl. data) were used to collect reflectance (vegetation and interspace), incoming solar radiation, soil moisture and air temperature data on native, reclaimed areas treated with herbicide (for cheatgrass control) near the Fall Creek Feedground and on the Jonah Field. Individual plants were monitored multiple times per week to track phenological events.

Study Area

Specific sampling locations in FY2010 included the Pinedale Anticline, the Jonah Field, historic sagebrush treatments, and current cheatgrass treatments within the jurisdiction of the BLM’s Pinedale Field Office (fig. 34).

Figure 33. The “mantis” near-surface sensor platform (H. Steltzer and others, developers) has downward-facing sensors (for visible and near infrared light) for measuring greenness and an upward-facing sensor for monitoring cloud cover. Reflectance and incoming solar radiation data were collected with 21 platforms from May 1 to September 1, 2010: 7 platforms on the Jonah Field (1 on a cheatgrass treatment; 2 on reclaimed well pads; 4 on remnants of native vegetation); 7 on the Fall Creek Feedground (3 each on cheatgrass treatments and controls, and 1 reflectance control); and 7 on native vegetation (3 each on sagebrush and interspaces, and 1 reflectance control) near the Fall Creek Feedground. Each site also had sensors to record air temperature and soil moisture at the surface (5 cm deep). Photo credit: Geneva Chong, Research Ecologist, U.S. Geological Survey.

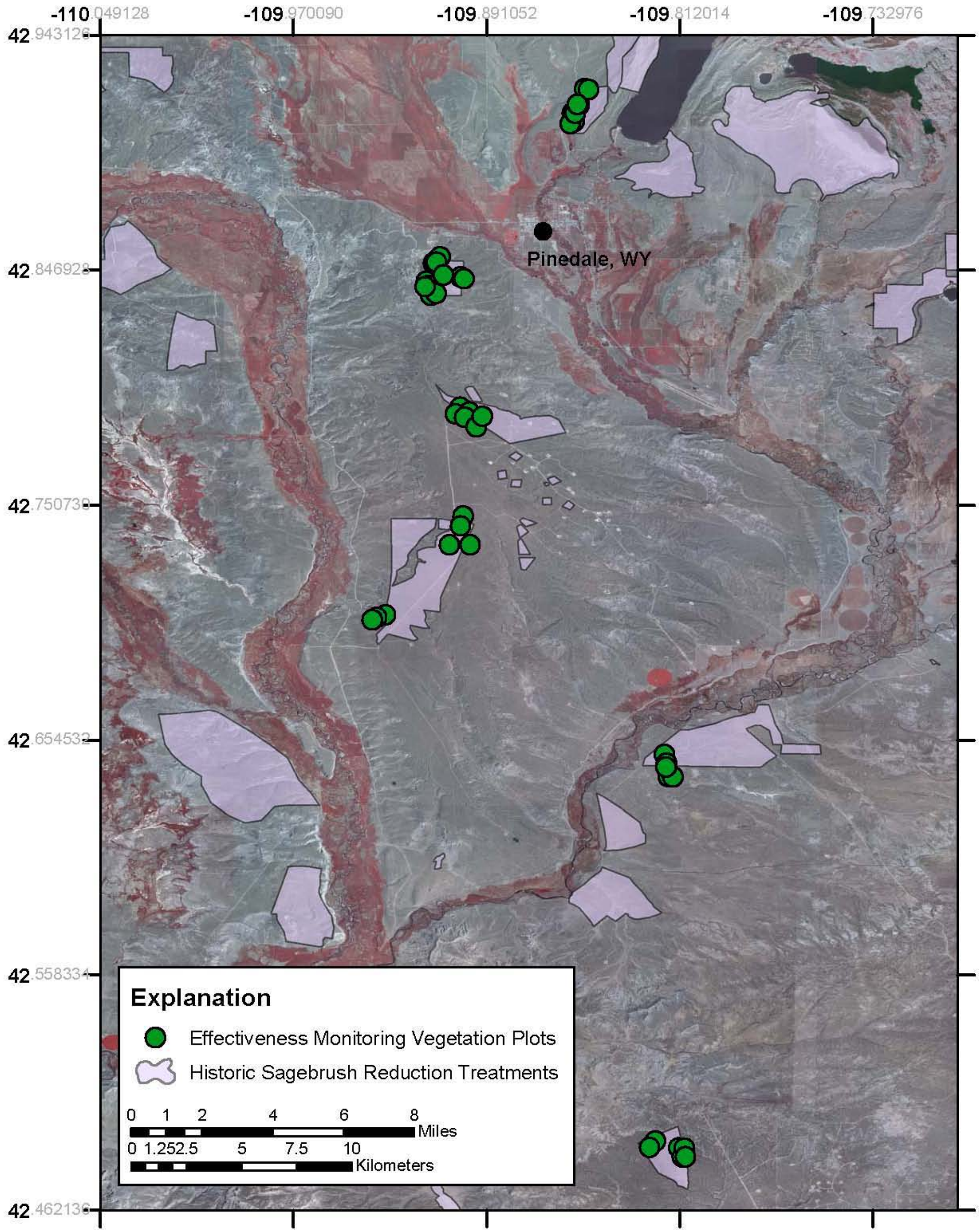


Figure 34. Locations of historic sagebrush treatments (mapped by Wyoming Wildlife Consultants, LLC 2007) and 2010 effectiveness monitoring vegetation-sampling plots.

Objectives

- Evaluate the composition and structure of plant species and the abiotic characteristics (for example, bare soil) of their habitat within historic sagebrush treatment areas by using stratified random sampling with multi-scale circular plots. Compare treated and control areas.
- 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.
- Initiate studies in the Jonah Field and near the Fall Creek Feedground areas to evaluate cheatgrass detection to conduct effectiveness monitoring in cheatgrass treatments.
- Initiate a study of and anomalous green-up on the Jonah Field.
- Coordinate with WLCI partners to select sample sites for monitoring in FY2011.

Work Accomplished in 2010 and Findings

Twenty-one near-surface sensor platforms ("mantis"; fig. 33) were installed during spring 2010, including 14 platforms established in cheatgrass-reduction treatments (Fall Creek Feedground area) and well-pad reclamation sites (Jonah Field) (fig. 34). The electronics were removed for the winter and will be re-installed in spring 2011. Native and non-native plant species were sampled on the Jonah Field in areas where anomalous green-up was observed in fall 2009 (based on SPOT satellite imagery), and events associated with plant phenological events (for example, green-up, flowering and senescence) were sampled. Vegetation and bare-ground (in 47 multi-scale circular plots) were sampled both inside and outside of six historic sagebrush-reduction treatment areas within the jurisdiction of the BLM's Pinedale Field Office. All plot data are being maintained in an MSAccess database and all plots were photographed.

Analyses of the reflectance, incoming radiation, soil moisture, and air temperature data from the mantis near-surface sensing platforms are ongoing; analyses are being conducted with software developed by Rick Shory (Botanist and Programmer, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, Colo.). Preliminary analyses indicate that significant phenological events (for example, green up and maximum greenness) can be detected, as hypothesized. Preliminary analyses of 2010 data comparing historic sagebrush-reduction treatments (fig. 34) do not indicate uniform effects across treatments (for example, persistent reduction in shrub cover or increase in bare ground), and some effects observed in 2008 were not recurrent—likely because of drought during growing seasons preceding 2008 that did not occur in 2008 and 2009. Of the six sites sampled and analyzed in 2010, however, there were some significant but inconsistent differences between treated and untreated areas (for example, in one area shrub cover was greater in treated than in untreated habitat, whereas in another area shrub cover was greater in the untreated habitat). When data by growth form (grass, forb, shrub) were analyzed, the results were similarly significant but inconsistent. Long-term effects of sagebrush-reduction treatments measured at any given time likely vary based on previous condition and land-use, current land-use, weather (for example, drought), topography, and soils. This variation provides additional rationale for planning, applying, and monitoring treatments within the context of the larger landscape. Treatments that may meet functional objectives one year (for example, brood-rearing for greater sage-grouse) may not do so in other years; thus, it would be important to maintain a functional mosaic that mimicks the extent of undisturbed, “natural” variation in vegetation. In addition, it is important to monitor both direct impacts to vegetation and soils (for example, species composition and phenology) and indirect impacts on wildlife, as measured through animal use and reproductive success.

Products Completed in FY2010

- Dataset: Reflectance, incoming radiation, soil moisture and air temperature dataset (1 reading every 10 minutes) from 21 near-surface sensing platforms (mantis) from approximately May 1 to September 1, 2010.
- Software: Beta version for conducting quality assurance/control on the dataset above, and to extract, plot, and analyze those data.
- Dataset: Plant species and abiotic (for example, bare soil, rock, litter) composition and cover from multi-scale vegetation plots on and adjacent (paired) to six historic sagebrush-reduction treatments.
- Digital photos from plots and mantis deployments.
- Dataset: Plant species and abiotic (for example, bare soil, rock, litter) composition and cover from multi-scale vegetation plots on anomalous green-up locations on the Jonah Field (identified in September 2009 SPOT imagery).
- Dataset: Plant phenology for specific species (for example, green-up, flowering, senescence) to correlate with mantis and satellite reflectance data.
- Manier, D.J., Aldridge, C.L., Anderson, P.J., Chong, G., Homer, C.G., O’Donnell, M., and Schell, S., in press, Land use and habitat conditions across the southwestern Wyoming sagebrush steppe—Development impacts, management effectiveness and the distribution of invasive plants, *in* Monaco, T.A., Schupp, E.W., Kitchen, S.G., and Pendleton, R.L., compilers, Threats to shrubland ecosystem integrity: Linking research and management, *in* Wildland Shrub Symposium, 16th, May 18-20, 2010, Proceedings: Logan, Ut., Utah State University Press; and S.J. and the Jessie E. Quinney Natural Resources Research Library, Natural Resources and Environmental Issues, v. 17, p. xx–xx.
- USGS/National Association of Geoscience Teachers Internship: Intern Katherine Rouse completed a 12-week internship based in Pinedale, Wyo. This was the second internship conducted on behalf of this Effectiveness Monitoring work activity. The intern’s work was invaluable and included downloading/managing data, maintaining the mantis platforms, collecting phenology data, and establishing vegetation-monitoring plots.

Work Planned for FY2011

In FY2011, analyses of the 2010 mantis data will be completed and the results will be presented at the 96th annual meeting of the Ecological Society of America. The oral presentation of this work—“Heralding change: How can plant phenology be used to facilitate sustainable natural resources management?”—has been accepted. Analyses to correlate mantis data with remotely sensed (satellite) data and ground-based phenology measurements will be initiated. Preliminary analyses will be conducted by an intern funded by the National Atmospheric Science Agency in cooperation with scientist, Jeff Pedelty, from the same agency. In addition, preliminary analyses and continued sampling will be conducted to determine the effectiveness of cheatgrass control treatments. A proposal submitted for funding to hire a U.S. Geological Survey/National Association of Geoscience Teachers intern was granted, which will allow for sampling all FY2011 vegetation sampling sites for sage-grouse use. Management and analysis or data collected during 2008–2010 will continue.

Greater Sage-Grouse Use of Vegetation Treatments

Status

Ongoing

Contact

Patrick Anderson; 970-226-9488; *andersonpj@usgs.gov*

Scope and Methods

Questions about whether sage-grouse are benefiting from past vegetation treatments have been raised by members of WLCI LPDTs, 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. Currently there are two locations where USGS is conducting this work: (1) the Moxa Arch gas field near Granger, Wyo., and (2) prescribed burns in the Little Mountain Ecosystem south of Rock Springs, Wyo. (fig. 35).

Moxa Arch Treatments—As part of the BLM "Moxa Arch Pronghorn Habitat & Livestock Forage Mitigation Plan," numerous vegetation treatments were conducted from 1997 through 2002. The goal of these treatments was to mitigate the effects of development on habitat and forage by creating a mosaic of sagebrush stands at different seral stages. Treatments were conducted within upland habitats that represented areas selected by pronghorn (*Antilocapra americana*) and by sage-grouse for nesting and early brood rearing. The areas selected for treatment were dominated by Wyoming big sagebrush. Vegetation surveys of areas treated by mowing and by applications of the herbicide, tebuthiuron (Spike®), 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 the long run, 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.

During 2009, USGS initiated a long-term study in the Moxa Arch treatment area (fig. 36) 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 area.

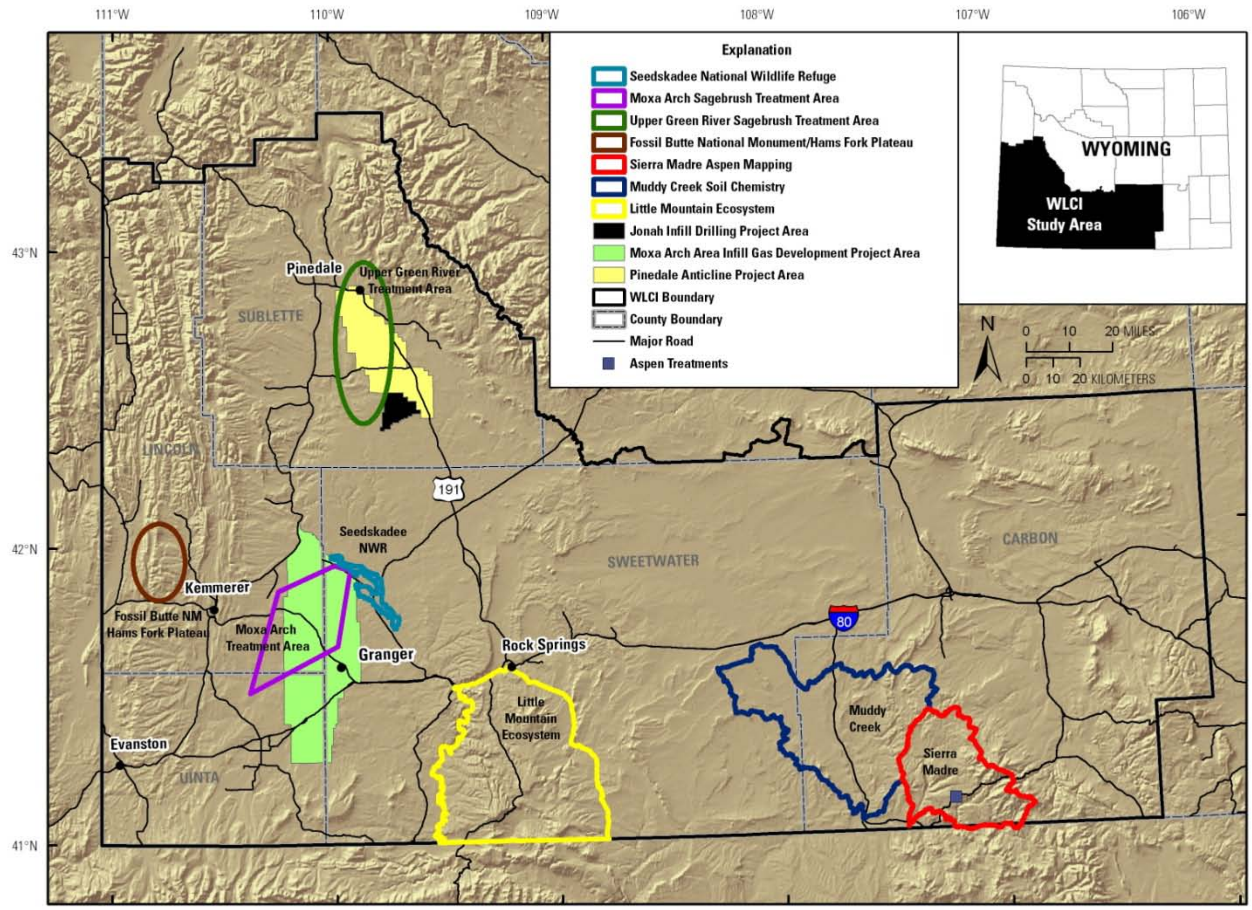


Figure 35. Locations of study areas associated with effectiveness monitoring work activities.

Both treatment sites and adjacent, untreated sites for assessing seasonal sage-grouse use were located on BLM lands. To measure sage-grouse use, pellet counts were conducted within 4- × 100-meter belt transects in the Moxa Arch Natural Gas Development Project area. In late May 2009, 44 transects were established within herbicide- and mowing-treatment areas at Cow Hollow and Ziegler's Wash, and during May and June 2010, 85 additional transects were established within the remaining treatment areas of Moxa Arch: Zeigler's Flats, Hampton, Fontenelle, Dodge Rim, and Seven Mile Gulch (fig. 36). Transects established for sampling treatment sites were randomly located and they were 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 the belt transect and 0.5 m beyond the 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.

