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Fort Collins Science Center
Fiscal Year 2011 Science Accomplishments

Compiled by Juliette T. Wilson

Open-File Report 2012–1169

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

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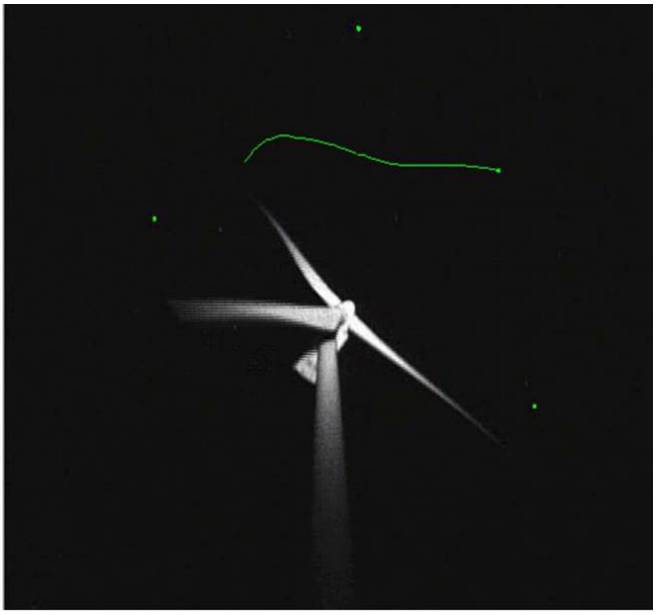
Fort Collins Science Center 2011 Annual Report Executive Summary

Introduction

The Fort Collins Science Center (FORT) is a multi-disciplinary research and development center of the U.S. Geological Survey (USGS) located in Fort Collins, Colo. Organizationally, FORT is within the USGS Rocky Mountain Area, although our work extends across the Nation and into several other countries. FORT research focuses on needs of the land- and water-management bureaus within the U.S. Department of the Interior (DOI), other Federal agencies, and the needs of State and non-government organizations. As a Science Center, we emphasize a multi-disciplinary science approach to provide information for resource-management decisionmaking. FORT's vision is to maintain and continuously improve the integrated, collaborative, world-class research needed to inform effective, science-based land management. Our innovative scientists and technical specialists accomplish this mission in two fundamental ways:

- **We build teams across USGS centers and Federal agencies**.

  Resource management decisions and planning processes require a broad range of biological, ecological, and economic analyses and often must consider a landscape or ecoregional perspective that involves multiple Federal and State agencies and often university and private partners. Our Center has a long history of addressing resource management and planning issues, leveraging shared data and expertise across centers and agencies. This collaborative work has been recognized through three consecutive DOI "Partners in Conservation" awards and our selection as the host site for the USGS John Wesley Powell Center for Analysis and Synthesis.



Infrared snapshot of a bat's flight trajectory (thin green line) as it passes a wind turbine approximately 80 meters above the ground. Image courtesy of Mark Hayes, Colorado State University.

- **We provide interdisciplinary science support and Information Technology infrastructure that facilitates integrated and collaborative research.**

  Advanced Information Technology (IT) and data capabilities at FORT include the Resource for Advanced Modeling laboratory, high throughput and high performance computing resources, and easily accessible libraries of large geospatial datasets. Our Center is also piloting for USGS a number of cutting-edge technologies that could dramatically lower IT costs and improve performance, such as network optimization tools and virtualization. These services provide support to as many as 14 working groups per year for the Powell Center, in addition to new

levels of data management and analysis for our own scientists. With an interdisciplinary science staff from several USGS science centers, we are located within the Natural Resource Research Center campus at Colorado State University, where there are more than 1,000 natural resource professionals from six Federal agencies.

Our science and technological development activities and unique capabilities support all six USGS scientific Mission Areas and contribute to successful, collaborative science efforts across the USGS and DOI. This year, we have organized our annual report into an Executive Summary with an appendix of 70 science accomplishments. These one-page accomplishment descriptions are organized by USGS Mission Area. As in prior years, lists of all FY2011 publications and other product types also are appended.

This executive summary of our annual report provides brief highlights of a few key FORT accomplishments for each Mission Area, along with a table cross-referencing all major FY11 accomplishments with the various Mission Areas each supports. I hope you will also peruse the accomplishment descriptions in Appendix 1, as they describe the many and diverse ways in which the "rubber meets the road" here at FORT.

Selected FORT Activities and Mission Area Support

Below are examples of some of this year's science accomplishments that illustrate support to the six USGS Mission Areas. Within the Ecosystems Mission Area, which funds the bulk of our work at FORT, we list accomplishments by program. Each subheading is linked to the section of Appendix 1 containing summaries for all associated FY11 accomplishments for that Mission Area or program.

HOW TO NAVIGATE THIS REPORT

- To "***jump to***" the section of appendix 1 containing science accomplishment summaries for a particular Mission Area or program, simply ***click on the heading*** in the Table of Contents or in the Executive Summary.
- To jump to an *individual* accomplishment summary, click on its Table of Contents heading or table 1 accomplishment title.
- ***Important!*** To ***return*** to the place of any originating link you just used, ***hold down the ALT key and click the left arrow key*** [**ALT ←**].

Climate and Land-Use Change

A changing climate will, among other things, modify habitats being preserved for protected species and possibly increase the land area at risk for invasive species. Regional- and taxa-specific research needed to connect climate drivers with species habitat must have practical applications for resource managers' top-priority conservation issues and must support the work of the *DOI Climate Science Centers*. Many FORT activities in FY11 addressed aspects of climate change (see table 1, especially the accomplishments listed under "Ecosystems—Terrestrial, Freshwater, and Marine

Environments"). Four notable activities focusing on climate-change needs, as well as its Landsat Mission component, are these:

- Continued collaborative field research and data integration through the Western Mountain Initiative (WMI) to provide perspectives on how climate variability and change are affecting disturbance regimes, vegetation dynamics, and hydrologic processes across the western United States. The WMI is a collaborative effort led by the USGS (including FORT, the Western Ecological Research Center, and the Northern Rocky Mountain Science Center) in cooperation with the U.S. Forest Service (USFS), National Park Service (NPS), Los Alamos National Laboratory, and university scientists from across the West and around the world.
- Conducting a landscape assessment of relations among land use, hydrology, and wildlife habitats in the Southern Great Plains region to support the multi-agency Great Plains Landscape Conservation Cooperative.
- Field and greenhouse studies addressing potential direct and indirect effects of climate change on both invasive and native riparian trees in the western United States.
- Completion of the first phase of an extensive survey conducted for the USGS Land Remote Sensing Program of the users, uses, and value of Landsat imagery. This imagery has been applied in a variety of research areas, such as global climate research, agriculture, and environmental management. With the impending decommissioning of Landsat 5 and the planned launch of Landsat 8 in 2013, the survey results are being used to inform delivery of the products and services related to Landsat imagery and to understand how and why the imagery is important to users in decisionmaking.