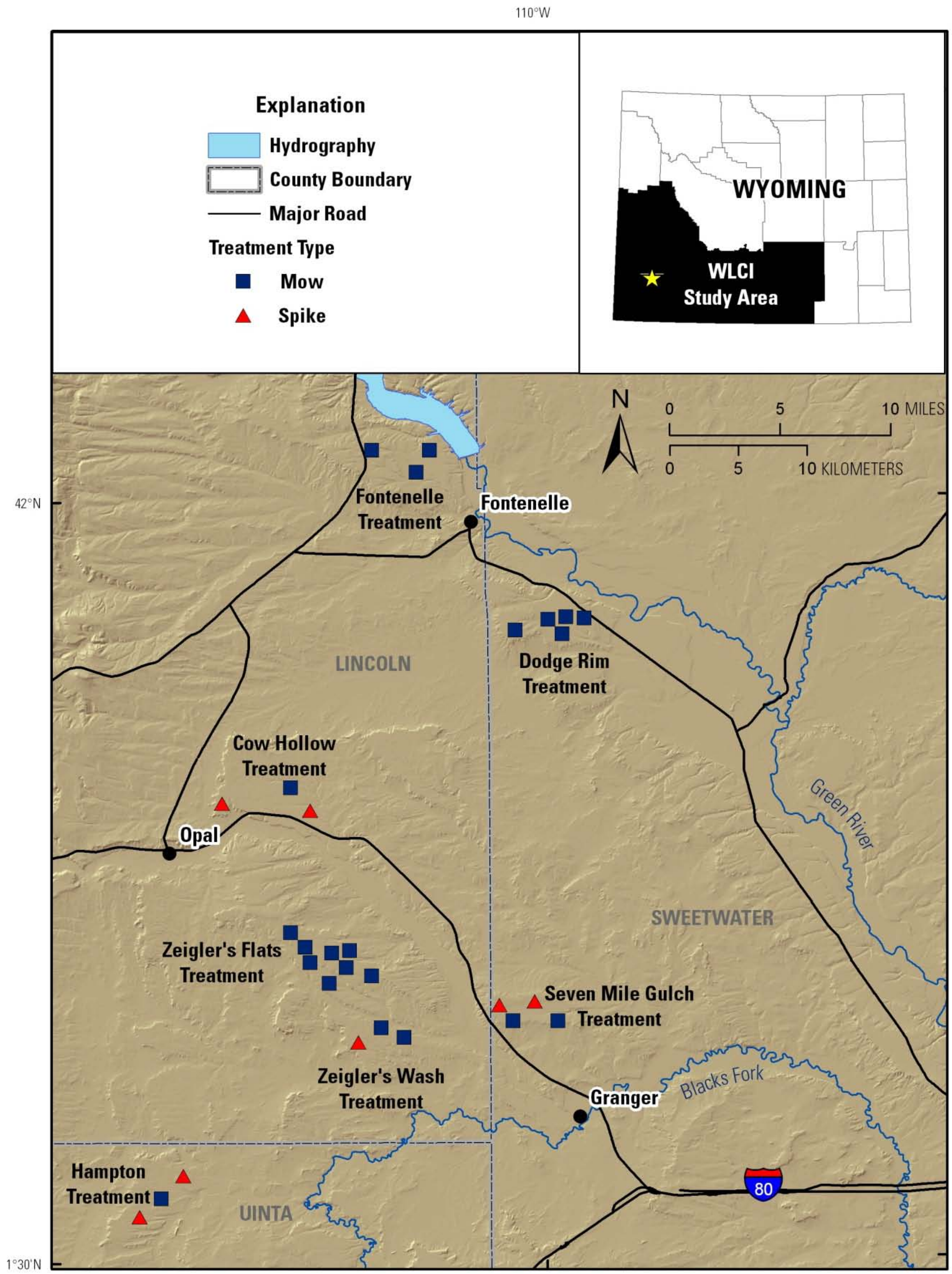


Figure 36. Locations of vegetation mowing and herbicide (tebuthiuron, trade name Spike®) treatments in the Moxa Arch Natural Gas Development Project Area in southwestern, Wyoming.

Little Mountain Ecosystem Burn Treatments—Since 1990, numerous restoration and habitat enhancement projects have been implemented in the Little Mountain Ecosystem area south of Rock Springs. Many of these projects involved prescribed burning to reduce sagebrush cover, increase herbaceous cover, and retard the expansion of junipers (*Juniperus* spp.) into sagebrush habitat (fig. 37). To assist USGS with developing preliminary survey designs for assessing the effectiveness of these habitat treatments, BLM Rock Springs Field Office personnel obtained geospatial data pertaining to the treatment areas as well as to areas where wildfire had occurred. Between August and September, 2009, preliminary sage-grouse pellet surveys had been conducted along the perimeters of burned patches and in adjacent, unburned areas to identify suitable habitat for sage-grouse nesting or brood rearing. This information will be used to help develop future evaluations of sage-grouse seasonal-use patterns associated with vegetation responses to burn treatments. Originally, this additional work was slated to begin in FY2010, but it was delayed to allow for the time and resources needed to expand the Moxa Arch sage-grouse study.

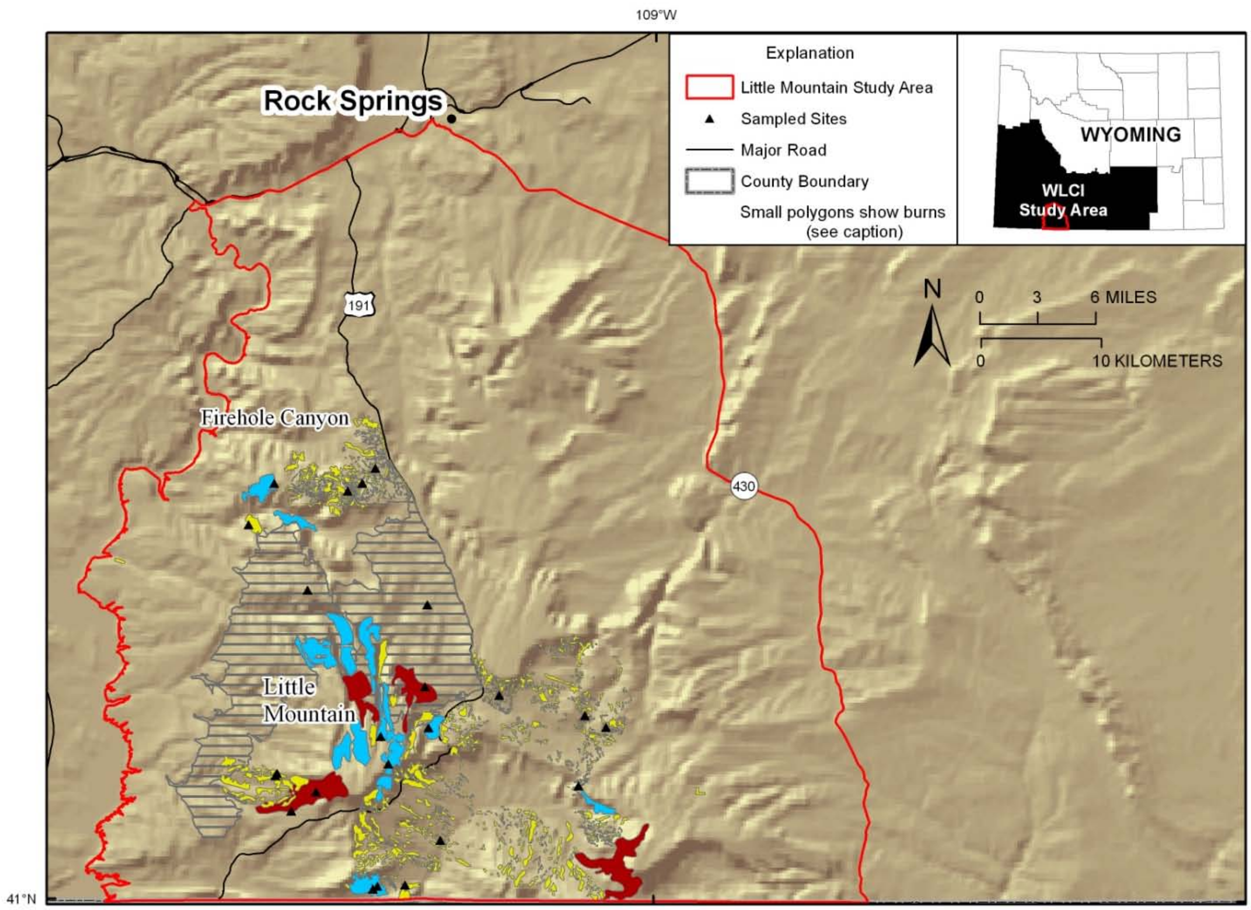


Figure 37. The distribution of recent fires (colored polygons) and sample units (black triangles) included within the Little Mountain Ecosystem, near Rock Springs, Wyo. The distributions of cheatgrass and other invasive species are being investigated using a stratified random sampling design across these 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 size classes (mean areas for the four size classes, from smallest to largest, were 7 km^2 (yellow), 287 km^2 (red), 954 km^2 (blue), and 14,387 km^2 (hatched).

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.

Study Area

Moxa Arch Treatment—There are seven general project areas where predominantly Wyoming sagebrush was treated either with (1) tebuthiuron or (2) mowing. The seven Moxa Arch treatment areas are located near the towns of Opal and Granger, Wyo., within the expanded Moxa Arch Natural Gas Development Project Area (figs. 35, 36). The Moxa Arch treatment area is located in Sweetwater, Lincoln, and Uinta Counties, and it encompasses approximately 476,300 acres of mixed federal, state, and private lands. Treatment information (treatment type, year treatments were conducted, acreage treated, and pattern of treatment features) are provided in Table 1. 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.

Little Mountain Ecosystem Burn Treatments—Preliminary surveys focused on prescribed burns in the Little Mountain Ecosystem (figs. 35, 37) where Wyoming sagebrush and mountain sagebrush (*A. t. vaseyana*) are dominant or where junipers have encroached into mountain-sagebrush communities. Burn treatments were implemented to create a mosaic of patches in larger sagebrush areas and to improve nesting and early and late brood-rearing habitat for sage-grouse. Similar to the Moxa Arch treatment area, smaller shrubs, grasses, and forbs are common. Several non-native grass and forb species are found in the general area, including cheatgrass.

Table 1. Treatment information associated with the Moxa Arch Vegetation treatments (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 pound/acre[2])	October 1999	530	2 large polygons
Dodge Rim	mow (8–10 inches)	Fall 2000	436	multiple long narrow mosaic strips
Cow Hollow	mow (~ 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 36.

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

Work Accomplished in 2010 and Findings

Both treated and untreated sites were assessed for sage-grouse seasonal habitat use using pellet counts within a 4- × 100-m belt transect. Forty-four belt transects were established at the Zeigler's Wash and Cow Hollow tebuthiuron and mowed treatment sites and at adjacent untreated sites during late May, 2009. Eighty-five transects were added to the remainder of the Moxa Arch vegetation treatment areas (Zeigler's Flats, Hampton, Fontenelle, Dodge Rim, and Seven Mile Gulch) during May and June, 2010 (table 1). Pellet counts and reconnaissance surveys were conducted during sage-grouse nesting season (April 20–May 14), early brood rearing (June 30–July 7) and late brood rearing (August 29–September 3). Individual foraging pellets, roost piles, hen clockers, and cecal casts were counted within each belt transect. All pellets within the transect area were collected during each survey.

This study confirms that sage-grouse are using the treated and surrounding untreated habitats within the Moxa Arch area during nesting and brood-rearing periods. Clocker deposits located near or within transects at both tebuthiuron-treated and mowed areas were observed, indicating nearby sage-grouse nesting activities. Based on observed abundance and type of pellets, and on sampling date, sage-grouse are using treated and untreated habitats for both roosting and foraging activities during all seasons; however, most use appears to take place from early spring through early summer. The abundance of observed pellets varied between and among treatment types, distance to energy infrastructure, and distance to leks. A preliminary assessment does indicate that sage-grouse are using treated and untreated habitats near infrastructures associated with energy development, although long-term patterns cannot yet be determined. Pellet abundance also varied within individual treatment fields; pellet counts within individual transects, however, were less variable. In 2010, transects with high or low pellet counts also had high or low pellet counts (respectively) in 2010; and transects with high or low pellet counts in early spring were high or low, respectively, throughout the season. This may be due to the strong site fidelity that sage-grouse are known to exhibit.

Products Completed in FY2010

- Anderson, P.J., 2010, Seasonal habitat use of sage-grouse in treated and untreated habitats in the Moxa Arch study area, presentation (field tour) to the WLCI Executive Committee.
- 2010 vegetation dataset with plot photos.

Work Planned for FY2011

Seasonal monitoring of sage-grouse use within the Moxa Arch habitat treatment areas will continue and analyses of data on sage-grouse habitat use for the years 2009 and 2010 will be conducted. In addition, map products showing transect-based trends for each treatment area will be developed. A protocol for estimating pellet age (by season) will be calibrated and validated, and soil texture will be ascertained at treatment locations where soil texture has not already been ascertained by a contractor working with the BLM. Findings of this work and the pellet-aging protocol will be presented to LPDT members.

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

Status

Ongoing

Contacts

Dan Manier; 970-226-9466; *manierd@usgs.gov*
Patrick J. Anderson; 970-226-9488; andersonpj@usgs.gov

Scope and Methods

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.

Cheatgrass (*Bromus tectorum*). Photo credit: Natrona County Weed and Pest.

Since 1990, numerous restoration and enhancement projects have been implemented in the Little Mountain Ecosystem. Many of these projects involved prescribed burns to reduce sagebrush cover and increase herbaceous cover, retard the expansion of junipers 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 Wyo., 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. 35). 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. 37).

Work Accomplished in 2010 and Findings

Field crews investigated the relationship between fires and the distribution of invasive species in 2009 by sampling vegetation associated with prescribed burns and wildfires in the Little Mountain Ecosystem. This study was based on records of recent burns in the study area between 1993 and 2008. The patch size of prescribed fires and wildfires ranged from less than 1 acre to 36,000 acres (fig. 37). This region was a focal area for 16 prescribed-burn treatments to stimulate aspen and herbaceous forage production in ungulate and sage-grouse habitats and 8 wildfires during the period of record. A preliminary assessment was conducted during 2010 to evaluate vegetation measurements of invasive species at prescribed burns and wildfires in the Little Mountain area.

Investigations of the distribution of cheatgrass and other invasive species also continued within the Firehole Canyon area of the Little Mountain Ecosystem. Six additional multi-scale plots were established during 2010, and percent cover and frequency of occurrence of native and introduced species were recorded at all plots. In addition, soil samples were collected at all plots and at the nearest location where cheatgrass was not present.

A preliminary assessment of vegetation data collected in 2009 indicates that cheatgrass and other invasive species varied with the size of burned areas and with burn year. Eighteen invasive species were observed in 2009 at 23 locations that were burned between 1993 and 2008 (table 2). Of these, cheatgrass was the only species that was observed at all 23 locations sampled (table 2). Fourteen of the invasive species were observed at only one to three locations. Cheatgrass and desert alyssum also were the most commonly observed invasive species where they were distributed. The consistent observation of these two species indicates their ability to respond positively in post-fire environments. In addition, African mustard, a previously undocumented invasive plant in the Little Mountain area was observed at one location.

Table 2. Eighteen invasive species were observed at locations that were burned (prescribed fires and wildfires) between 1993 and 2008 in the Little Mountain area, south of Rock Springs, Wyo. A total of 23 locations were sampled in the Little Mountain area during 2009.

Invasive Species	Number of locations where each species was observed
Cheatgrass (*Bromus tectorum*)	23
Desert alyssum (*Alyssum desertorum*)	7
Common dandelion (*Taraxacum officinale*)	6
Yellow salsify (*Tragopodon dubius*)	6
Bur buttercup (*Ceratocephala testiculata*)	3
Tansy mustard (*Descurania sophia*)	3
Halogeton (*Halogeton glomeratus*)	3
Goosefoot (*Chenopodium* sp.)	2
Smooth brome (*Bromus inermis*)	1
African mustard (*Malcomia africana*)	1
Prickly lettuce (*Lactuca serriola*)	1
Kentucky bluegrass (*Poa pratensis*)	1
Lambsquarter (*Chenopodium album*)	1
Kochia (*Bassia scoparia*)	1
Russian thistle (*Salsola tragus*)	1
Tumble mustard (*Sisymbrium altissimum*)	1
Yellow sweet clover (*Melilotus officinalis*)	1
Canada thistle (*Cirsium arvense*)	1

Products Completed in FY2010

- Manier, D.J., Aldridge, C.L., Anderson, P.J., Chong, G., Homer, C.G., O'Donnell, M., and Schell, S., in press, Land use and habitat conditions across the southwestern Wyoming sagebrush steppe—Development impacts, management effectiveness and the distribution of invasive plants, *in* Monaco, T.A., Schupp, E.W., Kitchen, S.G., and Pendleton, R.L., compilers, Threats to shrubland ecosystem integrity: Linking research and management, *in* Wildland Shrub Symposium, 16th, May 18-20, 2010, Proceedings: Logan, Ut., Utah State University Press; and S.J. and the Jessie E. Quinney Natural Resources Research Library, Natural Resources and Environmental Issues, v. 17, p. xx–xx.
- 2010 vegetation dataset with plot photos.

Work Planned for FY2011

Data will be compared with other invasive species data collected by the USGS during 2011 to evaluate the variability of invasive species distributions in southwestern Wyoming. Vegetation measurements (percent cover and frequency of occurrence) will continue to be collected in the Firehole Canyon during 2011 and analysis of soil samples that were previously collected will be conducted during 2011.

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

Status

Ongoing

Contacts

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

Scope and Methods

The scope of this work was adjusted in 2010 to meet the immediate needs of other effectiveness-monitoring efforts that were taking place in the Little Mountain Ecosystem. Restoration and maintenance of aspen communities in that area is a priority of the BLM and the USGS has been working with the BLM and WGFD to monitor these stands as part of the effectiveness monitoring task. A critical data gap for this effort is a fine-scale map of aspen distribution in the Little Mountain Ecosystem. LANDFIRE and ReGAP maps are considered the best spatial products that predict aspen locations at regional and landscape scales; however, these products were not designed to support decisions at localized scales. In 2010, uncompressed NAIP color-infrared imagery that was flown in September of 2009 became available and was used for this study. CART analysis was evaluated and applied to this data to produce an aspen map of Little Mountain (fig. 38a). The CART is a powerful data mining tool that extracts pattern from large data sets through the construction of decision trees and rule sets from reference data.

Photographs and stand evaluation were collected in July 2010 on Little Mountain and used to develop training data. NAIP imagery acquired in September of 2009 was provided to us by the BLM Wyoming State Office. This product was suitable for this task because it was recently acquired in 4-band (including an infrared band) and was available as uncompressed imagery (fig. 38b). Imagery is compressed to reduce the size of the data, but this can introduce error and a loss of data. Furthermore, uncompressed imagery is necessary for machine analysis used by remote sensing software.

A radiometric enhancement algorithm was applied to the imagery to reduce the noise in the data. Numerous indices were generated from the imagery (Silleos and others, 2006) and evaluated; those retained were used in the analysis as predictor variables (table 3). Training data collected in the field was used to generate polygons of various cover types (including aspen and conifer). CART was performed using the predictor variables and an output map was generated. See5© (Rulequest Research Pty., Ltd., 2011) software (for data mining) was used for the CART analysis in tandem with ERDAS IMAGINE image processing and compression software to produce an output map. In addition, an interface created for the National Land Cover Database that communicates between both pieces of software was utilized. A smoothing algorithm (5 × 5 window) was applied to the data to remove isolated pixels and improve the interpretability of the map. The output map was then evaluated using existing knowledge of the study area and by field crews.