Core Science Systems

Assembling data and presenting it in meaningful ways becomes increasingly important as natural resource issues span larger and larger geographic, political, organizational, and scientific boundaries. In FY11, FORT's cadre of more than 40 information technologists helped tackle a number of priority science and information issues by developing processes and products that have saved considerable time and money. These technologies have provided access to and easy use of enormous aggregations of data, and in one case have brought analyses that were once computationally intractable into the realm of not only possible but also fast, just using local resources. Examples include:

- LC MAP (Landscape Conservation Management and Analysis Portal), a Web-based system that allows State, Federal, university, and non-governmental organization (NGO) partners in the Great Northern Landscape Conservation Initiative (GNLCC) to securely share, access, and analyze datasets and information. Other LCCs are starting to adopt LC MAP as their data management and sharing system as well.

Mapping earthquake-related "tweets" in Central America. USGS image.

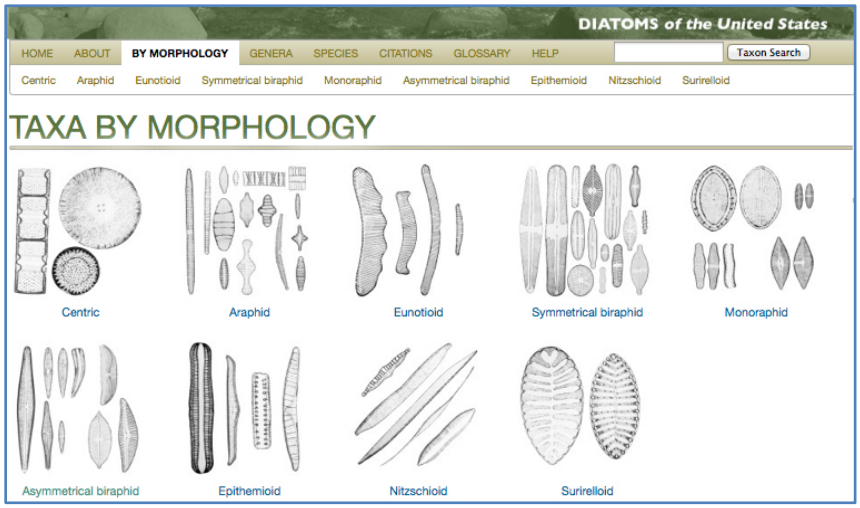
- A citizen-based Twitter application that allows for more rapid notification and assessment of earthquakes via “tweets” from people experiencing them.
- A Web-based portal by which State agencies can better share data related to the spread of white nose syndrome, a fungus-caused disease that is devastating bat populations in 16 eastern and midwestern states and 4 Canadian provinces.
- A Web-based application that helps the Bureau of Land Management (BLM) manage the thousands of documents, datasets, images, and information requests they receive related to natural gas extraction on almost 200,000 acres of sagebrush habitat in the Upper Green River Basin in Wyoming.
- High-throughput and high-performance computing systems to execute analyses of vast amounts of data requiring a significant amount of calculation, including species distribution models, two dimensional (2D) three dimensional (3D) hydrodynamic numerical modeling, species trend analysis, development of bioclimatic variables, landscape-scale ecological modeling, and geostatistical simulations and analysis.

Ecosystems

Knowledge of ecological systems and their responses to natural and human stressors is a continuing key science need. It is a serious challenge to integrate multiple science disciplines to conceptualize and plan the interdisciplinary research needed to produce this knowledge right from the beginning. FORT scientists led many interdisciplinary research projects in FY11 that connected (1) human impacts, decision processes, and economic analysis and (2) data integration, analyses, and access with complex ecological studies championed by the USGS. Examples follow, organized by program focus:

Ecosystems—Fisheries: Aquatic and Endangered Resources

- Applying landscape-ecology principles to aquatic systems in the emerging field of hydroscapes (a type of landscape wherein water covers a large number of patches or large areas for long time periods), and synthesizing the processes and patterns across multiple spatial scales.
- Developing a national taxonomic and ecological database for diatoms, which are used as barometers of environmental status and change for aquatic community and ecosystem assessment.
- Using the pattern of tree ages on a flood plain to reconstruct past channel migrations and flood history and to evaluate climate-induced changes in riparian forest establishment. Shifts in



Screen capture from Diatoms of the United States Web site. USGS image.

river flow resulting from climate change are a major threat to water supplies and riverine ecosystems worldwide, so predicting flow changes and their effects on vegetation is essential to effective river management.

Ecosystems—Invasive Species

Shane Siers weighs a captured brown treesnake on Guam. USGS photo.

- Continuing field research on brown treesnakes on Guam to better inform landscape-level management plans and snake suppression, and prevention strategies. We continue to assist Guam National Wildlife Refuge and Department of Defense facilities in snake-barrier construction and maintenance as well as snake detection. The brown treesnake has extirpated most native bird species on Guam, as well as bats and lizards. Were this snake to reach and become established on the Hawaiian Islands, it could result in economic and ecological disaster.
- Ongoing development of capture tools for Burmese pythons outside of Everglades National Park in Florida, genetic identification of shed skins to determine the extent of a newly discovered Northern African python population, and analysis of a new trap type and monitoring tool. Invasive Burmese pythons are established in the greater Everglades ecosystem, grow up to 20 feet and 250 pounds, and are expanding their range in southern Florida. FORT research is focused on preventing the snakes from establishing on the Florida Keys, where they could decimate federally threatened and endangered species.
- Field and greenhouse studies addressing potential direct and indirect effects of climate change on both invasive and native riparian trees in the western United States.

Ecosystems—Status and Trends of Biological Resources

Buffered wetland. Economic studies examine the benefits of conservation practices in the Plains and Prairie Potholes Landscape Conservation Cooperative. Photo by Mark Vandever, USGS.

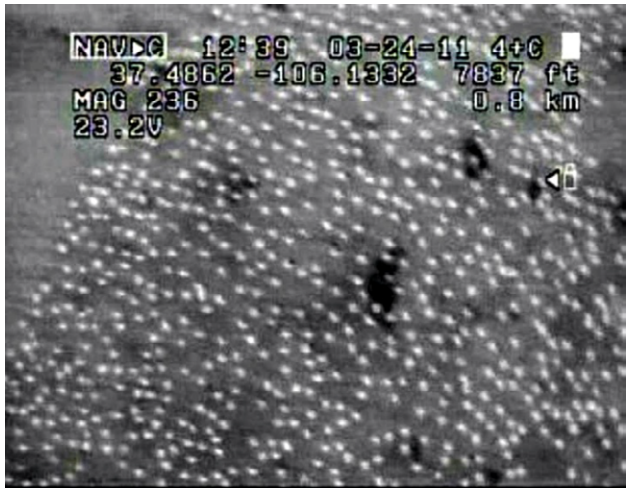
- Determining the critical loads of nitrogen deposition in mountain lakes in the Sierra Nevada, Rocky Mountains, and New England. A critical load is the input of a pollutant below which detrimental ecological effects are not observed to occur.
- Collaborating with economists from the DOI Office of Policy Analysis and the USGS Science and Decisions Center, and with economists, scientists, and land managers from BLM, NPS, U.S. Fish and Wildlife Service (USFWS), and USFS to develop case studies highlighting the

benefits to local economies of environmental restoration being conducted under the American Restoration and Recovery Act.