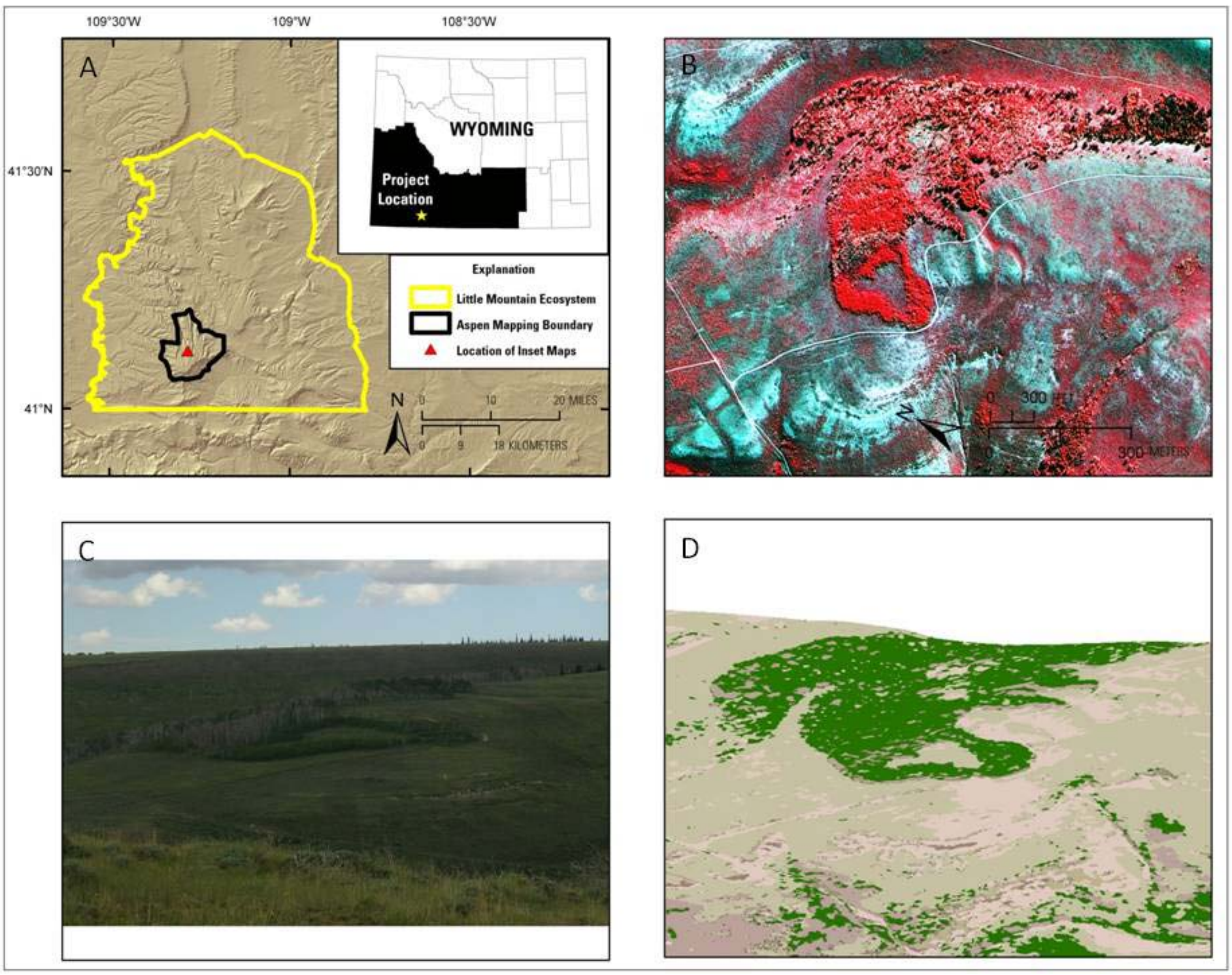


Figure 38. *A*, Vicinity map of the Little Mountain Ecosystem; *B*, 2009 National Agriculture Imagery Project with contrast stretch of aspen patch approximately 100 meters in width; *C*, photograph of aspen patch shown in 38B; and *D*, classified aspen map (green) of 38B draped on digital elevation model; note that the interior of the patch is part of the sagebrush matrix and is not classified as aspen. Graphics and photo by Tim Assal, Arctic Slope Regional Corporation management services, contracted to U.S Geological Survey.

Table 3. Predictor variables pertaining to aspen distribution derived from imagery and those used in the classification and regression tree analysis. Data derived from 30-meter National Elevation Dataset (NED) were not included in the DRAFT model due to the disparity in resolution from the National Agriculture Imagery Project (NAIP) data (1 meter).

Predictor Variable	Description	Source	Included in Final Model
b1	Band 1(blue) of the NAIP imagery	NAIP	Yes
b2	Band 2(green) of the NAIP imagery	NAIP	Yes
b3	Band 3(red) of the NAIP imagery	NAIP	Yes
b4	Band 4(infrared) of the NAIP imagery	NAIP	Yes
pca	Principal Component Analysis (all bands)	NAIP	Yes
imgtex	Image Texture (all bands)	NAIP	Yes
ndvi	Normalized Difference Vegetation Index	NAIP	Yes
rvi	Simple Ratio Vegetation Index	NAIP	Yes
ratio	Ration Vegetation Index	NAIP	Yes
vi	Vegetation Index	NAIP	Yes
elev	Elevation Raster Data Set	NED	No
slope	Slope Raster Data Set	NED	No
aspect	Aspect Raster Data Set	NED	No

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 WLCI 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.

Study Area

The study area was shifted from the west slope of the Sierra Madre Range to the Little Mountain Ecosystem (figs. 35 and 38). Within the Little Mountain Ecosystem, the area surrounding Little Mountain was prioritized to meet monitoring needs while minimizing the amount of data needed to perform the mapping.

Work Accomplished in 2010 and Findings

Training data was collected in July and field locations and photographs were cataloged in a GIS and photo database. This information was used to inform the classification process by identifying woodland areas, as well as discriminating between aspen and conifer patches. Multiple input variables were tested before arriving at the final set of predictor variables to be used (table 3). The draft aspen map was groundtruthed in late summer and used to select effectiveness-monitoring sites.

A subjective evaluation based on information provided by field crews determined that the CART process was successful in identifying aspen distribution, particularly the small aspen patches characteristic of the Little Mountain Ecosystem (figs. 38C and 38D). Furthermore, aspen was readily delineated from conifer stands. Two shortcomings of the current method were identified. First, aspen was overestimated (false positives) in steep draws and canyons, and second, shadows at the edge of aspen stands were misclassified as conifer cover. These areas, however, were minimal and incorporating additional predictors could eliminate or reduce these issues. However, this product fills the data gap of a fine-scale aspen map and was used to support site selection of sampling plots for effectiveness monitoring.

In addition, the predictor variables (table 3) and methodology used in this study can be applied to other areas of the WLCI to map aspen distribution. Given the resolution of the input data (1-m pixels) this method is data intensive and not appropriate to map the entire WLCI. However, this methodology can be applied to localized areas within the WLCI. Ancillary data, such as elevation, aspect, and slope, initially were incorporated into the model. However, it was not feasible to include these variables due to the disparity in resolution (30-m resolution) compared with the image-derived variables (1-m resolution).

Products Completed in FY2010

- Draft classification map of aspen vegetation on Little Mountain to provide baseline information on locations of aspen stands.
- Map used to support other tasks, such as informing sampling design for selecting sampling sites.
- Photo geodatabase, including location and direction of photos, created as part of groundtruthing effort.
- Methodology and covariates completed.
- Used to inform BLM fire-treatment map.

Work Planned for FY2011

The data product being developed for this work activity will be finalized and the accuracy will be quantified in an accuracy assessment. Finalized geospatial products will be distributed to the BLM and interested WLCI partners. Furthermore, USGS will continue to work with its partners to make such products applicable and useful for various applications. A document (USGS report or journal publication) detailing the methodology used will also be produced. The methodology discussed here will be used to quantify aspen cover on the western slope of the Sierra Madre.

Aspen Regeneration Associated with Mechanical Removal of Subalpine Fir

Status

Ongoing

Contact

Patrick J. Anderson; 970-226-9488; *andersonpj@usgs.gov*

Scope and Methods

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 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 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 macroplot size was adjusted from 168 to 78.5 m^2. Each macroplot consisted of three 1-m^2 subplots. Vegetation measurements included stem density, stem size (diameter at breast height), and canopy cover for live and dead aspen, conifers, and serviceberry trees that were greater than 2 m in height; herbivory of aspen and serviceberry trees less than 2 m in height; species composition, foliar cover, and frequency of occurrence for shrubs and herbs; herbaceous biomass; and soil texture and chemistry. Tree canopy cover, stem density and stem diameter, herbivory and soils were recorded at the macroplot level, whereas the other variables were recorded at the subplot level. The ages of conifer trees were estimated by counting annual growth rings on remaining stumps in each macroplot after conifers had been removed.

Percent soil disturbance and litter depth (debris from logging operations) were recorded in 2009. During 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 seedlings were recorded in each macroplot. Species composition and foliar cover of native and invasive herbaceous plant species were recorded within each subplot.

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.

Study Area

The study area is located in the Sierra Madre Range on Medicine Bow National Forest property in Carbon County (fig. 35). The treatment area (fig. 39) 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 the Stock Drive Road.

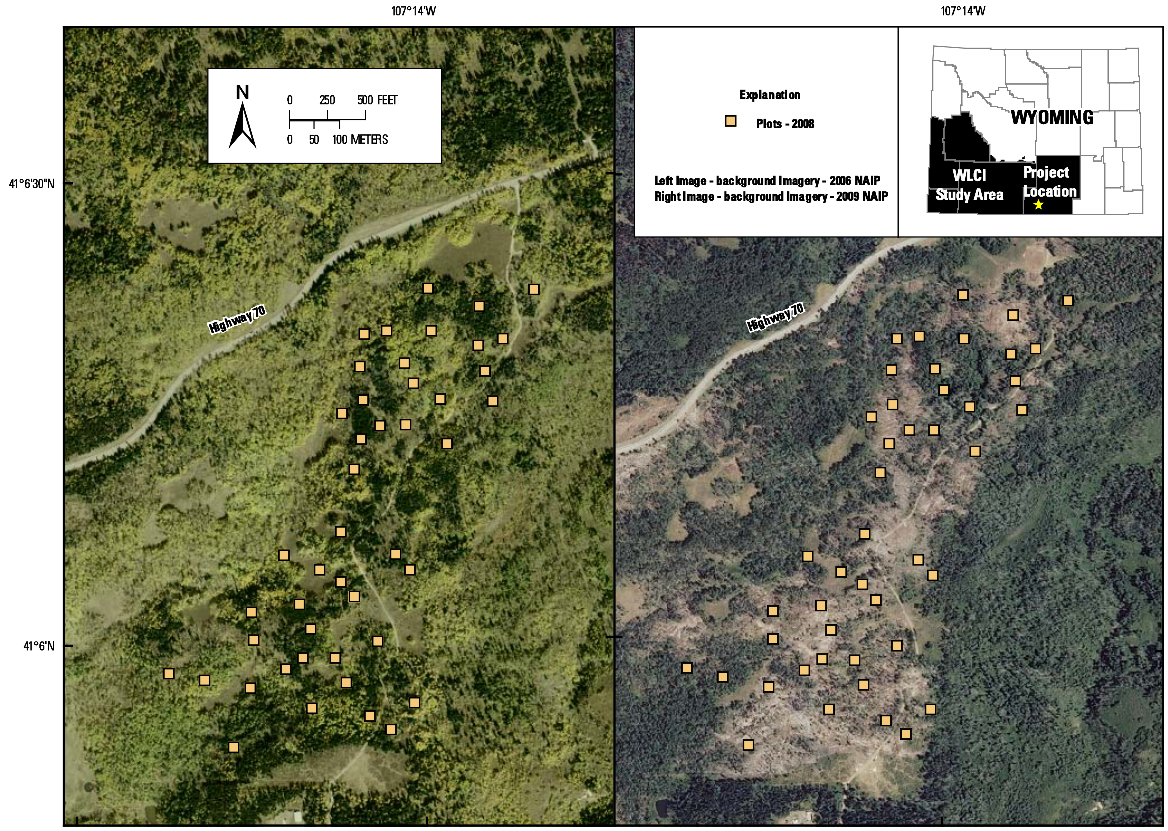


Figure 39. Locations of aspen-treatment plots being monitored for effectiveness of habitat treatments in the Sierra Madre, Medicine Bow National Forest, Carbon County, Wyo.

Work Accomplished in 2010 and Findings

Vegetation measurements were conducted at the same locations sampled during 2009. Annual growth (stem densities and height); extent of browsing by livestock, mule deer, and elk on aspen ramets and serviceberry plants; and conifer seedling recruitment were measured in all macroplots. In addition, each macroplot was photographed with a digital camera. Species composition, percent cover, and occurrence frequency of native and invasive herbs and shrubs were measured in each subplot at all 30 macroplots from which conifers had been removed during 2008.

Aspen ramet recruitment and growth continued to increase at most plots where conifers had been removed. Preliminary analyses indicate that there was less aspen ramet regeneration (number of stems in each macroplot) in plots characterized by larger and denser patches of conifer. Evidence of browsing on aspen ramets and smaller serviceberry shrubs was common in both treated and untreated locations, but more common prior to pretreatment. Preliminary analyses also indicate that herbaceous plant species responses to treatment depended on pretreatment conifer densities and post-treatment disturbances. For example, the post-treatment cover of native herbaceous vegetation was greater where the pre-treatment patches of conifer had been larger and denser than other pre-treatment patches, and percent cover and frequency of invasive forbs were greater in patches where soil disturbance was greatest. Overall management objectives for aspen regeneration are being accomplished. Monitoring activities will continue so that the spatial and temporal response of aspen and related herbaceous plant communities can be evaluated in relation to disturbances associated with conifer removal.

Products Completed in FY2010

- 2010 vegetation dataset with plot photos.

Work Planned for FY2011

Monitoring of aspen, under-canopy vegetation, and invasive species will continue during 2011. Aspen recruitment and growth rates will be calculated for each year following conifer removal, and species composition and distribution of invasive plants will be evaluated at treated and untreated locations. In addition, USGS will continue to manage and analyze data collected from 2008–2010 and present results from these analyses at LPDT meetings.

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

Status

Ongoing

Contacts

Patrick J. Anderson; 970-226-9488; *andersonpj@usgs.gov*
Natasha Carr; 970-226-9446; *carrn@usgs.gov*
Tim Assal; 970-226-9134; *assalt@usgs.gov*

Scope and Methods

Since 1990, more than $2 million has 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. Indeed, 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.

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. 40) across a gradient of conditions and 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

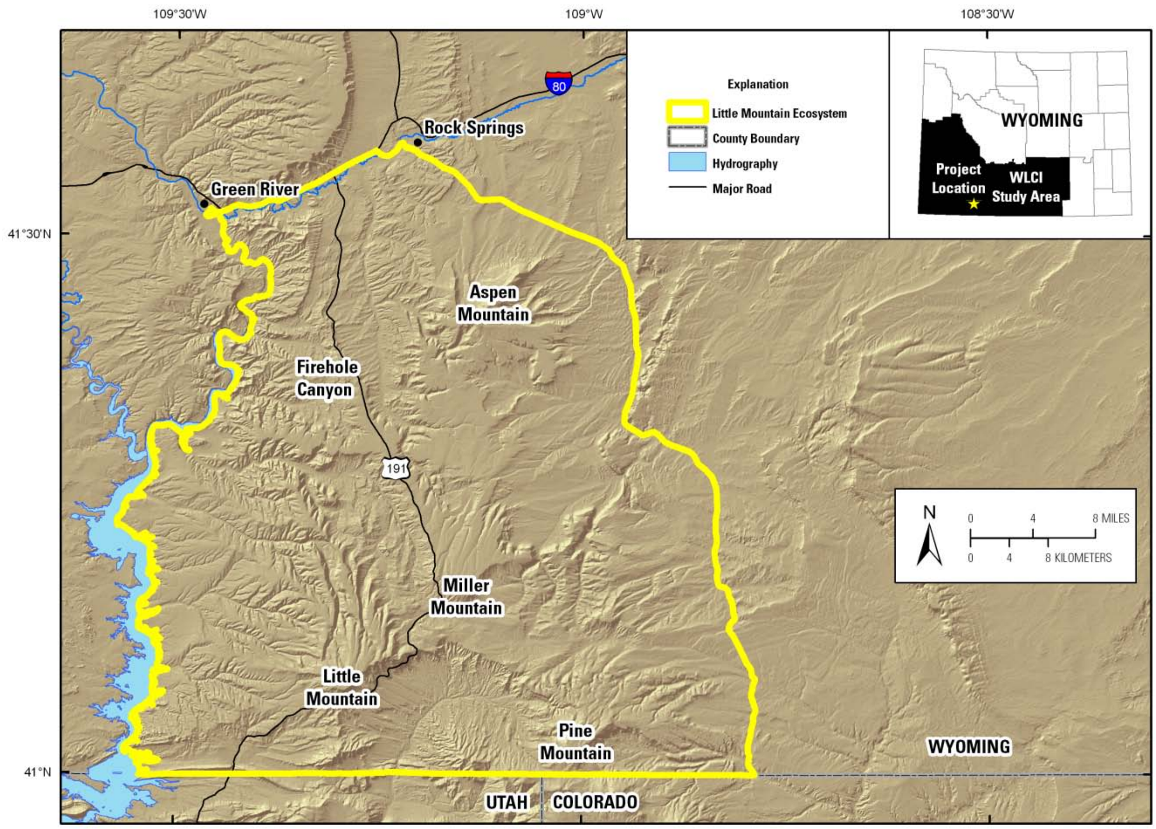


Figure 40. Locations of habitat treatment areas within the Little Mountain ecosystem, Wyoming.

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 LPDT for prioritizing and designing future treatments based on stand condition and conifer encroachment. The USGS is collaborating with the BLM Rock Springs Field Office and the 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 to be evaluated. 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-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 or below high-elevation mountains.

Maps generated with Classification and Regression Tree analysis (see section above, “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 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 (Barnett and others, 2007). For this study the macroplot size was expanded to 2,827 m^2 to accommodate variable tree densities. Each macroplot consists of a center point from which three 4- × 25-m belt transects originate (starting at 5 m from the center point) (fig. 41). Belt transects were located 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 macroplot was used to document tree-size classes that were not observed in belt transects, and terrain measurements (aspect, percent slope, and elevation).