- Investigating the economic impacts various land uses have on rural communities in the Plains and Prairie Pothole Landscape Conservation Cooperative (PPPLCC) area. Specific activities include estimating the economic contribution of recreation and management activities taking place on perennial habitat lands in sub-regions of the Prairie Pothole Region, and highlighting the economic value of various ecosystem services produced by perennial habitat lands under various land-use scenarios.

Ecosystems—Terrestrial, Freshwater, and Marine Environments

- With the USFWS, testing small unmanned aircraft systems (UASs), or drones, to conduct non-intrusive, safe, and accurate wildlife population estimates. We completed a successful pilot project that estimated sandhill crane population abundance on migratory roost sites in the Monte Vista National Wildlife Refuge in Colorado's San Luis Valley.
- Collaborating with USGS EROS Data Center and the BLM to combine intensive, targeted field sampling with three resolutions of satellite imagery to produce detailed maps of sagebrush habitat characteristics for the entire State of Wyoming. Sagebrush ecosystems are among the most threatened habitats in North America, supporting sagebrush-obligate species of conservation concern, such as sage-grouse and the pygmy rabbit.
- Completing the first full year of operation of the John Wesley Powell Center for Analysis and Synthesis with 10 working group meetings. The Powell Center facilitates the increasingly important task of synthesizing biologic, hydrologic, geologic, geographic, social science, and economic data to address complex environmental and societal problems. Working groups have the full range of FORT technology, modeling, and data services available to them to support their work.
- Developing a multi-resource Integrated Assessment (IA) for the Wyoming Landscape Conservation Initiative (WLCI) area to inform planning and decisionmaking in southwestern Wyoming. The IA evaluates the natural, economic, and social context for energy development and other land uses, with a focus on informing conservation actions and decisions. The IA identifies areas with high potential for conservation, restoration, and/or development on both the current landscape and future landscapes.



(Left) USGS certified Raven pilot Leanne Hanson launches the drone skyward. USGS photo. (Right) Infrared image taken from the Raven A unmanned aircraft vehicle, showing concentrations of migrating sandhill cranes (white spots). USGS image.

- With the Northern Rocky Mountain Science Center, initiating a public-private partnership three Federal agencies, an NGO, and a private rancher) to investigate expanding the existing bison population (and ultimately establishing a contiguous bison herd) in Colorado's San Luis Valley. This work supports DOI's recently initiated Bison Conservation Initiative.

Ecosystems—Wildlife and Terrestrial Resources

- Developing a draft model of nesting-habitat selection by golden eagles in northeastern Wyoming, and transposing spatial data on landscapes of high value to raptors against areas with high value for energy development, including wind energy development, to identify where to target conservation.
- Continuing wild horse studies for the BLM to (1) evaluate the effectiveness of fertility control to slow population growth and (2) develop survey techniques that provide more reliable estimates of population size. The BLM will use the results of both our contraception and population estimation studies to better manage wild horse populations on western ranges within the agency's jurisdiction.
- Conducting landscape genetics studies to quantify the effect of landscape features and their juxtaposition with gene flow and spatial genetic variation to provide a better understanding of population connectivity. Current studies are looking at the relation and connectivity between important areas of sage-grouse habitat and sage-grouse populations and are investigating the impact of altered hydrology on the distribution of wood frog genetic variation in Rocky Mountain National Park.

(Above) Black-footed ferret special edition of the Journal of Mammology. (Below) Gunnison sage-grouse with GPS backpack. Photo: Doug Ouren, USGS.

Wildlife diseases continue to be a particularly critical issue to species recovery and maintenance. In addition to the direct effects of wildlife diseases on populations of at-risk species, indirect effects of wildlife lost to disease include loss of ecosystem services that benefit human health and economies, as well as increased risk of disease transmission at the human-wildlife interface. In FY11, FORT scientists developed the knowledge base and mitigating measures by:

- Expanding a video-monitoring study to better understand the causes and consequences of white nose syndrome (WNS), an emerging disease of hibernating bats causing unprecedented population declines of multiple species in North America. Additional activities at FORT include using habitat-association modeling to predict the potential spread of WNS and developing an online database for tracking the disease.
- Participating with USGS National Wildlife Health Center scientists and biologists from other State and Federal agencies to form a "science advisory team" to help plan and oversee the required safety and efficacy trials of an oral plague vaccine in the field on prairie dogs. Plague is well known for its capability to cause large-scale epidemics in humans and similarly large-scale

epizootics in rodents, and the disease is a limiting factor in the successful reintroduction of endangered black-footed ferret.

Energy and Minerals, and Environmental Health

Integrated assessment of energy and mineral resources is an explicit goal in the USGS Science Strategy and is required for understanding the full costs and benefits of developing different energy and mineral resources. Although energy development is important for the economic growth and security of the Nation, it is likely to have unintended, harmful impacts on environmental health. Two particular areas of concern are (1) the extraction of unconventional gas resources using hydraulic fracturing and (2) wind-energy development. Several FY11 activities addressed these issues:

- A USGS Powell Center working group, led by FORT, that is conducting the first broad-scale, data-driven assessment of hydraulic fracturing's potential effects on U.S. water resources.
- Measuring contaminant exposure in riparian food webs of the lower Manistique River and Harbor in Michigan using sentinel species such as spiders to support remediation and restoration by the U.S. Environmental Protection Agency (EPA).
- Establishing a "Living Stream" laboratory facility at FORT for conducting a variety of experiments on lake, stream, and riparian ecosystems. Capabilities and planned work include investigating (1) the effects of climate change on stream chemistry and chemical exposure, (2) pathways of organism and contaminant movement between aquatic and riparian ecosystems, and (3) effects of contaminants (such as ash and fire retardants following forest fires) on stream communities.
- Conducting studies to address questions concerning the unprecedented mortality of migratory tree-roosting bats at wind turbines, including the origins of bats killed by turbines, whether bats are attracted to turbines, if mating and/or feeding behaviors play a role in fatalities, and how risk to bats might be predicted before turbines are built.
- Developing a draft model of nesting-habitat selection by golden eagles in northeastern Wyoming and transposing spatial data on landscapes of high value to raptors against areas with high value for energy development, including wind-energy development, to identify where to target conservation measures.

(Left) Jonah gas field, 2007, Sublette County, Wyo. Photo: Stephen Germaine, USGS. (Right) Sampling contaminated sediments in a backwater of the Manistique River in Michigan. Photo: David Walters, USGS

Water

Historically, "instream flows" have focused on annual minimum flows, but the pattern of flows both within and across years is extremely important in determining instream habitat quality for a variety of native fish, mussels, and invertebrates, as well as for invasive species. The pattern is also very important from the standpoints of geomorphology, bed movement, establishment of riparian vegetation, and water quality. In addition, predicting future flows and water quality due to energy development, climate change, changing agricultural practices, and increased domestic demand will be important. FORT has a 35-year history addressing these important issues. Although supported by funding from other mission areas, a number of FY11 accomplishments address key aspects of the Water science strategy as can be seen in the Water cross-reference column of table 1. A few examples described in previous sections include:

- Floodplain studies addressing the effects of climate change on both invasive and native riparian trees along rivers in the western United States.
- Applying landscape-ecology principles to aquatic systems in the emerging field of hydroscapes.
- Measuring contaminant exposure in riparian food webs of the lower Manistique River to support remediation and restoration by the EPA.
- A USGS Powell Center working group conducting the first broad-scale, data-based assessment of hydraulic fracturing's potential effects on water resources in the United States.
- Establishing a "Living Stream" laboratory for conducting a variety of experiments on lake, stream, and riparian ecosystems.
- Developing high throughput computing and high performance computing systems to perform analyses requiring a significant amount of calculation and data including 2D/3D hydrodynamic numerical modeling.

For the Rest of the Story…

The science accomplishments highlighted above represent just a few of the FORT activities associated with or supportive of each Mission Area. As table 1 and this summary show, results from the studies supported by one Mission Area often have implications across other Mission Areas as well. For summaries of each of the FY11 accomplishments selected for reporting this year, please refer to ***Appendix 1. FORT Science Accomplishments.*** Publications and products are listed in ***Appendix 2. FORT Publications and Other Products Issued in FY2011***.

David B. Hamilton

David B. Hamilton
Director, Fort Collins Science Center
August 20, 2012

Table 1. USGS Mission Areas and Programs supported by FY11 Fort Collins Science Center (FORT) scientific and technical accomplishments, as reported in this document. Task accomplishments are listed by their primary USGS Mission Area (and under the Ecosystems Mission Area, which supports the bulk of our research, also by Program). Click the accomplishment title to jump to its summary. To return to the table, hold down the Alt button and click the left arrow key: <ALT ←>.

Accomplishment Title by USGS Mission Area or Ecosystems Mission Area Program	Mission Areas Addressed					
	Eco-systems	Climate and Land-Use Change	Energy and Minerals, and Env. Health	Natural Hazards	Water	Core Science Systems
Administrative and Enterprise Information						
Using Information Technology to Increase Science Efficiency and Security						✔
Climate and Land-Use Change						
Supporting the Great Plains Landscape Conservation Cooperative	✔	✔	✔			✔
The Users, Uses, and Value of Landsat Imagery		✔				
The Western Mountain Initiative: Forest Ecosystem Responses to Climate Drivers in the Southern Rocky Mountains	✔	✔				
Core Science Systems						
Scientific Breakthroughs: The John Wesley Powell Center for Earth System Analysis and Synthesis	✔	✔	✔	✔	✔	✔
ScienceBase Data Repository and Catalog	✔			✔	✔	✔
Landscape Conservation Management and Analysis Portal (LC-MAP)	✔	✔				✔
Landscape Energy Action Plan Support (LEAP)	✔					✔
Pinedale-Anticline Data Management System (PADMS)	✔		✔			✔
The Use of High Throughput Computing for USGS Core Sciences Research	✔	✔			✔	✔
The Development and Application of Derived Bioclimatic Variables from Climate Normals and Time-Series Data	✔	✔				✔

Accomplishment Title by USGS Mission Area or Ecosystems Mission Area Program	Mission Areas Addressed					
	Eco-systems	Climate and Land-Use Change	Energy and Minerals, and Env. Health	Natural Hazards	Water	Core Science Systems
Geospatial Data Development of Wyoming Roads	✔					✔
Rediscovering the Oregon, California, Mormon Pioneer, and Pony Express National Historic Trails		✔				✔
Ecosystems—Fisheries: Aquatic and Endangered Resources (FAER)						
Developing a SmartRiverGIS Application for 2D Aquatic Habitat Modeling	✔					✔
Developing a National Taxonomic and Ecological Database for Diatoms	✔	✔			✔	✔
Processes and Patterns in Hydroscapes: Fragmentation, Domestication, and Consequences	✔	✔			✔	
Statistical Improvements for Estimating Body Condition of Fish	✔					
Ecosystems—Invasive Species						
Control of Invasive Giant Constrictor Snakes in Florida	✔					
Control and Prevention of the Invasive Brown Treesnake	✔					
Brown Treesnake Rapid Response Team	✔					
Potential Effects of Climate Change on Invasive and Native Riparian Plants in the U.S. West	✔	✔			✔	
Resource for Advanced Modeling and Software for Assisted Habitat Modeling	✔	✔				
Ecosystems—Status and Trends of Biological Resources						
Assessing Visitor Experience on National Wildlife Refuges	✔					✔
Monitoring Seasonal Change: Using Remote Sensing to Measure Year-to-Year Vegetation Variation at National Parks	✔	✔				
Science in Support of Policy: Identifying Air-Pollutant Critical Loads for Lakes	✔	✔				
Assessing Socioeconomic Planning Needs (ASPN)	✔					✔

Accomplishment Title by USGS Mission Area or Ecosystems Mission Area Program	Mission Areas Addressed					
	Eco-systems	Climate and Land-Use Change	Energy and Minerals, and Env. Health	Natural Hazards	Water	Core Science Systems
Assessing the Economic Impacts of Perennial Habitat Lands to Nearby Rural Communities in the Prairies: Potential Rural Development in the Face of Global Economic and Climate Changes	✔					
The Benefit Transfer and Visitor-Use Estimating Models Toolkit	✔					
Economic Contribution of Federal Investments in Restoration of Degraded, Damaged, or Destroyed Ecosystems	✔		✔			
Assessment of Iowa CREP Wetland Buffers	✔					
Evaluation of Limited Grazing on CRP in the Shortgrass Steppe	✔					
Do Natural or Restored Wetlands in Agricultural Landscapes Facilitate Source or Sink Amphibian Populations?	✔				✔	
Assessment of the Mexican Wolf Reintroduction Project	✔					
Negotiation Training	✔					
Ecosystems—Terrestrial, Freshwater, and Marine Environments						
Sandhill Cranes in Colorado's San Luis Valley: Exploring New Technology for Improved Population Assessments	✔	✔				
Landscape-Scale Sagebrush Habitat Mapping and Monitoring	✔	✔				
Integrated Assessment for the Wyoming Landscape Conservation Initiative	✔	✔	✔	✔	✔	✔
Assessing Effects of Energy Development in Colorado and New Mexico	✔	✔	✔		✔	✔
Reconstructing Flood History from Tree Rings	✔	✔			✔	
Managing Public Access as an Adaptive Wildlife Management Tool: Impacts of OHV Use on Elk	✔		✔			✔
Gunnison Sage-Grouse Habitat Use and Movement: The Crawford Population	✔	✔	✔			✔