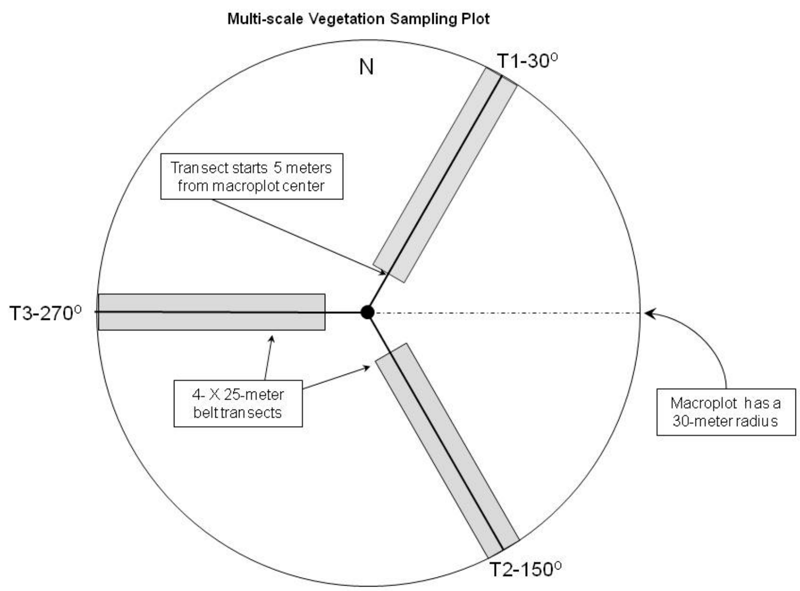


Figure 41. Multi-scale plot design used to collect vegetation measurements (2,827-meter^2 area circle and three 4- × 25-meter belt transects: T1, T2, and T3 located at 30°, 150°, and 270°, respectively, relative to true north). Adapted from Barnett and others (2007).

Objectives

- Evaluate spatial and temporal aspen regeneration, herbivory, and ecohydrology on burned and unburned plots.
- Evaluate effects of big-game herbivory on aspen and adjacent serviceberry.
- Correlate stand dynamics with use of burned and unburned aspen stands by migrant songbirds.
- Compare aspen regeneration associated with burning to the mechanical removal of aspen to other treated aspen stands in the WLCI area.

- Develop an aspen index based on sucker density and growth rate.
- Develop geospatial products that show aspen condition to support prioritization of restoration projects.

Study Area

The study area is associated with the Little Mountain Ecosystem south of Rock Springs, Wyo. (fig. 35). 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 2010 and Findings

During FY2010, this study was expanded to evaluate relationships between structure and composition of, and herbivory on, aspen at different ecohydrological settings. A suite of vegetation and terrain measurements were made in vegetation-sampling plots at 60 locations across the Little Mountain Ecosystem. The sampling plots were randomly located in pure aspen stands and at locations with varying densities of aspen and conifer species across a gradient of ecohydrological settings.

Products Completed in FY2010

- Initial products will be forthcoming in FY2011.

Work Planned for FY2011

Data collected during 2010 will be analyzed to compare the abundance, growth rate, and herbivory of aspen ramets between different ecological and hydrological settings and conifer densities. In addition, increment cores of aspen and conifer species will be collected at previously sampled locations. This information will be used to determine age structure of each stand sampled and to estimate long-term trends in aspen recruitment and encroachment patterns of conifers in the Little Mountain Ecosystem. Data will be used to validate aspen maps generated from the CART assessments and BLM fire maps.

Use of Aspen Stands by Migratory Birds for Effectiveness Monitoring

Status

Ongoing

Contacts

Natasha Carr; 970-226-9446; *carn@usgs.gov*
Patrick J. Anderson; 970-226-9488; *andersonpj@usgs.gov*

Scope and Methods

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. 35). 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.

Work Accomplished in 2010 and Findings

In FY2010, all bird surveys were completed, all data were entered, and preliminary data summaries were conducted. Field crews observed 112 bird species using aspen and riparian stands of the Green River Basin: 86 species were observed in aspen stands, and 82 species were observed in riparian stands. Fifty-eight percent of the observed species were songbirds (passerines), of which 36 were Neotropical migratory species (winter south of the United States), and 30 of which were short-distance migratory species (winter in the southern United States). The most abundant Neotropical migratory species were Wilson’s warbler (*Wilsonia pusilla*), yellow-rumped warbler (*Dendroica coronata*), orange-crowned warbler (*Vermivora celata*), house wren (*Troglodytes aedon*), Townsend’s warbler (*Dendroica townsendi*), western tanager (*Piranga ludoviciana*), western wood-pewee (*Contopus sordidulus*), Cassin’s vireo (*Vireo cassinii*), Plumbeous Vireo (*V. plumbeus*), and

Yellow-rumped warbler (left) and Hammond's flycatcher (right) caught and banded in aspen stands of the Little Mountain Ecosystem, fall 2009. Photo credits: Tasha Carr, Ecologist, U.S. Geological Survey.

Macgillivray's warbler (*Oporornis tolmiei*). Four species of the neotropical migrants do not breed in Wyoming, indicating that the aspen and riparian stands in this area are important to migrants at a regional scale. The results of this study represent the first documentation of fall migrant use of aspen stands in Southwest Wyoming.

Products Completed in FY2010

- Dataset of species observed using aspen and riparian stands in the Green River Basin, including abundance and migratory status.

Work Planned for FY2011

In FY2011, analysis of the 2010 datasets will be completed and a final report will be produced.

Muddy Creek Synoptic Study

Status

New in FY2010

Contact

Melanie Clark; 307-775-9163; *mlclark@usgs.gov*

Scope and Methods

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) have listed as impairments to aquatic life in Muddy Creek. 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.

A synoptic to simultaneously sample stream-water chemistry, basin sediments, and macroinvertebrates was conducted in the Muddy Creek drainage basin during summer 2010 to characterize conditions within that 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, 1997–2010). 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).

Objectives

- Conduct 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. 42). 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 2010 and Findings

The synoptic study for the Muddy Creek drainage basin was conducted from June 27 to July 1, 2010. This work integrated data collection of water-quality, basin-sediment, and macroinvertebrate samples. Sampling sites were located on Muddy Creek from the headwaters area downstream to near Baggs, Wyo. Samples also were collected from three of Muddy Creek’s tributaries: Cow Creek, Wild Cow Creek, and Cherokee Creek.

Water-quality samples were collected for measuring levels of major ions and selected trace elements (including mercury and selenium). Samples of basin sediments included bed-sediments from within the stream channel and from upland soils. Aquatic and terrestrial insects also were collected. The occurrence of selenium in the various media and how it relates to basin characteristics, including geology, is of particular interest to USGS scientists.

Preliminary results indicate that concentrations of selenium, the primary constituent of concern, in the Muddy Creek Basin were spatially variable at the time of data collection. Concentrations of dissolved selenium in Muddy Creek ranged from 3.9 µg/L in the upper basin to 1.1 µg/L in the mid-basin. Concentrations of dissolved-solids in Muddy Creek ranged from 393 milligrams per liter (mg/L) in the upper basin to 1,020 mg/L near Baggs, Wyo. Compared to the Muddy Creek mainstem, the tributaries generally had greater concentrations of dissolved-solids and lower concentrations of selenium.

Products Completed in FY2010

- Project web page: *http://wy.water.usgs.gov/projects/muddy_creek/index.htm*.
- Water-chemistry data made publicly available on the National Water Information System Web Interface (NWISWeb) at *http://nwis.waterdata.usgs.gov/wy/nwis/qwdata*.

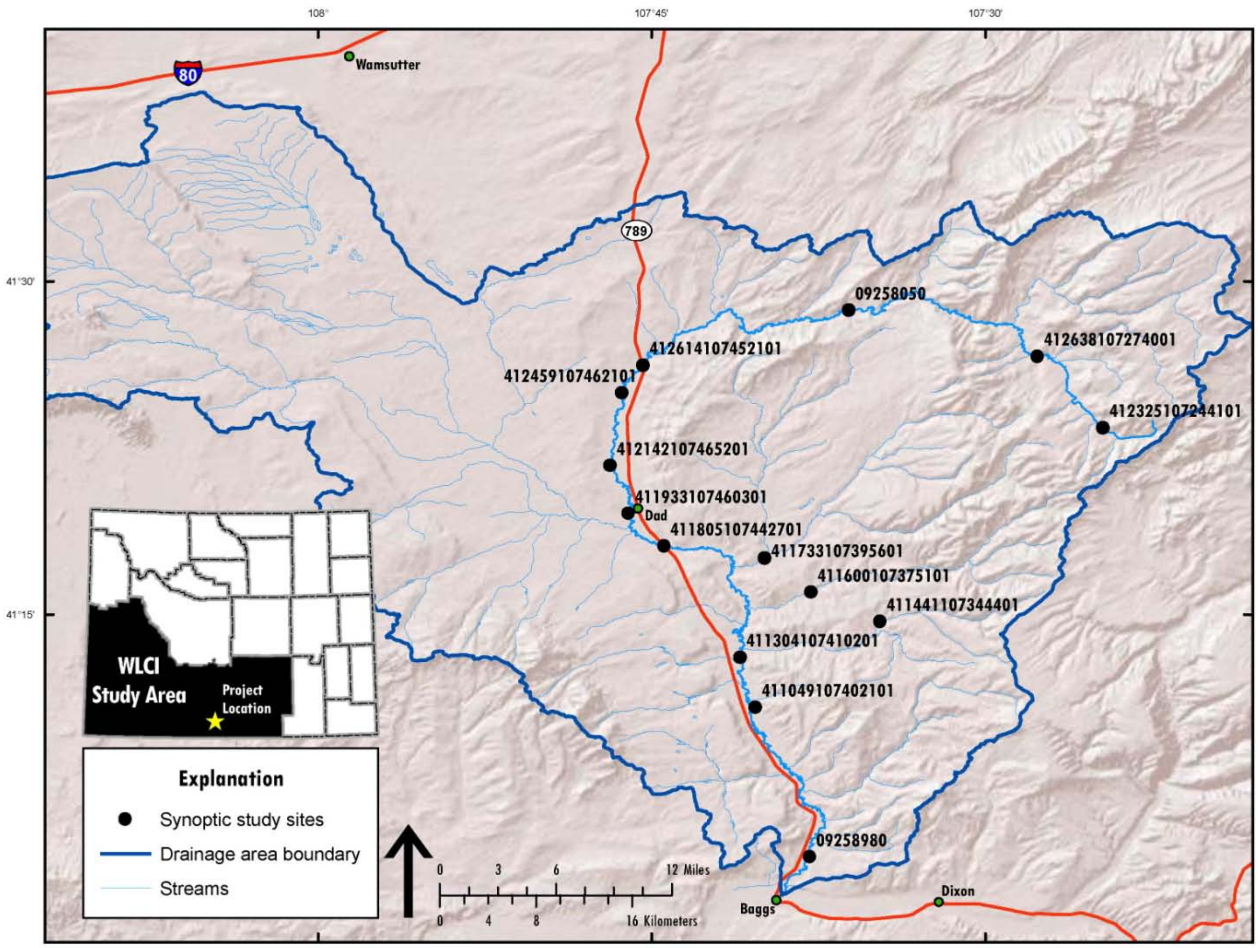


Figure 42. Sampling sites for the 2010 synoptic study in the Muddy Creek basin.

Muddy Creek's upper basin, looking upstream from Muddy Creek above Olson Draw, near Dad, Wyo. (streamflow gaging station 09258050). Photo credit: Melanie Clark, Hydrologist, U.S. Geological Survey.

Work Planned for FY2011

Proposed work for FY2011 includes compilation and review of the synoptic study data collected in FY2010. If additional data needs are identified, a small follow-up field effort may be conducted during summer 2011. Data synthesis for an interdisciplinary product will be conducted as staff time and resources allow.

Summary of FY2010 Activities for Mechanistic Research of Wildlife

Mechanistic research of wildlife can elucidate the relationships between the habitats and distributions of important and protected species and their responses to changes in land use (particularly energy development) and to other factors. The 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, a highly sought after (thus, economically important) game species in Wyoming.

In FY2010, the pygmy rabbit study continued with validating two existing distribution maps for the pygmy rabbit and initial development of a new habitat-association model. Collection of pre-treatment pygmy rabbit site-occupancy data began in the Non-Pressurized Lands gas field (slated for development southwest of and adjacent to the Jonah Field). Collection of data for vegetation, pygmy rabbits, and sagebrush-obligate songbirds also began in a region of the WLCI study area for which USGS acquired Light Detection and Ranging (LiDAR) imagery data. Analysis is ongoing for each of these project components. Finally, development of a pygmy rabbit survival/demography study was initiated in conjunction with the University of Wyoming.

The sage-grouse studies in FY2010 continued with examination of long-term population trends and expanded into a study of habitat use and prioritization. Two manuscripts associated with this work were accepted for peer-reviewed publication: one manuscript assessed the protocols underlying long-term sage-grouse monitoring and the other demonstrated highly correlated long-term trends between sage-grouse and cottontail rabbits across Wyoming. Another manuscript addressing interseasonal movement distances in Wyoming sage-grouse also was submitted for publication.

In FY2010, work on the songbird study entailed identifying several important patterns with respect to songbirds and the intensity of energy development in southwest Wyoming. Notably, both songbird abundance and nesting productivity were negatively influenced by increased density of well pads and increased proximity to the nearest well pad. Follow-up work will help determine why nest predation rates increased with energy development in order to better inform potential management and mitigation efforts for non-game sagebrush-obligate birds.

The mule deer study continued with phase II, which entails assessing how energy development affects use of migration routes and behavior of ungulate species. Previous work for this project revealed that the deer exhibit a high level of fidelity to stopover sites during their spring and fall migrations; thus, in FY2010, a phenological analysis was conducted to assess the forage value of these sites during

Pygmy rabbit burrow, located on lands under the jurisdiction of the Bureau of Land Management's Kemmerer Field Office. Photo credit: Steve Germaine, Ecologist, U.S. Geological Survey.

stopover use. Stopover use consistently occurred 44 ± 6 days (mean ± standard deviation (SD)) before peak green-up, suggesting that the timing of stopover use was tied to phenological changes along the elevational migration routes. These findings suggest that migrating ungulates require access to stopover locations along the elevational migration routes at time periods that coincide with specific stages in plant phenology.

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

Pygmy Rabbit

Status

Ongoing

Contact

Stephen Germaine; 970-226-9107; *germaines@usgs.gov*

Scope and Methods

Several key information gaps must still be filled to effectively manage for pygmy rabbit conservation. To address these gaps, USGS scientists are collaborating with biologists at the WYNDD, Wyoming Chapter of TNC, BLM, and the University of Wyoming to (1) validate existing distribution maps for pygmy rabbits in Wyoming; (2) develop a model that characterizes sites occupied and unoccupied by pygmy rabbits with new information regarding anthropogenic features on the landscape; (3) evaluate the effects of new gas field development on pygmy rabbits; and (4) determine whether LiDAR data can help predict pygmy rabbit distributions. Collectively, this work will provide resource managers new information about pygmy rabbit distributions, habitat relationships, and responses to energy development.

In 2008–2009, 189 sites were surveyed for pygmy rabbits across and near the WLCI region (fig. 43) to generate data for use in validating existing pygmy rabbit range maps developed by WYNDD and TNC, and to develop a new habitat association model for the pygmy rabbit. The USGS GIS analysts are helping to complete both of these tasks. Also in FY2010, pre-development collection of site-occupancy data was initiated on the Non-Pressurized Lands (NPL) gas field (slated for development southwest of and adjacent to the Jonah field) and at three adjacent control sites (fig. 44). Analyses of the 2010 data will be used to guide survey planning for 2011. Finally, LiDAR data were acquired for the region outlined in red (fig. 43). From these data, vegetation structure will be derived and related statistically to survey data for pygmy rabbits and songbirds that inhabit sagebrush habitat.

Objectives

- Validate two existing range maps and generate a new habitat-associations model for the pygmy rabbit.
- Collect pre-development pygmy rabbit site-occupancy data on the NPL gas field.
- Complete analysis of LiDAR-derived pygmy rabbit site-occupancy data.
- Develop a pygmy rabbit demography study.

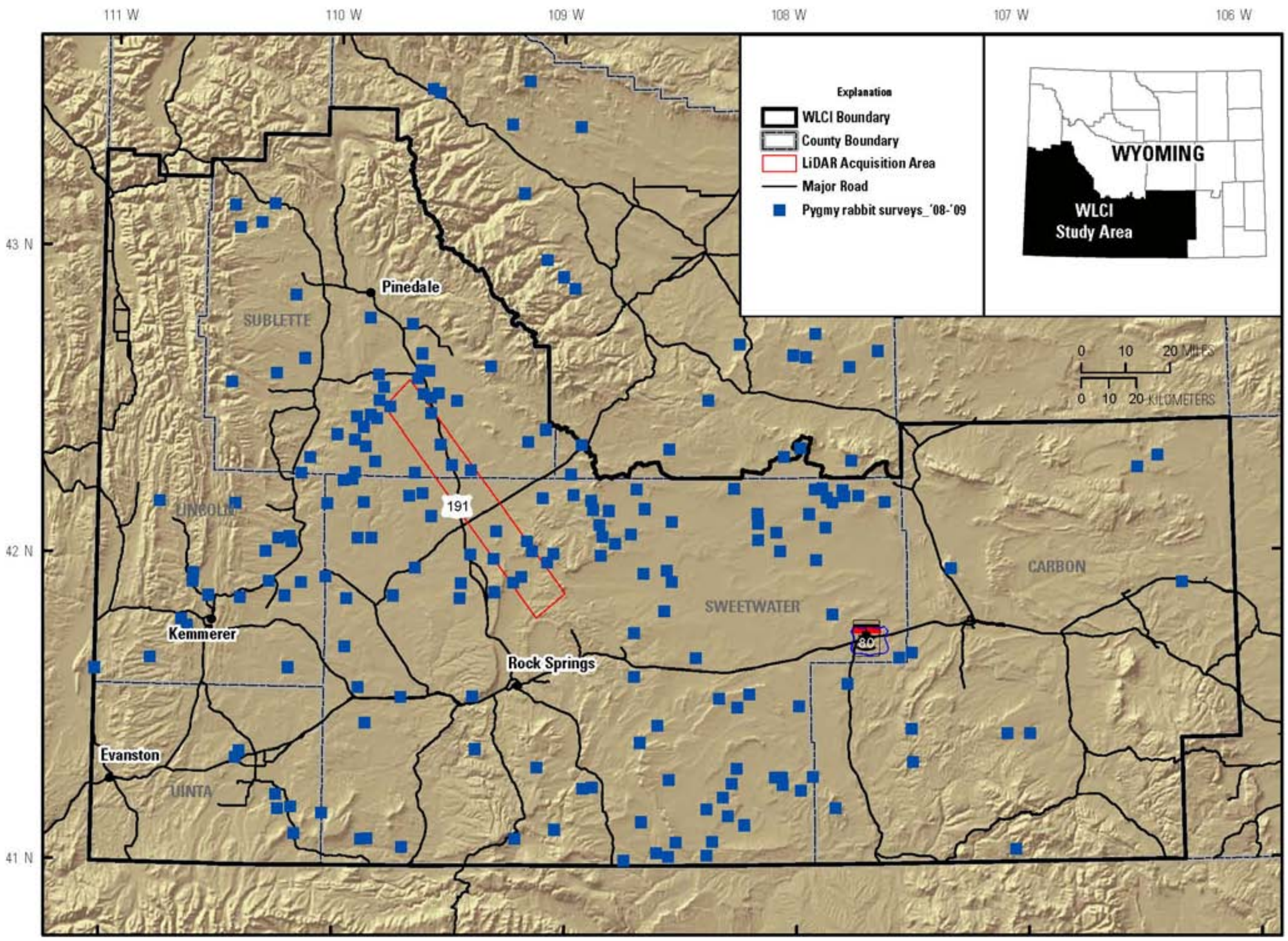


Figure 43. Location of pygmy rabbit surveys (blue squares) conducted throughout southwestern Wyoming for use in validating pygmy rabbit habitat models developed by USGS, new model development, and Light Detection and Ranging imagery (LiDAR) based analyses (LiDAR data acquired for the area outlined in red).