Accomplishment Title by USGS Mission Area or Ecosystems Mission Area Program	Mission Areas Addressed					
	Eco-systems	Climate and Land-Use Change	Energy and Minerals, and Env. Health	Natural Hazards	Water	Core Science Systems
Developing a Public–Private Partnership to Support Potential Bison Restoration in the San Luis Valley, Colorado	✔					
Sulfur Biogeochemistry of Aquatic Ecosystems	✔				✔	
Ecosystems—Wildlife and Terrestrial Resources						
Field Testing an Oral Plague Vaccine for Prairie Dogs	✔					
Commemorating the 30th Anniversary of Re-discovery of Black-footed Ferrets	✔					
Evaluating Habitat Objectives in Comprehensive Conservation Plans for National Wildlife Refuges	✔					
Ecological Investigations of White-Nose Syndrome in Bats	✔					
Investigating Causes and Consequences of Bats Fatalities at Wind Turbines	✔	✔	✔			
Bats of Ouray National Wildlife Refuge, Utah	✔					
The Ecological Role of Bats as Reservoirs of Rabies Viruses: Final Mathematical Model	✔					
Population Size of Island Loggerhead Shrikes on Santa Rosa and Santa Cruz Islands	✔					
Science in Support of Wild Horse Management	✔					
Food Webs and Nutrition Inferred from Stable Isotopes	✔	✔				
Re-examining Genetic Patterns in Sage-Grouse Using Genomic Methods	✔					
Landscape Genetics: Integrating Population Genetics and Landscape Ecology	✔					
Assessing Greater Sage-Grouse Population Connectivity Using Genetic Approaches	✔	✔	✔			
Mapping Seasonal Habitats for Greater Sage-Grouse in Wyoming	✔	✔	✔			

Accomplishment Title by USGS Mission Area or Ecosystems Mission Area Program	Mission Areas Addressed					
	Eco-systems	Climate and Land-Use Change	Energy and Minerals, and Env. Health	Natural Hazards	Water	Core Science Systems
Identifying Crucial Nesting Habitat for Gunnison Sage-Grouse	✔	✔				
Raptors and Wind Development: Developing Science-based Conservation Tools	✔	✔	✔			
Using LiDAR to Measure Sagebrush Vegetation	✔	✔	✔			
Pygmy Rabbits and Gas Field Development in Wyoming	✔	✔	✔			
Integrated Monitoring to Support the Wyoming Landscape Conservation Initiative	✔	✔	✔		✔	✔
Wyoming Basins Ecoregional Assessment	✔	✔	✔			
Energy and Minerals, and Environmental Health						
Assessing Potential Effects of Hydraulic Fracturing for Energy Development on Water Resources	✔		✔		✔	✔
Distribution of Infrastructure and Invasive Plants in Southwestern Wyoming	✔	✔	✔			✔
Aquatic Experimental Laboratory Capabilities Developed at FORT	✔	✔	✔		✔	
Quantifying Biological Fluxes of Stream Metals to Terrestrial Food Webs	✔	✔	✔		✔	
Using Spiders to Track Ecosystem Exposure to Contaminants	✔		✔			
Natural Hazards						
USGS Twitter Earthquake Dispatcher (@USGSted)				✔		✔

Appendix 1. FORT Science Accomplishments for FY11

Highlights of FORT project accomplishments in FY11 are described below grouped under the specific USGS Mission Area (and within Ecosystems, the science program) with which each task is most closely associated, although there is considerable overlap. The work of FORT's six branches (Aquatic Systems, Ecosystem Dynamics, Information Science, Invasive Species Science, Policy Analysis and Science Assistance, and Trust Species and Habitats) often involves major partnerships with other agencies and cooperation throughout the USGS across its Mission Areas, geographic areas, and science centers. These are noted using the following symbols:

 = major collaborative venture

 = integrated science projects across USGS Mission Areas

= new science direction

Administrative and Enterprise Information

Using Information Technology to Increase Science Efficiency and Security

During FY11, FORT's Computer Operations Team continued to support the Information Technology (IT) Transformation goals of the U.S. Department of the Interior (DOI) in areas such as virtualization (servers and desktops), continuous monitoring (that is, Cyberscope compliance) and malware protection. As FORT's Computer Operations Team improves and implements leading-edge IT, they also share successes with other agencies, with the sole goal of helping other USGS offices and DOI Bureaus gain the same benefits for their scientists and users.

FORT's Computer Operations Team completed its goal of having over 95 percent of FORT's servers virtualized by the end of 2011. Overall, FORT now has over 50 virtual servers (that as physical servers would take up over 4 racks) and is down to 5 physical servers (taking up about 25 percent of 1 rack). This has greatly reduced power consumption, server life-cycle costs, and server-room cooling requirements. Staff hours dedicated to system maintenance have decreased considerably as a result. Return on investment was immediate and is saving funds every year that can now be directed towards other initiatives and science. Additionally, the FORT Computer Operations Team has begun extending virtualization to user desktops using VmWare View 5.x. When completed, this technology will allow users to access any information or application they use in the office from anywhere, using any device, while ensuring high levels of security and avoiding a complicated system infrastructure in the backend. The FORT Computer Operations Team demonstrated this technology in two 3-hour, hands-on classes for multiple DOI Bureaus in FY11, as well as to representatives from USDA and the U.S. Army.

FORT's Computer Operations Team also presented a webinar for government agencies concerning efficient, continuous, secure, and rapid monitoring of Federal IT assets, which will result in higher compliance with Federal IT rules (Cyberscope) while reducing staff hours and freeing up dollars to other needed areas in the Federal government. We also helped DOI's Office of Special Trustee (OST) implement the same solution, which allowed OST to rapidly deploy the solution across their entire Bureau in a few hours. Results were immediate, real-time reporting, patching, and compliance information in a single, centralized console. At the end of FY11, FORT and OST were the only organizations in DOI that were able to consistently and easily upload real-time mandated security information to the Department of Homeland Security's Cyberscope portal, according to DOI personnel responsible for monitoring and tracking DOI submissions to Cyberscope. The solution allows centralized, real-time asset inventory and auditing; real-time patching of all operating systems, including third-party software; Federal compliance-checking on all operating systems (Windows, Linux, Mac, and Solaris); real-time power management; monitoring, compliance enforcement, and reporting for Federal information system security controls (including custom security-control checklists); mobile device management; antivirus monitoring and compliance; and software license tracking and reporting.

The FORT Computer Operations Team also worked with the local U.S. Fish and Wildlife Service (USFWS) IT team, co-located at the FORT headquarters building, and successfully completed a project to combine multiple network circuits (USGS DS3 lines and USFWS T1 lines) into a single, shared 20-megabit DS3 circuit. This greatly increased bandwidth for both USFWS and USGS while saving money and maintaining network security requirements for both the USFWS and USGS.

Overall, FORT's Computer Operations Team is investigating and implementing leading-edge technologies that can be scaled to other user groups with a potential goal of helping all offices within DOI meet their IT consolidation and IT efficiency strategies. Initiatives such as continuous monitoring/compliance, server and desktop virtualization, and circuit consolidation are all examples of how our team is continually working to modernize DOI mission support with 21st Century IT.

Contact: *Jeff Schafer*

Climate and Land-Use Change

Supporting the Great Plains Landscape Conservation Cooperative

The Great Plains Landscape Conservation Cooperative (GPLCC) is a partnership that provides applied science and decision-support tools to assist natural resource managers in conserving plants, fish, and wildlife in the mid- and short-grass prairie of the southern Great Plains. It is part of a national network of public-private partnerships, known as Landscape Conservation Cooperatives (LCCs), that work collaboratively across jurisdictions and political boundaries to leverage resources and share science capacity. The GPLCC identifies science priorities for the region and helps foster science that addresses these priorities, thus supporting wildlife conservation efforts throughout the Great Plains. It also assists partners in building their own capacity to address scientific challenges associated with our rapidly changing environment.

FORT is supporting the GPLCC with three projects initiated in FY11:

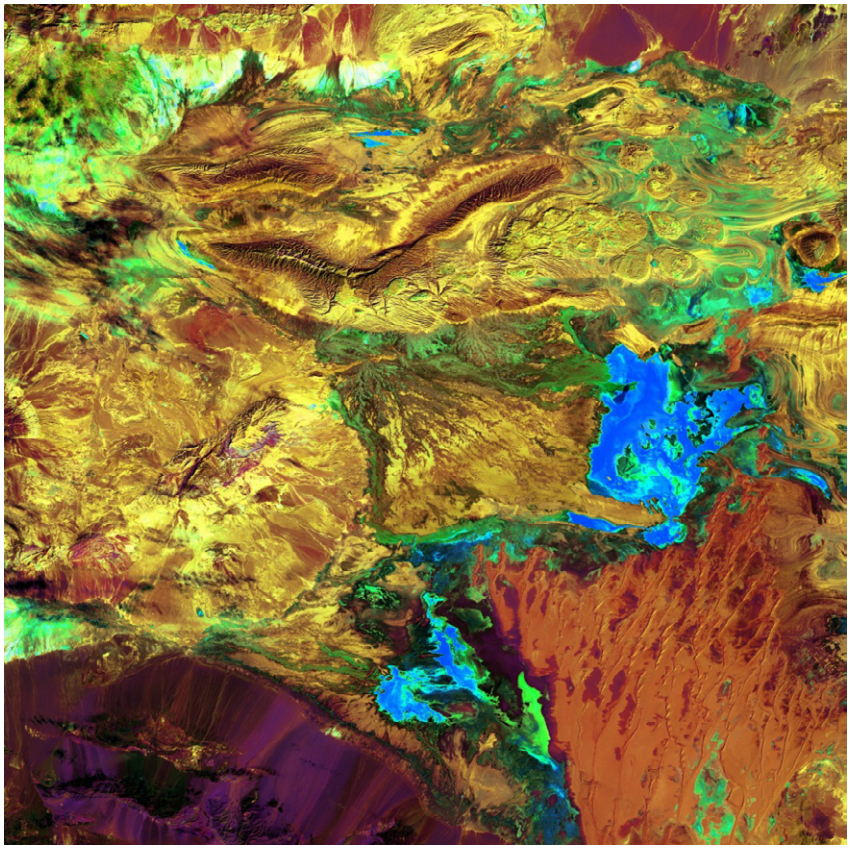
- A landscape assessment of the relations among land use, surface-water and groundwater hydrology, and wildlife habitats in the Southern Great Plains Region and an associated broad-perspective, decision-support tool for managing ecosystems and wildlife. Specific objectives are to (1) identify and characterize associations between habitat conditions and surface and sub-surface patterns and processes; (2) identify risks and direct threats to ecosystems, priority species, water quantity, and water quality due to overlap and/or interactions with human land-use patterns such as energy development, habitat conversion, fragmentation, and hydrologic stress; (3) identify and characterize areas with particular values and opportunities for conservation, restoration, or amended management practices to improve land use, hydrology, and habitat conditions; and (4) integrate representative data and statistical models for ready application by managers and conservation planners in a geographic information system (GIS).
- A network analysis of playas and other wetlands in the GPLCC under various future scenarios, including climate change, and a valuation of the ecosystem goods and services (such as water storage, biodiversity, carbon sequestration, aquifer recharge, water quality, and others) provided by playas and other wetlands in the GPLCC under similar scenarios. This work is being done in collaboration with the USGS Cooperative Research Unit at Kansas State University.
- Development of the *Landscape Conservation Management and Analysis Portal (LC-MAP)*, a Web-based system that allows State, Federal, university, and nongovernmental-organization partners in the Great Plains Landscape Conservation Initiative to securely share, access, and analyze datasets and information.

Clockwise from top left: Lesser prairie chicken (U.S. Fish and Wildlife Service photo); screen capture from LC-Map (USGS image); wind turbines (U.S. Department of Commerce photo); shortgrass prairie (GPLCC photo).

Contact: *Dave Hamilton*

The Users, Uses, and Value of Landsat Imagery

The currently operating Landsat satellites provide high-quality, multi-spectral, moderate-resolution imagery of urban, rural, and remote lands for all areas of the world. Although the imagery has been applied in a variety of research areas like global climate research, agriculture, and environmental management, little is known about how private businesses, nonprofit organizations, tribes, and State and local governments actually use and value the availability of Federally sponsored, moderate-resolution land imaging. In FY11, FORT social scientists reported the results of an extensive 2009 survey conducted for the USGS Land Remote Sensing Program on the users, uses, and value of Landsat imagery. Along with the publication of the final report, presentations of the results were given at the annual meeting of the Association of American Geographers in Seattle, Wash., in April 2011, and at the USGS Workshop on the Role of Economics in Reston, Va., in June 2011. We also developed and served a Web feature (*www.fort.usgs.gov/landsatsurvey*) that presents the background of the study, survey results, and more information about our survey methods. The USGS Land Remote Sensing Program is using the study results to inform delivery of the products and services related to Landsat imagery and to understand how and why the imagery is important to users in decisionmaking.



Landsat image of Dasht-e Kavir, or Great Salt Desert, Iran. Image from Earth as Art collection by USGS Earth Resources Observation and Science Center.

Product:

Miller, H.M., Sexton, N.R., Koontz, Lynne, Loomis, John, Koontz, S.R., and Hermans, Caroline, 2011, *The users, uses, and value of Landsat imagery and other moderate-resolution satellite imagery in the United States—Executive report*: U.S. Geological Survey Open-File Report 2011–1031, 42 p.

Contact: *Holly Miller*

The Western Mountain Initiative: Forest Ecosystem Responses to Climate Drivers in the Southern Rocky Mountains

Climate-induced changes in water dynamics are beginning to affect mountain ecosystem processes in the western United States as pervasive warming drives increased drought stress. Cascading effects on forest ecosystems include increasing vegetation mortality, die-off of entire forest stands, longer and more intense fire seasons, and increasing susceptibility to insect outbreaks. Over the past decade, these trends have been particularly evident in montane forests of the U.S. Southwest, where warm droughts are resulting in widespread tree mortality. Climate projections suggest that these phenomena will become more pronounced in the Southwest. Improved understanding of how mountain ecosystems respond to climate change is essential for successful natural resource management, and taking climate effects into consideration during management planning and implementation will reduce surprises and damage to natural resources.