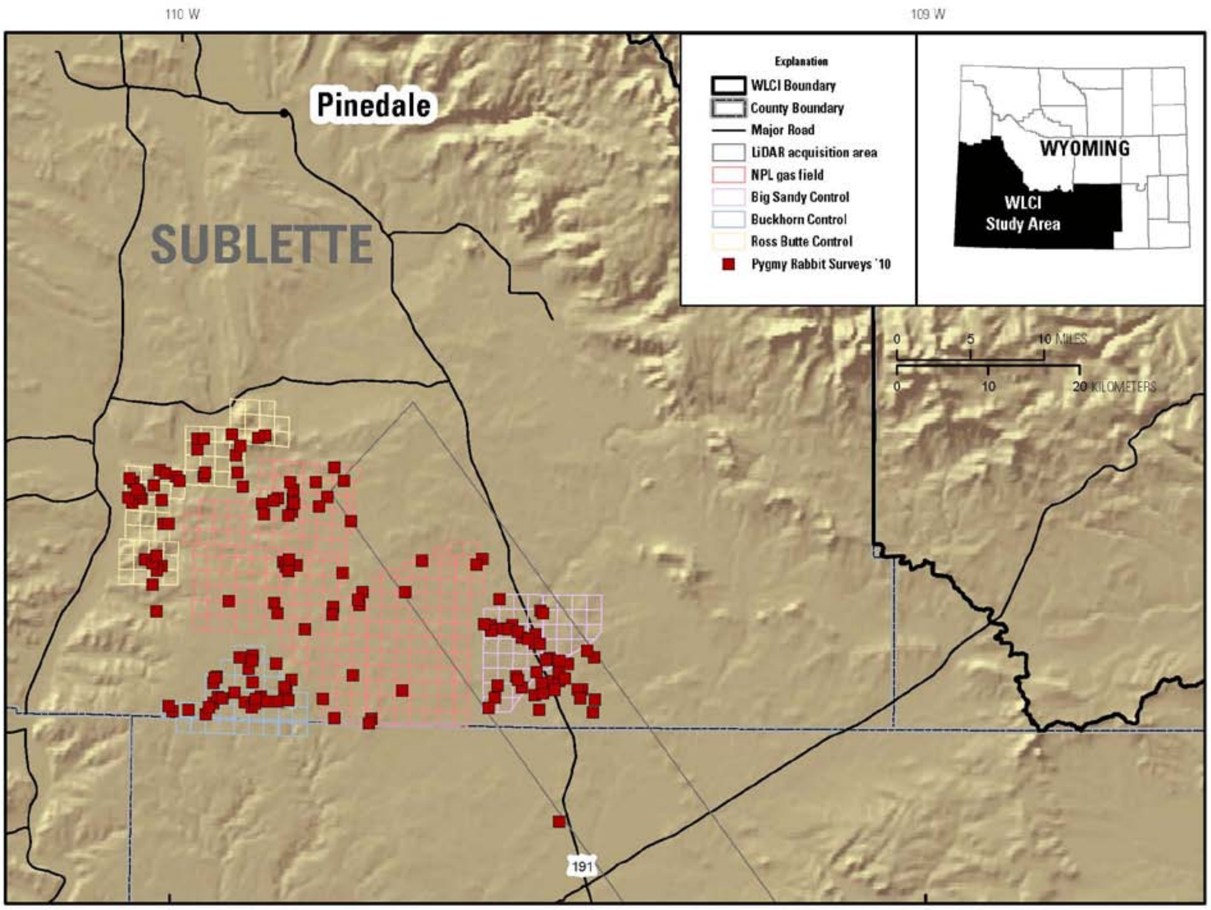


Figure 44. Pygmy rabbit survey sites (red squares) associated with the USGS new gas field and Light Detection and Ranging (LiDAR) data acquired for the polygon (outlined in gray).

Study Area

The pygmy rabbit model validation and habitat modeling research conducted by USGS encompasses all of the predicted pygmy rabbit range in Wyoming, which extends beyond the WLCI boundary (including parts of Park County near Cody). Energy, LiDAR, and demography research are occurring entirely within WLCI. The focal habitat type is sagebrush. Ongoing fieldwork is concentrated in Sublette and Sweetwater Counties. Figure 43 illustrates where in the WLCI region and immediately outside of it pygmy rabbit surveys were conducted for the model validation and habitat research (not shown are the sampling sites near Cody, Wyo.).

Work Accomplished in 2010 and Findings

Work to validate TNC's pygmy rabbit range map and develop a new pygmy rabbit habitat model continued. Pygmy rabbit surveys were conducted at 129 sites on the NPL and adjacent lands, and at 43 sites in the area for which LiDAR data were acquired. Vegetation sampling surveys were conducted at 104 sites in support of the LiDAR work. Also, a map displaying the current potential for wind-energy development and pygmy rabbit distributions was completed. The map indicates that the potential for wind-energy development to overlap pygmy rabbit habitat is very low. Furthermore, in 2010 pygmy rabbit occupancy rates near the NPL gas field and in the LiDAR study area were very low (22.6 and 16.7 percent, respectively).

Products Completed in FY2010

- Germaine, S., 2010, Using LiDAR to measure sagebrush habitat structure in southwest Wyoming, presented to the WLCI Executive Committee, January 2010, Rock Springs, Wyo.
- Map of pygmy rabbit distributions and potential for wind-energy development.
- LiDAR dataset: ground-truthed vegetation data, and survey data for pygmy rabbits and songbirds.

Work Planned for FY2011

In 2011, a report describing the validation of the WYNDD and TNC pygmy rabbit maps will be completed and a journal manuscript presenting the new pygmy rabbit habitat model will be submitted for publication. The LiDAR-based analyses will be conducted and presented to the WLCI EC. Surveys in the NPL project area will be continued, and a University of Wyoming graduate student will be hired to begin the demography study of pygmy rabbits inhabiting gas fields.

Sage-Grouse

Status

Ongoing

Contacts

Brad Fedy; 970-226-9456; *fedyb@usgs.gov*
Cameron Aldridge; 970-226-9433; *aldridgec@usgs.gov*

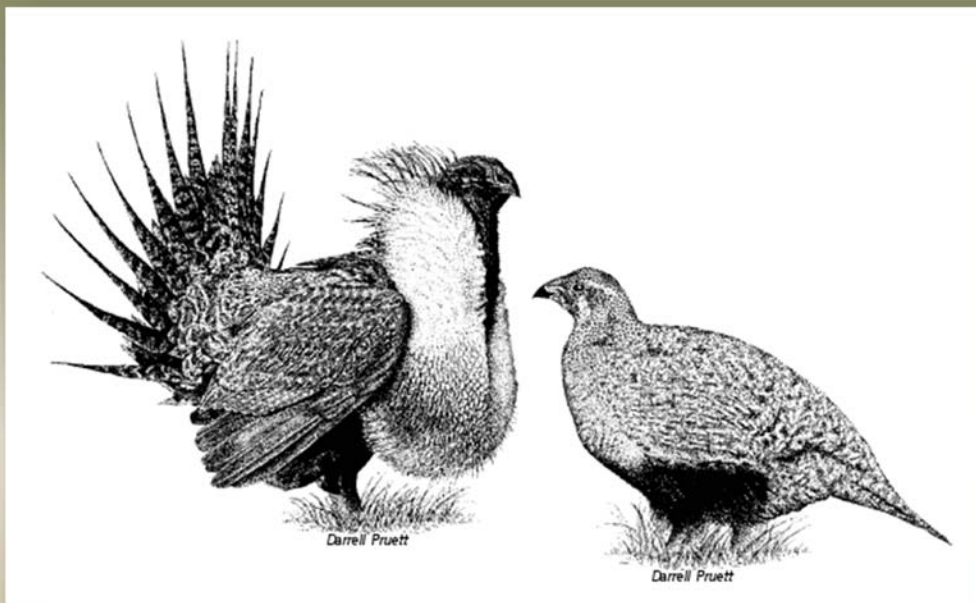
Scope and Methods

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 will inform research for 2011 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 will focus on developing predictive habitat-selection models for sage-grouse.

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 “Long-term Monitoring” section on “Remote Sensing and Vegetation Inventory and Monitoring”) 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.



Sage-Grouse male (left) and female (right). Darrell Pruett, Illustrations.

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 2010 and Findings

Sage-grouse interseasonal movements—Animals can require different habitat types throughout their annual cycles. When considering habitat prioritization, it is important to explicitly consider habitat requirements throughout the annual cycle, particularly for species of conservation concern. Understanding annual habitat requirements begins with quantifying how far individuals move across landscapes between key life stages to access required habitats. Individual interseasonal movements for greater sage-grouse were quantified by using a compilation of many radio-telemetry studies spanning the majority of the species distribution in Wyoming. The sage-grouse is currently a candidate for listing under the U.S. Endangered Species Act, and Wyoming contains some of the largest expanses of sagebrush habitat that support a significant proportion of remaining sage-grouse populations. Sage-grouse use distinct seasonal habitats throughout their annual cycle for breeding, brood rearing, and wintering. In Wyoming, average movement distance from nest sites to summer/late brood-rearing locations was 7.3 km (standard error (SE) = 0.3 km; n = 673 individuals), and the average distance moved from summer sites to winter locations was 14.7 km (SE = 0.6 km; n = 538 individuals). Average nest-to-winter movement distance was 12.9 km (SE = 0.6 km; n = 332 individuals). Remarkable variation was documented in the distances moved within and among sites across Wyoming, with some individuals remaining year-round in the same vicinity and others moving more than 50 km between locations used for different life stages. This underscores the importance of addressing all seasonal habitat needs in conservation efforts for greater sage-grouse.

Sage-grouse and cottontail population cycles—Animal species across multiple taxa demonstrate multi-annual population cycles, which have long been of interest to ecologists. Correlated population cycles between species that do not share a predator-prey relationship are particularly intriguing and challenging to explain. The annual population trends of greater sage-grouse (*Centrocercus urophasianus*) and cottontail rabbits (*Sylvilagus* sp.) across Wyoming were investigated to explore the possibility of correlations between unrelated species over multiple cycles, very large spatial areas, and relatively southern latitudes in terms of cycling species. Sage-grouse lek counts and annual hunter harvest indices from 1982 to 2007 were analyzed. The analysis shows that greater sage-grouse (currently designated as a candidate for protection under the U.S. Endangered Species Act), and cottontails have highly correlated cycles (r = 0.77) (fig. 45). Possible mechanistic hypotheses are being explored to explain the synchronous population cycles. This research highlights the importance of control populations in both adaptive management and impact studies. Furthermore, the results demonstrate the functional value of these indices (lek counts and hunter harvest) for tracking broad-scale fluctuations in the species. This level of highly correlated long-term cycling has not previously been documented between two non-related species, over a long time-series, very large spatial scale, and within more southern latitudes.

Products Completed in FY2010

- Fedy, B.C., and Doherty, K.E., 2011, Population cycles are highly correlated over long time series and large spatial scales in two unrelated species: Greater sage-grouse and cottontail rabbits: Oecologia, v. 165, p. 915–924.
- Fedy, B.C., and Aldridge, C.L., 2011, Long-term monitoring of sage-grouse populations—The importance of within-year repeated counts and the influence of scale: Journal of Wildlife Management, v. 75.
- Fedy, B.C., 2010, Sage-grouse in Wyoming: Long-term trends and seasonal habitat use, in Wyoming Landscape Conservation Initiative Executive Committee Meeting, October 2010, Saratoga, Wyo. [presentation]
- Fedy, B.C., 2010, Sage-grouse in Wyoming—Long-term trends and seasonal habitat use, presented to the U.S. Bureau of Land Management, November 2010, Rawlins, Wyoming.
- 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., in review, Interseasonal movements of sage-grouse in Wyoming: submitted to the Journal of Wildlife Management.
- In preparation: Fedy, B.C., and Aldridge, C.L., Influence of climate and weather on long-term fluctuations in Wyoming sage-grouse.

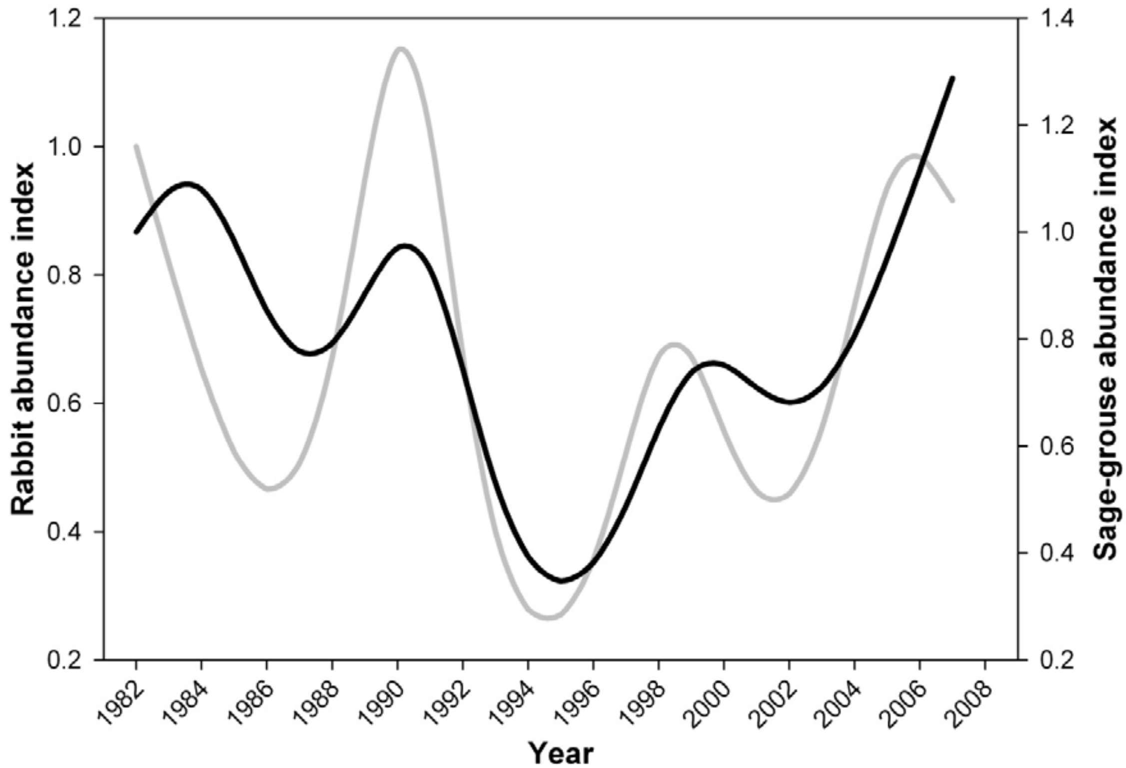


Figure 45. Trend estimates for sage-grouse, based on male lek counts (black line) and cottontail rabbits, based on hunter-harvest records (gray line), in Wyoming from 1982–2008, estimated by using generalized additive models.

Work Planned for FY2011

Major efforts in 2011 will focus on developing predictive habitat-selection models for sage-grouse in WLCI and across Wyoming. In FY 2011, completion of analyses and manuscript preparation are anticipated. In addition, the manuscript on climate and weather influences on sage-grouse trends that was initiated in FY2010 will be completed and submitted to a peer-reviewed journal. Progress will continue on developing a time-specific well-dispersion data set; once completed, analyses of the impacts of energy development on long-term sage-grouse trends can be conducted.

In addition, analyses comparing the utility of the newly developed maps of sagebrush cover components (see “Remote Sensing for Vegetation Inventory and Mapping” under “Long-term Monitoring”) to other more traditional cover-type mapping products will be completed for predicting wildlife-habitat relationships in Wyoming. Specifically, spatial datasets have been generated to summarize habitat characteristics from USGS sagebrush mapping products, as well as from products generated from Landfire, NLCD, ReGap, and from the Wyoming Geographic Science Center cover map product. Using a dataset consisting of over 700 nest locations from 5 different study areas within the WLCI region, assessments will be conducted to determine how well each product predicts wildlife habitat.

Finally, recently developed products delineating changes in components of sagebrush cover (Homer and others, unpubl. data; Xian and others, 2011) will be used to assess whether the changes in habitats surrounding leks correlate with observed sage-grouse population trends from 1985–2006. Maps of bi-annual changes in sagebrush components in areas surrounding lek locations will be summarized for the southwestern portion of the WLCI region, and patterns related to annual peak counts of male sage-grouse at leks will be analyzed.

Songbird Community

Status

Ongoing: phase II completed, phase II to begin in FY2011

Contact

Anna D. Chalfoun; 307-766-6966; *achalfou@uwyo.edu*

Scope and Methods

Songbird species that breed within western North American sagebrush habitats have been showing marked declines, commensurate with ongoing changes to sagebrush steppe systems. Little is known about how sagebrush-obligate songbirds are influenced by energy development, although such disturbances have the potential to increase physiological stress, alter habitat selection, disrupt nesting, and reduce survival and reproduction. This study is designed to quantify songbird community structure (abundance, diversity) and reproductive success across gradients in energy development intensity (well densities/km^2).

One-day-old Brewer's Sparrow. Photo credit: Michelle Gilbert, Department of Zoology and Physiology, University of Wyoming.

The songbird community was surveyed via point counts with distance sampling. Nests of all songbird species present were located and monitored for nesting productivity, variation in clutch size, hatching success, and abandonment rates. Morphological measurements of nestlings at a sub-set of nests provided an index of offspring quality and likelihood of post-fledging survival. Relevant habitat characteristics (for example, shrub cover, height and density, and shrub condition) were measured at each point count and nest location for evaluating possible habitat-disturbance interactions.

Objectives

- Evaluate the influence of energy development on the non-game bird community within sagebrush habitats of the Green River Basin, Wyo.
- Measure avian community structure (abundance, diversity) and productivity (nest success) across gradients of energy development intensity (well-pad density).

Study Area

Study areas were established across gradients in well density within three energy-development fields located in Sublette County, southwestern Wyoming: the Jonah Field, the Pinedale Anticline, and the Labarge Oil Field (fig. 46). All work took place within sagebrush habitats.

Work Accomplished in 2010 and Findings

During FY2010, final analyses were completed, results were presented at several state and national scientific conferences, and the M.Sc. student conducting the work completed and defended her thesis. The first manuscript from this work was accepted by the Journal of Wildlife Management, and another is in preparation for submission to the Ecological Applications journal.

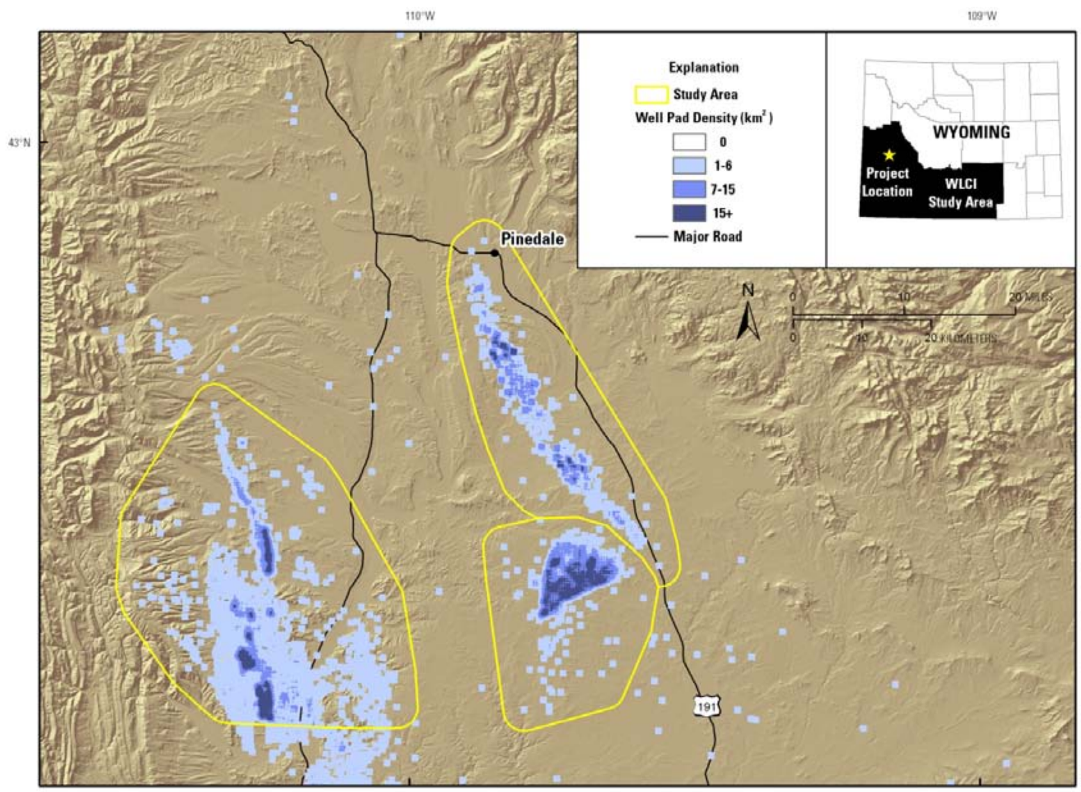


Figure 46. Three energy-development areas where songbird sampling occurred; the left polygon is the LaBarge Field, the upper right polygon is the Pinedale Anticline, and the lower right polygon is the Jonah Field. Colored squares within the study areas illustrate well-pad densities per square kilometer.

The relative abundance of the Brewer's sparrow (*Spizella breweri*) and sage sparrow (*Amphispiza belli*) (after correcting for detection probability), but not the sage thrasher (*Oreoscoptes montanus*), decreased with well density and proximity to the nearest well pad. Approximately 90 percent of nest failures were due to nest predation. For all three sagebrush-obligate species, the probability of daily nest success decreased as well density and proximity to the nearest well pad increased, suggesting greater nest-predation rates with greater densities of energy development (fig. 47). Nestling mass of the largest study species, the sage thrasher, also decreased with increasing well density, suggesting potential food limitation with more energy development. Shrub vigor (percent live crown, an index of condition) decreased slightly with proximity to the nearest well pad, especially in the natural-gas fields.

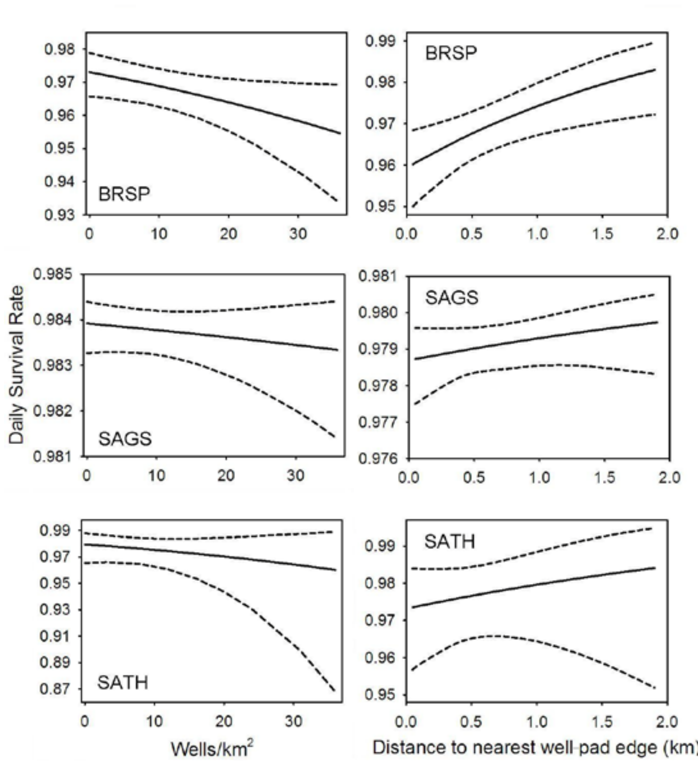


Figure 47. Daily survival rates (DSR) of Brewer's sparrow (BRSP), sage sparrow (SAGS), and sage thrasher (SATH) nests *A*, decreased with increasing well density and B, decreased with increasing proximity to the nearest well-pad edge. Solid lines represent DSR estimated by using beta values from best-fit energy development models; dashed lines represent 95 percent confidence intervals.

Products Completed in FY2010

- GIS maps of study area and locations of point counts and nests.
- Dataset consisting of avian abundance, diversity, nest success, nestling quality, habitat, and information on distance from and extent of disturbance.

- Gilbert, M., 2009, Influence of energy development on sagebrush-obligate songbirds in southwestern Wyoming, *in* Wyoming Wildlife Society annual meeting, Sheridan, November, 2009 Wyo., (awarded best student presentation). [presentation]
- Gilbert, M., 2010, Influence of energy development on sagebrush-obligate songbirds, *in* Joint Ornithological Conference, February, 2010, San Diego, Calif. [presentation]
- Gilbert, M., 2010, Demographic responses of sagebrush-obligate songbirds to energy development in western Wyoming, *in* The Wildlife Society Annual Meeting, October, 2010, Snowbird, Utah. [presentation]
- Gilbert, M., 2010, Demographic responses of sagebrush-obligate songbirds to oil and natural gas development in western Wyoming: Laramie, Wyo., University of Wyoming, M.Sc. thesis, 72 p. Online at *http://www.uwyo.edu/wycoopunitsupport/docs/Gilbert%202010%20Thesis%20songbirds%20energy%20development.pdf*.
- Gilbert, M., and Chalfoun, A.D., 2011, Energy development affects populations of sagebrush songbirds in Wyoming: Journal of Wildlife Management, v. 74, no. 4., p. 816–824.
- Gilbert, M., and Chalfoun, A.D., Nest predation and food limitation as potential drivers of sagebrush songbird declines within energy development fields (in preparation).

Work Planned for FY2011

During FY2011, the study design will be finalized for follow-up research that focuses on understanding the mechanisms underlying the lower songbird nest success associated with greater densities of energy development observed during Phase I of this study. The first field season for Phase II will take place during May–August 2011. Data will be collected to test alternative hypotheses as to why predation rates at songbird nests were elevated where densities of natural gas wells and proximity to the nearest well pad were greater during 2008 and 2009. Specifically, species of major nest predators will be identified via 24-hour nest monitoring with infrared cameras, nest-predator abundance across gradients of well-pad density will be ascertained, and the interactions between nest concealment, energy development, and nest predation will be examined. In fall of 2011, preliminary analyses will be conducted, preliminary results will be presented, and preparations will be made for 2012 data-collection efforts.

Mule Deer

Status

Ongoing: phase II (identifying threshold levels of development) will be completed in early FY2012

Contact

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

Scope and Methods

As habitat loss and fragmentation increase across ungulate ranges, identifying and prioritizing migration routes for land-use planning and conservation has taken on a new urgency. In phase I of this work, a general framework was created to (1) provide a probabilistic estimate of the migration routes of a sampled population, (2) identify which segments of the route function as foraging and resting areas or primarily as movement corridors, and (3) indicate which routes are most important based upon their proportional use by the sampled population. This approach has been applied to migratory mule deer populations that winter near the Atlantic Rim and Pinedale Anticline Project areas. 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 in long-distance migrations of avian taxa. In addition, phenological analyses indicate that mule deer use stopovers during their spring migrations to match the timing of plant phenology along elevational migration routes.

Overall, the work of this project to date has indicated that migrating ungulates derive considerable foraging benefit from the habitats through which they migrate. Although migrating ungulates are able to navigate through habitats that have some level of development (for example, fig. 48), the levels of development (all types) at which ungulate migration routes become compromised is unknown. In particular, it is not known when threshold levels of development are met or exceeded (Frair and others, 2008; Saunders and others, 1991). This is an important research need because it strongly affects both the efficiency and necessity of on-the-ground conservation measures aimed at altering development to sustain migration routes. An understanding of threshold levels of development (all types) will allow resource managers to properly manage Wyoming's ungulate populations while designing for sustainable energy development.

During previous studies by the Wyoming Cooperative Fish and Wildlife Research Unit, ungulate-movement data were collected with a GPS from radio collars on mule deer, elk, moose (*Alces alces*), and pronghorn (approximately 300 animals) using migration routes that overlap key energy development areas within the WLCI region. 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. The overall approach to evaluating threshold levels of development is to quantify attributes regarding how individual animals use migratory routes (for example, speed of travel, time spent in stopovers, route fidelity), and then to investigate whether these behavioral patterns are altered along routes where development levels are high. Behavioral-response variables that will be derived from GPS-tracked movements include duration and timing of migration, route fidelity, percent time spent in stopover areas, and proportional use by the sampled population. After evaluating the migratory behavior of marked individuals along each route, GIS layers for roads, well pads, and other disturbances will be used to score the level of development along each route and ascertain whether development influences the use of corridors by migrating ungulates. Several GIS disturbance layers already have been tested. This analysis will demonstrate whether ungulates move faster through highly developed areas or spend less time stopping over in them. The analysis also may be useful in determining whether ungulates have abandoned migration routes in highly developed areas.

Objectives

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

Figure 48. The migrations of ungulates like these elk can be impeded by human development, but the threshold levels of development at which ungulate migration routes become compromised is not known. Photo credit: Arthur Middleton, Ph.D. candidate, Department of Zoology and Physiology University of Wyoming, and Wyoming Cooperative Fish and Wildlife Research Unit.

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. Recorded migration routes pass through or around Atlantic Rim Project, Moxa Arch, Jonah Field, Pinedale Anticline, and the Piney-Labarge areas (as depicted in figs. 3, 35, and 46).

Work Accomplished in 2010 and Findings

In seasonal environments, NDVI can be used to track phenological patterns of vegetation growth, where seasonal changes in “greenness” can broadly characterize the timing of spring green-up and late-summer or fall senescence. To assess whether the timing of stopover use corresponded with the phenology of emergent plant growth (when forage quality is highest), the mean NDVI value was calculated for each stopover for every 8-day period in 2005. The NDVI was estimated from 47 MODIS (Moderate Resolution Imaging Spectroradiometer) composite images obtained from the Wyoming View Web site (*http://www.uwyo.edu/wyview*), which had a resolution of 250 m. With the 47 mean NDVI values for each stopover, local polynomial regression (LOESS) function in R© (R Foundation for Statistical Computing, Vienna, Austria) was used to fit a curve and determine the date (Julian day) of the maximum NDVI value within each stopover. The timing of stopover use relative to the peak green-up was estimated by subtracting the median date of stopover use from the date of maximum NDVI (in Julian days).

In addition to the new phenological analysis of stopovers, the USGS has been building a GIS database from existing migration datasets suitable for the threshold analysis. The GIS work is not yet complete, but includes movement data from pronghorn, elk, mule deer, and moose, mostly in the WLCI study area. In addition, the USGS has been discussing with other researchers in Wyoming the possibility of including their GPS movement data with these analyses. Because it is necessary to identify the migratory periods of hundreds of animals, GIS visualization tools are being developed to assist in processing large amounts of movement data.

During spring migration, stopover use consistently occurred on 44 ± 6 days (mean ± SD) before peak green-up, suggesting that the timing of stopover use was tied to phenological changes along migration routes. In contrast, had deer not used stopovers and simply migrated directly to summer range, their arrival on summer range would have been 75 ± 19 days (mean ± SD) prior to peak green-up. The use of stopovers 44 days prior to peak green-up was a remarkably consistent response across individual animals (n = 18) and led us to conclude that this was the optimal time period for deer to exploit high-quality forage. These findings suggest that migrating ungulates require access to stopover locations along the migration routes at specific time periods that coincide with plant phenology. The threshold analysis should be able to determine whether disturbance alters the ability of deer to optimize their migrations in this way.

Products Completed in FY2010

- Sawyer, H.S., 2010, Habitat use and migration ecology of mule deer in developing gas fields of western Wyoming: Laramie, Wyo., University of Wyoming, Ph.D. dissertation.
- Sawyer, H., and Kauffman, M.J., 2011, Stopover ecology of a migratory ungulate: Journal of Animal Ecology, v. 80, 10 p., online at *http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2656.2011.01845.x/pdf*.
- Sawyer, H., 2010, Big game impact assessment—Lessons learned from natural gas development in Wyoming, *in* National Wind Coordinating Collaborative, October 20, 2010, in Denver, Colo. [presentation]

Work Planned for FY2011

The work on delineating migration routes and the conservation value of stopovers is now completed. There may be some minor revisions to the manuscript when it comes out of peer review, but most efforts in FY2011 will focus on the thresholds analysis. The movement data for 300–400 individual animal have been procured, and the seasonal ranges and migratory periods will be identified with each data set. Once this identification is complete, the duration, speed of travel, stopover use, distance, timing, and fidelity for each migration path will be measured. In addition, the development-footprint summary will be completed such that each movement path will receive a relative development score. This will allow analysis of whether the level of development influences migration behavior.

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 Web site, 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 FY2010.

More specifically, progress on the data management framework and clearinghouse entailed continued amalgamation, refinement, and management of WLCI data and information resources via ScienceBase, the scientific-data- and information-management system developed by the USGS for broad application. Advanced data-management capabilities in the WLCI Data Clearinghouse, including data visualization and uploading and sharing of data, were developed and will be introduced to the WLCI community in FY2011. The science and projects database—available on the WLCI Web site to provide WLCI partners and stakeholders accessible, descriptive information and locations of (1) "on-the-ground" conservation projects managed by the WLCI CT and (2) science projects being conducted by USGS and other science-agency partners—required maintenance and information refinement to ensure accuracy and completeness, and to ensure that the information is current. Efforts were initiated to more easily stream information to the WLCI Web site using Web services; these efforts will continue in FY2011. Finally, FY2010 work on outreach and graphics products entailed enhancing and updating the WLCI Web site, and offering new information and improved graphics and layout. Work was initiated to improve information sharing about WLCI science projects by using Web services to access science project information cataloged in the WLCI Data Clearinghouse. Two Fact Sheets were written about (1) information management for WLCI and (2) development of the ScienceBase data management system, using WLCI as an example.

Details of the data and information management work are provided in the three sections that follow.

Data Management Framework and Clearinghouse

Status

Ongoing

Contact

Natalie Latysh; 303-202-4637; *nlatysh@usgs.gov*

Scope and Methods

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 these resources available online to the public and WLCI researchers and decisionmakers, and (4) collaboration promoted by the use of a document-management utility and a wiki for informal discussions. 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.

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 Web site for information. The Data Management Framework must be developed continuously to meet user needs and evolve with fastpaced technological innovations. Likewise, the WLCI Data Clearinghouse must be maintained continuously to ensure that 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. 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 the 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. Harvesting methods using Web services must be developed to document resources made vailable 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 has collaborated 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. 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 partners are used to understand required capabilities of data management tools sought by the WLCI community. The USGS Science Team for the WLCI is contributing information resources for the WLCI to guide development of data-integration tools that provide visualization capabilities for spatial information.

Objectives

- 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.
- Build and maintain a WLCI Data Clearinghouse.
- Advance data-management tools and capabilities to enable efficiency and progression of WLCI efforts.

Study Area

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

Work Accomplished in 2010 and Findings

The primary focus of data-management framework and clearinghouse work in FY2010 was developing protocols for assembling, cataloging, and serving datasets associated with WLCI, and exploring online visualization techniques for cataloged data. The WLCI Data Clearinghouse (part of the USGS ScienceBase Catalog) is a searchable online database that enables use of WLCI data and products (for example, maps, locations, and information on 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. Tasks associated with the data management framework for the WLCI include assembling, cataloging, and providing information resources relevant to southwest Wyoming. Ongoing development work for advancing data management for the WLCI consists of (1) discovering and cataloging data and information useful to researchers, land managers, decision-makers, and the public; (2) refining and promoting the value of these existing information artifacts by completing and enhancing associated metadata; and (3) enabling access to these resources online through the use of comprehensive downloading and visualization methods.

The WLCI Data Clearinghouse references many data sets, 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. To understand the effects of separate processes in the WLCI region, the WLCI community needs methods and tools to integrate and visualize information resources. In FY2010, preliminary WLCI monitoring data sets were identified to help guide the development of ScienceBase visualization tools, which will enable discovery, access, and view of these data in the WLCI Data Clearinghouse. Work on ScienceBase visualization tools will continue in FY2011.

Products Completed in FY2010

- Work has entailed improvements of previous efforts.

Work Planned for FY2011

Work planned for FY2011 will entail continuing to (1) refine data sets, ensuring they are adequately described; (2) develop and advance data harvesting capabilities to obtain existing resources from data providers and add them to the WLCI Data Clearinghouse; (3) introduce capabilities that allow direct data uploading to ScienceBase, promoting storing and sharing of WLCI-pertinent information resources in a central locale; (4) develop a WLCI project geodatabase; (5) build a set of visualization options enabling interaction with the project database; (6) engineer spatial tools to allow GIS analysts to manage visualization options and data packaging for the WLCI project geodatabase; and (7) expose the WLCI project geodatabase and visualization packages to the National Map viewer and work with National Map personnel to further refine the application through separate iterations. In FY2011, products will include (1) more refined-information artifacts in the ScienceBase catalog; (2) data uploading capability to allow WLCI community members to add information resources directly to the ScienceBase catalog; (3) a WLCI project geodatabase; (4) production capacity and training for data management using ArcGIS and Web-based toolkit; and (5) online data visualization and interaction capability through National Map and viewers built into the WLCI Web site.

Science and Conservation Projects Database

Status

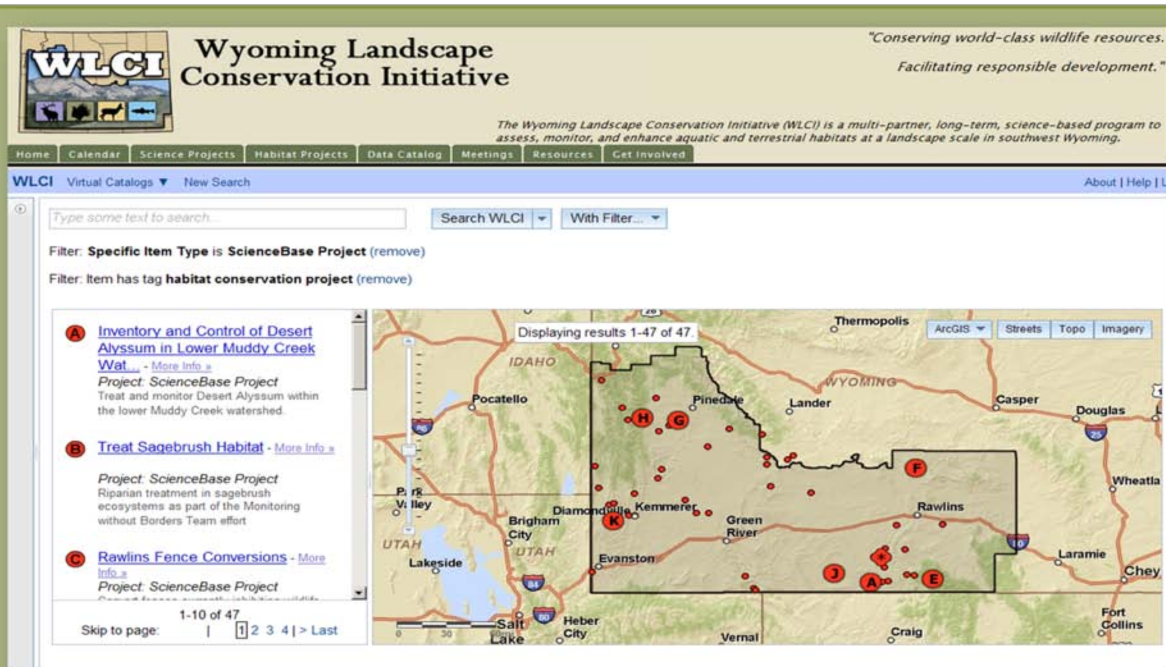
Ongoing

Contacts

Natalie Latysh; 303-202-4637; *nlatysh@usgs.gov*

Scope and Methods

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 USGS and other science-agency partners. In response to this need, WLCI project database maps were developed for science and conservation projects and are now available on the WLCI Web site. The system provides an interactive map environment, which 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 on 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 so on). Project information is entered into the project database, which is part of the ScienceBase data management system, and also made available on the WLCI Web site. This work also entails ongoing development of a conservation project data model that displays habitat- and science-project locations on a map with descriptive (attribute) information. This model is used for maintaining the online system. The USGS data and information personnel tasked with developing data management capabilities for the WLCI regularly communicate with WLCI CT and Science Team members to identify data management needs.



Wyoming Conservation Landscape Initiative Website, ScienceBase Habitat Project page, at *http://www.wlci.gov/* (click on the Habitat Projects tab).

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 subtask apply to the entire WLCI region (fig. 1).

Work Accomplished in 2010 and Findings

During FY2010, the WLCI Project Database required maintenance and information refinement to ensure accuracy, completeness, and currency. Authorized WLCI community members added and edited project information through the project-database map, accessed via the WLCI Web site. Work has been initiated to revamp the WLCI science project Web page to dynamically provide project information using cataloged project information in the WLCI Data Clearinghouse. Work to enhance the comprehensive display of cataloged information will continue in FY2011.

Products Completed in FY2010

- Most of the work has been improvements of previous efforts.

Work Planned for FY2011

In FY2011, work on this task will continue to (1) develop and evolve a WLCI project geodatabase; (2) build a set of visualization options enabling interaction with the project database; (3) dynamically provide project information from WLCI Data Clearinghouse to Science Project Web page; (4) engineer spatial tools to allow GIS analysts to manage visualization options and data packaging for the WLCI project geodatabase; and (5) expose the WLCI project geodatabase and visualization packages to the National Map viewer and work with National Map personnel to further refine the application through separate iterations. Products in FY2011 will include enhancement to the WLCI project geodatabase and to the Science Project information-sharing capabilities.

Outreach and Graphic Products

Status

Ongoing

Contacts

Natalie Latysh; 303-202-4637; *nlatysh@usgs.gov*

Scope and Methods

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 Web site 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 Web site.

The USGS data and information team routinely communicates with the WLCI CT to identify modifications and issues with the WLCI Web site. Authorized WLCI CT and Communication Team members routinely add and update information, including projects, photographs, and meeting notes and agendas. The USGS DIMT for the WLCI generate outreach products, including information articles, that share methods used to advance WLCI information management.

Objectives

- Develop and maintain a public Web site 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.

Study Area

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

Work Accomplished in 2010 and Findings

The WLCI Web site requires regular maintenance and refinement. In FY2010, a significant overhaul of the Web site requested by the WLCI CT was completed. Work to further refine the WLCI Web site and to advance the information-handling capabilities of the Web site will extend into FY2011. Detailed information about USGS science projects and other scientific studies conducted in southwest Wyoming will be added to the Web site. In FY2010, two Fact Sheets were prepared for USGS publication, and will become final products in FY2011. One Fact Sheet focused on data management and development for the WLCI. The other Fact Sheet focused on data cataloging in ScienceBase; this publication exhibited WLCI as one of the demonstration projects using and advancing the capabilities of the system.

Products Completed in FY2010

- Most of the work has been improvements of previous efforts.

Work Planned for FY2011

In FY2011, work will continue to (1) develop web-servicing capability for displaying cataloged science-project information in WLCI web pages, (2) complete a Fact Sheet focusing on the ScienceBase data management system, (3) complete a Fact Sheet focusing on data management and development for the WLCI, (4) improve the WLCI bibliography (accessible through the WLCI Web site), and (5) continue to refine and evolve information sharing capabilities of the WLCI community using the WLCI Web site. In FY2011, products will include the items mentioned in the list above.

WLCI Coordination, Science Integration, Decisionmaking, and Evaluation

Summary of FY2010 Activities for WLCI Coordination, Science Integration, Decisionmaking, and Evaluation Activities

Integration and Coordination activities continue to be critical components of USGS involvement in the WLCI. A full-time USGS scientist, who is a member of the WLCI CT, works 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

USGS and patners. In addition to the CT, the USGS also supports and(or) provides leadership (representation) for other WLCI teams and committees, including the WLCI EC, the WLCI MT, the WLCI DIMT, and the STAC.

During 2010, 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.

WLCI Coordination, Science Integration, Decisionmaking, and Evaluation

Status

Ongoing

Contacts

Patrick Anderson; 970-226-9488; *andersonpj@usgs.gov*
Zachary Bowen; 970-226-9218; *bowenz@usgs.gov*
Frank D'Erchia; 303-236-1460; *fderchia@usgs.gov*

Scope and Methods

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 subtask apply to the entire WLCI region (fig. 1).

Work Accomplished in 2010 and Findings

During FY2010, the USGS participated in numerous activities designed to inform WLCI partners about its science activities, improve collaboration, and integrate science with decisionmaking. These activities included participating on WLCI teams and committees, (EC, CT, STAC, MT, DIMT, and the USGS Science Team) and serving as a WLCI liaison and member of the steering team for the Great Northern Landscape Conservation Cooperative (GNLCC). Activities also included providing direction and oversight of WLCI strategic conservation planning, presenting science activities and science findings at WLCI meetings and field tours; and 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 were focused on defining WLCI conservation priorities, issues, and areas of interest. Some of the activities included working with CT support staff to meet with project leads, conduct site visits, photograph and map areas of interest, and pursue related issues. The Coordinator also developed the necessary framework and scheduling for a consensus driven prioritization process and drafted the outline for the WLCI Conservation Action Plan. The conservation framework was presented at LPDT meetings and at EC meetings during 2010.

In addition to conservation planning, some of these FY2010 coordination activities included (1) providing direction and coordination between the WLCI Data and Information Management Team, WLCI Science and Technical Advisory Committee, WLCI MT, and USGS Science Team; (2) presenting information about USGS science activities and products at numerous LPDT meetings and with staff from the WGFD and BLM field offices; (3) participating in the evaluation and selection of WLCI habitat projects for 2011; (4) meeting with Jonah Interagency Office and Pinedale Anticline Project Office staff to coordinate planning and to discuss data-management systems; (5) working with WLCI partners to acquire data to support science studies, conservation planning, and integrated assessments; and (6) supporting structured planning activities associated with the Ruby Conservation Fund. The USGS WLCI Coordinator and other USGS staff organized or participated in several meetings and activities to share and integrate science information with WLCI partners, including

- sharing information about USGS aspen research and monitoring activities and discussing additional science needs with staff associated with BLM Rock Springs Field Office and the WYNDD;
- working with staff from the WGFD Green River Office and the Conservation Research Center of Teton Schools to revise Tamarisk assessment protocol, assessment planning, and review the 2010 assessment findings;
- developing and implementing pygmy rabbit protocols (BLM Pinedale Field Office);
- meeting with County Weed and Pest Districts to discuss approaches for managing and collecting spatial information on invasive plant species;
- conducting field tours associated with Bitter Creek restoration and science needs;
- meeting with the WLCI CT to discuss status and progress on the Integrated Assessment; and
- discussing USGS research activities in the Muddy Creek Watershed (south of Rawlins, Wyo.) with WLCI partners.

During 2010, an effort was made to provide the WLCI EC with more information about USGS science activities and how they are being applied to support the WLCI. 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.

Products Completed in FY2010

The products that follow were all presentations made by USGS scientists at WLCI EC meetings and tours that occurred throughout FY2010.

- USGS surface- and groundwater-monitoring networks in the WLCI area: David Mott (USGS Wyoming Water Science Center) presented information about USGS surface and ground water monitoring networks in the WLCI area. Dave discussed objectives of each monitoring network, related products, and data access with the EC during their April meeting.
- Real-time surface water monitoring—Development and data availability: Jerrod Wheeler and David Mott (USGS Wyoming Water Science Center) discussed USGS real-time stream flow measurement, the need for these data by partners ranging from water-management engineers to regulatory agencies, and how data collected from gage stations are commonly used. This discussion was presented to the WLCI EC during a tour stop at the USGS gage station on the Green River below Fontenelle Reservoir.
- Development of regional curves for estimating bankfull discharge and channel dimensions, and restoration applications for the WLCI: Kathy Foster (USGS Wyoming Water Science Center) presented information about USGS efforts to develop regional curves to estimate bankfull elevations and channel dimensions at a tour stop on the Encampment River. This approach and related data are currently being used to help WLCI partners develop river-restoration projects such as those observed at the tour stop.
- LiDAR technology and applications to the WLCI: Steve Germaine (USGS Fort Collins Science Center) presented information to the WLCI EC about a USGS led effort to map 500^2 mi using LiDAR technology. Steve discussed the process, costs, ground validation, and integration with his pygmy rabbit studies.
- Rancher perceptions of energy development: Jessica Montag (USGS Fort Collins Science Center) presented to the WLCI EC results of a survey conducted to assess rancher perceptions of energy development in southwestern Wyoming. Jessica also discussed her development of an energy bibliography and its application to the WLCI.
- Invasive species distributions and their proximity to disturbance features: Dan Manier (associated with the USGS Fort Collins Science Center) presented to the WLCI EC the results from his study evaluating cheatgrass and other invasive species in southwest Wyoming. This study evaluated (1) the distribution of invasive plants across the landscape and (2) their proximity to numerous disturbance features.
- Sage-grouse use of seasonal habitat in treated and untreated habitats in the Moxa Arch study area: Pat Anderson (WLCI Coordinator, USGS Fort Collins Science Center) provided information about the Moxa Arch vegetation treatments at a WLCI EC tour stop. Pat discussed history and habitat objectives of the treatments, recent results from a BLM study evaluating the vegetation response, and USGS study objectives and preliminary findings associated with sage-grouse use of these treatments.
- Long-term trends and sage-grouse use of seasonal habitat in Wyoming: Brad Fedy (associated with the USGS Fort Collins Science Center) presented information to the WLCI EC about his studies on long-term trends and sage-grouse use of seasonal habitat in Wyoming.

- Development and status of the WLCI Integrated Assessment: Zack Bowen (WLCI Science Team Lead, USGS Fort Collins Science Center) provided the WLCI EC with information about the status, development, and applications of the WLCI Integrated Assessment to support conservation planning and decisionmaking.

Work Planned for FY2011

The USGS WLCI Coordinator will continue to provide direction and oversight in developing a strategic conservation framework and will pursue actions necessary to implement strategic conservation activities, including structuring priorities, funding, and project tracking associated with the Ruby Pipeline Conservation Fund. This work will include coordinating, conducting, and facilitating a series of workshops designed to establish WLCI priorities, develop landscape-scale objectives, and identify monitoring and data needs. Each workshop will be based on a topical theme that was identified as a priority by LPDT members. Currently, topical themes include aspen regeneration, invasive species, species of concern (including sage-grouse), and conservation actions associated with connectivity of terrestrial and aquatic habitats. The USGS WLCI Coordinator and USGS representatives associated with WLCI teams and committees will work with WLCI partners to conduct a programmatic review of WLCI and begin planning the 2012 WLCI Science Workshop with the WLCI STAC. The USGS will continue to work with the WGFD as a WLCI liaison to the GNLCC and other Landscape Conservation Cooperatives. The USGS also will assist with developing a process by which USGS and WLCI partners may compete collaboratively for GNLCC funding and similar funding sources. USGS investigators will meet with land management agencies to discuss interim and final assessment and map products associated with the Integrated Assessment, and they will continue to present science activities and findings at WLCI EC meetings and tours and at LPDT meetings.

References Cited

Barnett, D.T., Stohlgren, T.J., Jarnevich, C.S., Chong, G.W., Ericson, J.A., Davern, T.R., and Simonson, S.E., 2007, The art and science of weed mapping: Environmental Monitoring and Assessment, v. 132, p. 235–252, at *http://www.refugenet.org/new-pdffiles/ArtandScience.pdf*.

Biewick , L.R.H., 2009, Oil and gas development data in southwestern Wyoming—Energy data and services for the Wyoming Landscape Conservation Initiative (WLCI): U.S. Geological Survey Data Series DS-437, unpaged, at *http://pubs.usgs.gov/ds/437*.

Blecker, S.W., Stillings, L.L., Amacher, M.C., Ippolito, J.A., and DeCrappeo, N., 2010, Ecosystem health in mineralized terrane—Data from podiform chromite (Chinese Camp mining district, California), quartz alunite (Castle Peak and Masonic mining districts, Nevada/California), and Mo/Cu porphyry (Battle Mountain mining district, Nevada) deposits: U.S. Geological Survey Open-File Report, 2010–1040, 38 p. (Also available at *http://pubs.usgs.gov/of/2010/1040/*.)

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

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

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

Brookes, P.C., 1995, The use of microbial parameters in monitoring soil pollution by heavy metals: Biology and Fertility of Soils, v. 19, p. 269–279.

Clarey, K.E., Bartos, T.T., Copeland, D., Hallberg, L.L., Clark, M.L., and Thompson, M.L., 2010, Available groundwater determination—Technical memorandum, *in* Copeland, D., and Ewald, M., eds., WWDC Green River Basin Water Plan II—Groundwater study level I (2007-2009): Laramie, Wyo., Wyoming State Geological Survey Report, variously paginated.

Collins, W.D., Bitz, C.M., Blackmon, M.L., Bonan, G.B., Bretherton, C.S., Carton, J.A., Chang, P., Doney, S.C., Hack, J.J., Henderson, T.B., Kiehl, J.T., Large, W.G., McKenna, D.S., Santer, B.D., and Smith, R.D., 2006, The community climate system model version 3 (CCSM3): Journal of Climate, v. 19, p. 2122–2143.

Copeland, H.E., Doherty, K.E., Naugle, D.E., Pocewicz, A., and Kiesecker, J.M., 2009, Mapping oil and gas development potential in the U.S. intermountain west and estimate impacts to species: PloS One, v. 4, no. 10, e7400. doi:10.1371/journal.pone.0007400.

Cross, P.C., Edwards, W.H., Scurlock, B., Machaik,E., and Rogerson, J., 2007, Management and climate impacts on brucellosis in elk of the Greater Yellowstone Ecosystem: Ecological Applications, v. 17, no. 4, p. 957–964.

Doran, J.W., and Parkin, T.B., 1994, Defining and assessing soil quality, *in* Doran, J.W., and others, eds., Defining soil quality for a sustainable environment: Madison, Wis., Soil Science Society of America Special Publication 35, p. 3–21.

Elith, J., Graham, C.H., Anderson, R.P., Dudik, M., Ferrier, S., Guisan, A., Hijmans, R.J., Huettmann, F., Leathwick, J.R., Lehmann, A., Li, J., Lohmann, L.G., Loiselle, B.A., Manion, G. Moritz, C., Nakamura, M., Nakazawa, Y., Overton, J.M., Peterson, A.T., Phillips, S.J., Richardson, K., Scachetti-Pereira, R., Schapire, R.E., Soberon, J., Williams, S., Wisz, M.S., and Zimmermann, N.E., 2006, Novel methods improve prediction of species' distributions from occurrence data: Ecography, v. 29, p. 129–151.

Fielding, A.H., and Bell, J.F., 1997, A review of methods for the assessment of prediction errors in conservation presence/absence models: Environmental Conservation, v. 24, p. 38–49.

Fishman, M.J., ed., 1993, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of inorganic and organic constituents in water and fluvial sediments: U.S. Geological Survey Open-File Report 93–125, 217 p.

Freeman, E.A., and Moisen, G.G., 2008, A comparison of the performance of threshold criteria for binary classification in terms of predicted prevalence and kappa: Ecological Modelling, v. 217, p. 48–58.

Frair, J.L., Merrill, E.H., Beyer, H.L., and Morales, J.M., 2008, Thresholds in landscape connectivity and mortality risks in response to growing road networks: Journal of Applied Ecology, v. 45, no. 5, p. 1504–1513.

Garbarino, J.R., Kanagy, L.K., and Cree, M.E., 2006, Determination of elements in natural-water, biota, sediment and soil samples using collision/reaction cell inductively coupled plasma-mass spectrometry: U.S. Geological Survey Techniques and Methods, book 5, sec. B, chap.1, 88 p.

Gil-Sotres, F., Trasar-Cepeda, C., Leiros, M.C., and Seoane, S., 2005, Different approaches to evaluating soil quality using biochemical properties: Soil Biology and Biochemistry, v. 37, p. 877–887.

Graham, C., and Elith, J., 2005, Testing alternative methodologies for modeling species' ecological niches and predicting geographic distributions, *in* Ecological Society of America 2005 Annual Meeting, August 7–12, 2005, Montreal, Ontario, Proceedings: Washington D.C., Ecological Society of America.

Graham, C.H., Elith, J., Hijmans, R.J., Guisan, A., Peterson, A.T., Loiselle, B.A., and the NCEAS Species Distribution Modeling Group, 2008, The influence of spatial errors in species occurrence data used in distribution models: Journal of Applied Ecology, v. 45, p. 239–247.

Greaves, R.K., Sanderson, R.A., and Rushton, S.P., 2006, Predicting species occurrence using information-theoretic approaches and significance testing: An example of dormouse distribution in Cumbria, UK: Biological Conservation, v. 130, p. 239–250.

Guisan, A., and Thuiller, W., 2007, Predicting species distribution—Offering more than simple habitat models: Ecology Letters, v. 10, p. 435–435.

Halvorson, J.J., Smith, J.L., and Papendick, R.I., 1996, Integration of multiple soil parameters to evaluate soil quality—A field experiment example: Biology and Fertility of Soils, v. 21, p. 207–214.

Hamerlinck, J.D., and Arneson, C.S., eds., 1998, Wyoming ground water vulnerability assessment handbook, volume 1—Background, model development, and aquifer sensitivity Analysis: Laramie, Wyo., University of Wyoming, Spatial Data and Visualization Center Publication SDVC 98-01-1, variable pagination.

Harrelson, C.C., Rawlins, C.L., and Potyondy, J.P., 1994, Stream channel reference sites—An illustrated guide to field technique: USDA Forest Service, Rocky Mountain Research Station, General Technical Report RM-245, 67 p.

Hijmans, R.J., and Graham, C.H., 2006, The ability of climate envelope models to predict the effect of climate change on species distributions: Global Change Biology, v. 12, p. 2272–2281.

Holloran, M.J., 2009, Greater sage-grouse focused herbaceous monitoring of the Moxa Arch sagebrush vegetation treatments: Pinedale, Wyo., Wyoming Wildlife Consultants, LCC, 22 p. [Job completion report prepared for the U.S. Bureau of Land Management, Kemmerer Field Office]

Homer, C.G., Aldridge, C.L., Meyer, D.K., Coan, M.J., and Bowen, Z.H., 2009, Multiscale sagebrush rangeland habitat modeling in Southwest Wyoming: U.S. Geological Survey Open-File Report 2008-1027, 14 p. (Also available at *http://pubs.usgs.gov/of/2008/1027*.)

Insam, H., and Domsch, K.H., 1988, Relationship between soil organic carbon and microbial biomass on chronosequences of reclamation sites: Microbial Ecology, v. 15, p. 177–188.

ITT Visual Information Solutions, 2009, ENVI 4.7/ IDL version 7.1 user's guide: Boulder, Colo., ITT Visual Information Solutions, unpaged.

Jimenez-Valverde, A., and Lobo, J.M, 2006, The ghost of unbalanced species distribution data in geographical model predictions: Diversity and Distributions, v. 12, p. 521–524.

Johnson, C.J., and Gillingham, M.P., 2008, Sensitivity of species-distribution models to error, bias, and model design—An application to resource selection functions for woodland caribou: Ecological Modelling, v. 213, p. 143–155.

Jobes, P.C., 1987, The disintegration of gemeinschaft social structure from energy development—Observations from ranch communities in the Western United States: Journal of Rural Studies, v. 3, no. 3, p. 219–229.

Keinath, D.A., Andersen, M.D., and Beauvais, G.P., 2010, Range and modeled distribution of Wyoming's species of greatest conservation need: Laramie, Wyo., Wyoming Natural Diversity Database, University of Wyoming, accessed at *http://www.uwyo.edu/wynddsupport/docs/Reports/WYNDDReports/U10KEI01WYUS.pdf*. [Report prepared for the Wyoming Game and Fish Department and the U.S. Geological Survey.]

Kenney, T.A., 2010, Levels at gaging stations: U.S. Geological Survey Techniques and Methods 3-A19, 60 p. (Also at *http://pubs.usgs.gov/tm/tm3A19/*.)

Kirschbaum, M.A., Charpentier, R.R., Crovelli, R.A., Klett, T.R., Pollastro, R.M., and Schenk, C.J. (USGS Southwestern Wyoming Province Assessment Team), 2004, Assessment of undiscovered oil and gas Resources of the Wyoming Thrust Belt Province, 2003: U.S. Geological Survey Fact Sheet 2004–3025, 2 p. (Also available online at *http://pubs.usgs.gov/fs/2004/3025*.)

Kokaly, R.F., 2011, Detecting cheatgrass on the Colorado Plateau using Landsat data: A tutorial for the DESI software: U.S. Geological Survey Open-File Report 2011-1327, 88 p. (Also available at *http://pubs.usgs.gov/of/2010/1327/*.)

Leopold, L.B., 1994, A view of the river: Cambridge, Mass., Harvard University Press, 298 p.

Manier, D.J., Aldridge, C.L., Anderson, P.J., Chong, G., Homer, C.G., O'Donnell, M., and Schell, S., in press, Land use and habitat conditions across the southwestern Wyoming sagebrush steppe—Development impacts, management effectiveness and the distribution of invasive plants, *in* Monaco, T.A., Schupp, E.W., Kitchen, S.G., and Pendleton, R.L., compilers, Threats to shrubland ecosystem integrity: Linking research and management, *in* Wildland Shrub Symposium, 16th, May 18-20, 2010, Proceedings: Logan, Ut., Utah State University Press; and S.J. and the Jessie E. Quinney Natural Resources Research Library, Natural Resources and Environmental Issues, v. 17, p. xx–xx.

McCandless, T.L., and Everett, R.A., 2002, Maryland stream survey—Bankfull discharge and channel characteristics in the Piedmont hydrologic region: Annapolis, Md., U.S. Fish and Wildlife Service, CBFO-S02-02, 41 p.

Meehl, G.A., Covey, C., Delworth, T., Latif, M., McAvaney, B., Mitchell, J.F.B., Stouffer, R.J., and Taylor, K.E., 2007, The WCRP CMIP3 multi-model dataset—A new era in climate change research: Bulletin of the American Meteorological Society, v. 88, p. 1383–1394.

Miller, K.A., 2003, Peak-flow characteristics of Wyoming streams: U.S. Geological Survey Water-Resources Investigations Report 2003–4014, 79 p.

Mummey, D.L., Stahl, P.D., and Buyer, J.S., 2002. Soil microbiological properties 20 years after surface mine reclamation—Spatial analysis of reclaimed and undisturbed sites: Soil Biology and Biochemistry, v. 34, p. 1717–1725.

Nakicenovic, N., Alcamo, J., Davis, G., de Vries, B., Fenhann, J., Gaffin, S., Gregory, K., Grübler, A., Jung, T.Y., Kram, T., Lebre La Rovere, E., Michaelis, L., Mori, S., Morita, T., Pepper, W., Pitcher, H., Price, L., Riahi, K., Roehrl, A., Rogner, H.-H., Sankovski, A., Schlesinger, M., Shukla, P., Smith, S., Swart, R., van Rooijen, S., Victor, N., and Dadi, Z., 2000, Special report on emissions scenarios—A special report of Working Group III of the Intergovernmental Panel on Climate Change: Cambridge, Mass., Cambridge University Press, 599 p.

New, M., Lister, D., Hulme, M., and Makin, I., 2002, A high-resolution data set of surface climate over global land areas: Climate Research, v. 21, p.1–25.

Nielsen, M.N., and Winding, A., 2002, Microorganisms as indicators of soil health: Copenhagen, Denmark, National Environmental Research Institute, Technical Report 388, 85 p., accessed online September, 2008, at *http://www.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/FR388.pdf*.

Papendick, R.I., and Parr, J.F., 1992, Soil quality—The key to a sustainable agriculture: American Journal of Alternative Agriculture, v. 7, p. 2–3.

Phillips, S.J., Anderson, R.P., and Schapire, R.E., 2006, Maximum entropy modeling of species geographic distributions: Ecological Modelling, v. 190, p. 231–259.

Phillips, S.J., and Dudik, M., 2008, Modeling of species distributions with Maxent—New extensions and a comprehensive evaluation: Ecography, v. 31, p. 161–175.

Phillips, S.J., Dudik, M., Elith, J., Graham, C.H., Lehmann, A., Leathwick, J., and Ferrier, S., 2009, Sample selection bias and presence-only distribution models—Implications for background and pseudo-absence data: Ecological Applications, v. 19, p. 181–197.

Powell, R.O., Miller, S.J., Westergard, B.E., Mulvihill, C.I., Baldigo, B.P., Gallagher, A.S., and Starr, R.R., 2003, Guidelines for surveying bankfull-discharge geometry and developing regional hydraulic-geometry models for streams of New York State: U.S. Geological Survey Open-File Report 03-92, 26 p. (Also available at *http://ny.water.usgs.gov/pubs/of/of03092/of03-092.pdf*.)

Rosgen, D.L., 1996, Applied river morphology: Pagosa Springs, Colo., Wildland Hydrology, 388 p.

Rosgen, D.L., 2006, Watershed assessment of river stability and sediment supply (WARSSS): Fort Collins, Colo, Wildland Hydrology, 193 p.

RuleQuest Research Pty, Ltd., 2011, Data mining tools See5 and C5.0: St. Ives, New South Wales, Australia, RuleQuest Research, accessed at *http://www.rulequest.com/see5-info.html*.

Salant, P., and Dillman, D.A., 1994, How to conduct your own survey: New York, John Wiley & Sons, Inc., 232 p.

Sauer, V.B., and Turnipseed, D.P., 2010, Stage measurement at gaging stations: U.S. Geological Survey Techniques and Methods book 3, chap. A7, 45 p. (Also available at *http://pubs.usgs.gov/tm/tm3-a7/*.)

Saunders, D.A., Hobbs, R.J., and Margules, C.R., 1991, Biological consequences of ecosystem fragmentation—A review: Conservation Biology, v. 5, p. 18–32.

Shinneman, D.J., and Baker, W.L., 2009, Environmental and climatic variables as potential drivers of post-fire cover of cheatgrass in seeded and unseeded semiarid ecosystems: International Journal of Wildland Fire, v. 18, p. 191–202.

Silleos, N.G., Alexandridis, T.K., Gitas, I.Z., and Perakis, K., 2006, Vegetation indices—Advances made in biomass estimation and vegetation monitoring in the last 30 years: Geocarto International, v. 21, p. 21–28.

Sitch, S., Smith, B., Prentice, I.C., Arneth, A., Bondeau, A., Cramer, W., Kaplan, J.O., Levis, S., Lucht, W., Sykes, M.T., Thonicke, K., and Venevsky, S., 2003, Evaluation of ecosystem dynamics, plant geography and terrestrial carbon cycling in the LPJ dynamic global vegetation model: Global Change Biology, v. 9, p. 161–185.

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, 10 p. (Also available at *http://pubs.usgs.gov/ds/510/downloads/DS-510.pdf*.)

Smith, D.B., Woodruff, L.G., O'Leary, R.M., Cannon, W.F., Garrett, R.G., Kilburn, J.E., and Goldhaber, M.B., 2009, Pilot studies for the North American Soil Geochemical Landscapes Project—Site selection, sampling protocols, analytical methods, and quality control protocols: Applied Geochemistry, v. 24, no. 8, p. 1357–1368.

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M., and Miller, H.L., eds., 2007, Climate change 2007—The physical science basis—Contribution of working group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change: Cambridge, Mass., Cambridge University Press, 996 p.

Turnipseed, D.P., and Sauer, V.B., 2010, Discharge measurements at gaging stations: U.S. Geological Survey Techniques and Methods book 3, chap. A8, 87 p. (Also available at *http://pubs.usgs.gov/tm/tm3-a8/*.)

U.S. Bureau of Land Management, 2006, Final environmental impact statement for the Atlantic Rim natural gas field development project: Rawlins, Wyo., U.S. Bureau of Land Management Rawlins Field Office, variously paged.

U.S. Department of Agriculture, 1995, A guide to field identification of bankfull stage in the western United States: Fort Collins, Colo., Rocky Mountain Forest and Range Experiment Station, Stream Systems Technology Center, USDA Forest Service, VHS video.

U.S. Geological Survey, 1997–2010, National field manual for the collection of water-quality data—U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps. A1-A9, 2 v., variable pagination. (Also available online at *http://pubs.water.usgs.gov/twri9A*. [Chapters originally were published during 1997–1999; updates and revisions are ongoing and are summarized at *http://water.usgs.gov/owq/FieldManual/mastererrata.html*]

U.S. Geological Survey, 2010a, Mineral Resources Program—New Mineral Resources Data System (MRDS): U.S. Geological Survey master database, online at *http://mrds.cr.usgs.gov:7777/mrds/f?p=130:1* (access for internal users only).

U.S. Geological Survey, 2010b, Mineral Resources Data System (MRDS): U.S. Geological Survey public access database, online at *http://tin.er.usgs.gov/mrds/* (access for general public).

U.S. Geological Survey, 2010c, Water-resources data for the United States, Water year 2000: U.S. Geological Survey Water-Data Report WDR-US-2009, unpaged. (Also available at *http://wdr.water.usgs.gov/*.)

U.S. Geological Survey, variously dated, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps., A1-A9, unpaged. (Also available online at *http://pubs.water.usgs.gov/twri9A*.)

U.S. Geological Survey Southwestern Wyoming Province Assessment Team, comps., 2005, Petroleum systems and geologic assessment of oil and gas in the Southwestern Wyoming Province, Wyoming, Colorado, and Utah: U.S. Geological Survey, Digital Data Series DDS-69- D, ver. 1, 1 CD–ROM. (Available at *http://pubs.usgs.gov/dds/dds-069/dds-069-d/*.)

Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1-D3, 51 p. and 8 attachments. (also available at *http://pubs.water.usgs.gov/tm1d3*.)

Wilson, A.B., Klein, T.L, and Heran, W.D., 2001, Databases and simplified geology for mineralized areas, claims, mines and prospects in Wyoming: U.S. Geological Survey Open-File Report 01-497, 17 p. (Also available at *http://pubs.usgs.gov/of/2001/ofr-01-0497/WY_text.pdf*.)

Wisz, M.S., Hijmans, R.J., Li, J., Peterson, A.T., Graham, C.H., Guisan, A., and Distribut, N.P.S., 2008, Effects of sample size on the performance of species distribution models: Diversity and Distributions, v. 14, p. 763–773.

Wyoming Department of Environmental Quality, 2010, Wyoming water-quality assessment and impaired waters list (2010 Integrated 305(b) and 303(d) Report): Cheyenne, Wyo., Wyoming Department of Environmental Quality, accessed March 04, 2011, at *http://deq.state.wy.us/wqd/watershed/Downloads/305b/2010/WY2010IR.pdf*.

Wyoming Game and Fish Department, 2005, A comprehensive wildlife conservation strategy for Wyoming: Cheyenne, Wyo., Wyoming Game and Fish Department, 562 p.

Wyoming Game and Fish Department, 2010, Wyoming State wildlife action plan: Cheyenne, Wyo., Wyoming Game and Fish Department, unpaged, accessed March 02, 2011 at *http://gf.state.wy.us/SWAP2010/Plan/index.asp.*

Wyoming Wildlife Consultants, LLC, 2007, Upper Green River Valley mapping project: Pinedale, Wyo, Wyoming Wildlife Consultants, LLC.

Xian, G., Homer, C.G., and Aldridge, C.L., in press, Assessing long-term variations of sagebrush habitat—Characterization of spatial extents and distribution patterns using multi-temporal satellite remote sensing data: International Journal of Remote Sensing, v. 32.

Publishing support provided by:
Denver Publishing Service Center

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

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

USGS

U.S. Geological Survey Science for the Wyoming Landscape Conservation Initiative—2011 Annual Report— Open-File Report 2011–1219