The USGS, including FORT, the Western Ecological Research Center, and the Northern Rocky Mountain Science Center, has been collaborating with the U.S. Forest Service, National Park Service, Los Alamos National Laboratory, and university scientists from across the West and around the world associated with long-term, global change research. Together they are addressing these and related issues through an integrated project, "The Western Mountain Initiative (WMI): Vulnerability and Adaptation to Climate Change in Western Mountain Ecosystem." Initiated in 2003, the WMI conducts long-term studies centered on national parks and forests in the Sierra Nevada, Cascade Range, and Rocky Mountains. Our objective is to synthesize and integrate data and other information to provide perspectives on how climate variability and change are affecting disturbance regimes, vegetation dynamics, and hydrologic processes across the West. FORT scientists based at the Jemez Mountains Field Station, located at Bandelier National Monument in New Mexico, have been focusing on the southern Rocky Mountains. Specifically, we are studying recent changes in long-term patterns of disturbance processes; forest growth; dynamics of change in vegetation cover; interactions among broad-scale forest die-off, fire, and insect outbreaks; and the variability of these disturbances across time, space, and land use.

In 2011, we continued our research on drought-caused tree mortality, fire history, and fire effects, and we co-organized a week-long workshop for land managers in northern New Mexico on adapting to climate change. We also provided extensive emergency support to interagency land managers responding to the high-severity Las Conchas Fire, which burned 156,000 acres in the Jemez Mountains, including 60 percent of Bandelier National Monument. Overall, our work is advancing the scientific community's understanding of how global climate change is affecting forests and disturbance processes that drive these ecosystems. The products and results of our work are being used by agencies and organizations throughout the world to inform policy and management.

Research community concern over [drought and heat anomalies implicated in tree die-offs, reported by Allen et al. 2010] subsequently rocketed: in June 2011 Science Watch Essential Science Indicators (http://www.sciencewatch.com/dr/tt/2011/11-juntt/) identified the Top Topic for the March 2005–February 2011 interval in "Environment/Ecology" as "global-change-type drought," "drought-induced tree mortality," "heat-induced tree mortality," and associated terms; additionally, Allen et al. (2010) shot to the most cited paper of the past five years in Forest Ecology and Management within ~18 months following publication with already >100 citations. —Dr. David Breshears, University of Arizona, January 2012

Products:

Wilson, J.T., and C.D. Allen,. 2011, Seeing the forest and the trees—USGS scientist links local changes to global scale: Fort Collins, Colo., USGS Fort Collins Science Center. Web feature, *http://www.fort.usgs.gov/CAllen/*.

Williams, A.P., Allen, C.D., Swetnam, T.W., Millar, C.I., Michaelsen, J., Still, C.J., and Leavitt, S.W., 2010, *Forest responses to increasing aridity and warmth in southwestern North America*: Proceedings of the National Academy of Sciences U.S.A., v. 107, p. 21289–21294.

Adams, H.D., Luce, C.H., Breshears, D.D., Weiler, M., Hale, V.C., Allen, C.D., Smith, A.M.S., and Huxman, T.E., 2011 (online), *Ecohydrological consequences of drought- and infestation-triggered tree die-off—Insights and hypotheses*: Ecohydrology, v. 5, no. 2, p. 145–159.

Contact: *Craig Allen*

Core Science Systems

Scientific Breakthroughs: The John Wesley Powell Center for Earth System Analysis and Synthesis

We are drowning in information, while starving for wisdom. The world will henceforth be run by synthesizers, people able to put together the right information at the right time, think critically about it, and make important choices wisely.

—E.O. Wilson, 1988

Housed at the USGS Fort Collins Science Center (FORT), the John Wesley Powell Center for Earth System Analysis and Synthesis (*http://powellcenter.usgs.gov*) addresses this prognostication of Dr. Wilson and completed its first full year of operation in FY 2011. Five new Working Groups were selected (in addition to the four initiated in the 2009–2010 pilot study years) through peer-review by the Science Advisory Board. The Powell Center facilitates the important task of synthesizing biologic, hydrologic, geologic, geographic, and socioeconomic data to address complex environmental and societal problems. The Center encourages use of USGS databases to create new knowledge and tools, offers the opportunity to focus on complex earth system and natural resource questions, and supports scientist-initiated interdisciplinary activities.

In addition to hosting 10 Working Group meetings and one preparatory workshop, we expanded our computing capabilities in conjunction with FORT to provide shared disk space of at least one terabyte capacity, licenses for geographic information systems (ERDAS, ENVI, and ArcGIS), and statistical software for Working Group members. We now offer cloud computing capabilities for a number of complex models requiring ever-larger datasets, and we are working to accommodate more model frameworks. Working Groups appreciate access to our state-of-the-art computing capability.

Current Working Groups represent a broad range of earth system sciences and offer post-graduate Powell Center Fellows and Mendenhall Fellows opportunities to enrich their experiences through collaborative and interdisciplinary research.

On the first day of our workshop I got one of those rare, treasured 'Aha!' moments — an epiphany that gave me a deep new insight into tree mass growth. This sudden breakthrough simply wouldn't have happened without the engaged and focused discussion of the workgroup members.

—Nate Stephenson, USGS

John Wesley Powell historic photo composite. Carol Quesensbury, USGS.

Contact: *Jill Baron*

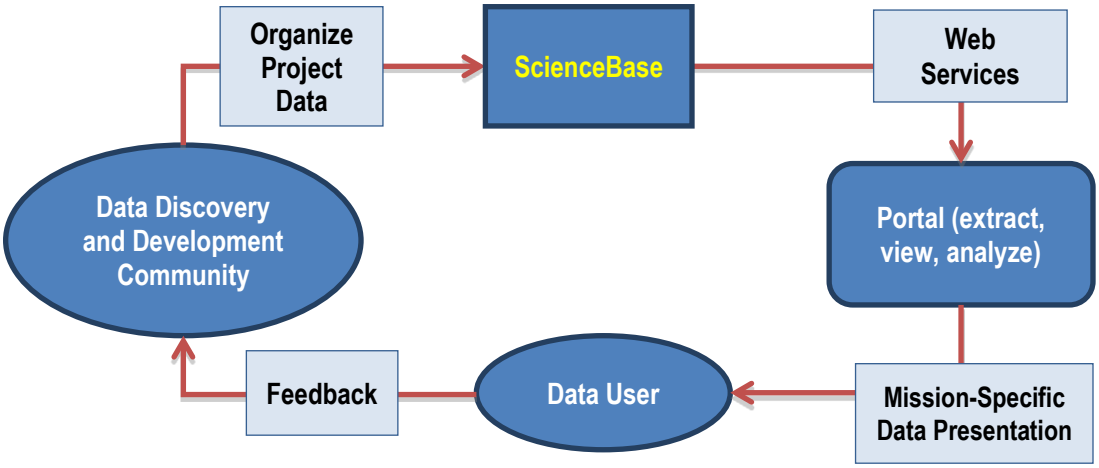
ScienceBase Data Repository and Catalog

ScienceBase is a USGS-led, collaborative scientific data- and information-management platform used directly by science teams. The challenge for 2011 was to begin to move the product from proof of concept to enterprise tool. In FY11, the FORT Applications Development Team accomplished these activities:

- A user can now upload information directly into the catalog. This was a major integration of a separate uploader tool into ScienceBase. Now the workflow of adding data to the catalog so that others may take advantage of it is seamless.
- The initial Web-page layout was revamped to look and act more like Google. Nearly everyone likely to use ScienceBase knows how to Google, so arranging the ScienceBase page to work in the same way makes the application easy to use. We also added an "Advanced Search" to narrow down search results and a folder tree organization that allows communities to organize their uploaded data just like on a local hard drive.
- The users of other Web applications find it useful to be able to search for and display ScienceBase results inside these other applications. ScienceBase's "RESTful" Web services now provide a programmatic way to search for and return catalog items. These results are delivered in either the XML or JSON code formats.
- ArcGIS professionals can now load complex maps into ScienceBase using an ESRI technology called "map packages." When a map-package catalog item is retrieved, the user not only sees the map but can also manipulate it. This allows any user to see and work with geospatial data within ScienceBase.
- We continued improved support for the workflow of scientific data. As the diagram below demonstrates, ScienceBase is the collaboration, data collection, and data publication "glue" that enables a science team to execute a project and make results available globally.

The ScienceBase global catalog is available to anyone at *http://www.sciencebase.gov*. ScienceBase is now the collaboration tool of choice for the multi-agency Landscape Conservation Cooperatives, the USGS National Climate Change and Wildlife Science Center, and a growing number of DOI Climate Science Centers.

The USGS Mission Area of Core Science Systems calls for us to make information available. In today's electronic world, stability, quality, and ease of use are paramount to the effective use of software tools. We made significant strides in 2011 to improve ScienceBase and match industry standards while also providing an infrastructure, security, and work flow that support the scientific review process. By investing in ScienceBase, the USGS has provided a "one-stop shop" for scientific data collaboration within a project team as well as publication of the resulting data into the global catalog for the use of the global scientific community.



Schematic of the ScienceBase work flow. USGS image.

Contact: *Tim Kern*

Landscape Conservation Management and Analysis Portal (LC-MAP)

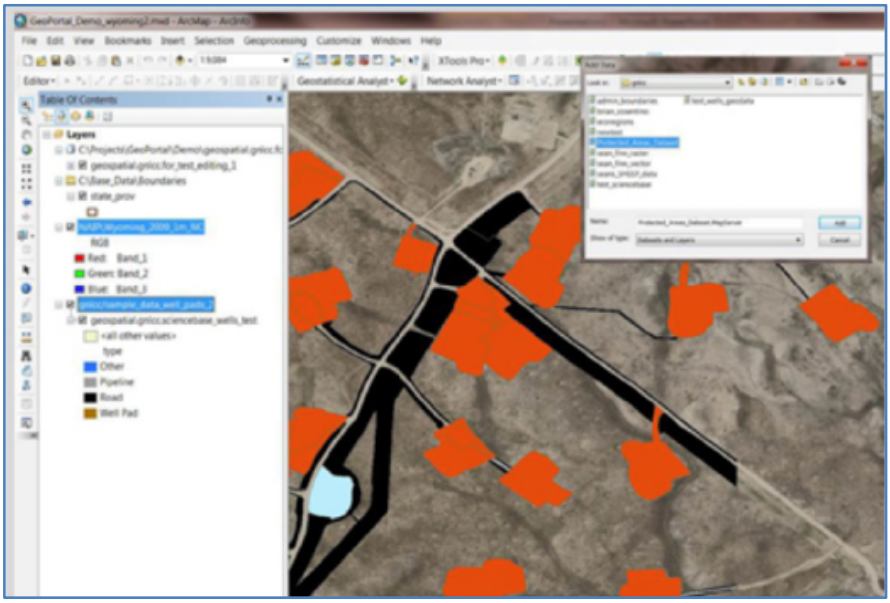
The Great Northern Landscape Conservation Cooperative (GNLCC) faced a daunting challenge: how to capture, assess, manage, and integrate hundreds of datasets over a vast area. While the GNLCC could take advantage of some of the data-portal options available through USGS, they needed a way to let a network of analysts in different locations work on spatial datasets to build an integrated picture of the GNLCC as a whole. The analysts came from state, local, Canadian provincial, and U.S. Federal government agencies as well as non-governmental groups.

In 2010–2011, the FORT Applications Development Team worked with GNLCC and the USGS ScienceBase project to build the Landscape Conservation Management and Analysis Portal (LC-MAP). The application provides a collaborative virtual workspace allowing GNLCC partners, regardless of their agency affiliation, to securely share, access, and analyze common datasets and information to further coordinate research, management, and resource conservation. Project-level research, dataset development, and modeling can occur in a secure virtual workspace where multiple partners can discover, assess, edit, analyze, and model common data themes in near real-time. All GNLCC partners can safely store their data, control access, and develop metadata using customized, intuitive data documentation tools.

We built LC-MAP on the USGS ScienceBase project, an open-source, scientific-data management and integration system that employs Web-service communications to display and transfer data in a variety of formats. ScienceBase allows the GNLCC to take advantage of data discovery and management features developed for other user groups, as well as data storage, delivery, and notification features. For LC-MAP, we took advantage of the infrastructure provided by ScienceBase and added analysis and modeling components to the application. The core of the LC-MAP addition is the GIS Shared Work Environment. This allows users to do real-time distributed research collaboration on GIS layers and geodatabases. ScienceBase then provides tools to capture metadata, develop new and derived spatial layers, and publish completed datasets.

The Web Service features facilitate tracking and versioning of workflows. This allows geographically dispersed collaborators to work in a shared, virtual environment, editing project datasets, implementing spatial models, and publishing results to online portals and mappers. The GNLCC implemented the GIS Share for multijurisdictional and international dataset collaboration and layer development.

LC-MAP builds new capability into ScienceBase, a core USGS Community for Data Integration project. All ScienceBase users can take advantage of the technology and components contributed by LC-MAP.



Screen capture from the Landscape Conservation Management and Analysis Portal. USGS image.

Contact: *Tim Kern*

Landscape Energy Action Plan Support (LEAP)

The U.S. Fish and Wildlife Service (USFWS) receives thousands of requests per year for new energy development and transmission projects. These requests require extensive environmental review. The USFWS discovered that many of these proposals fell in areas of significant resource sensitivity, an area that the project proponent would undoubtedly not have chosen to develop if they had known the costs and restrictions in advance. The USFWS needs to encourage project proponents to site projects in less restricted and sensitive areas.

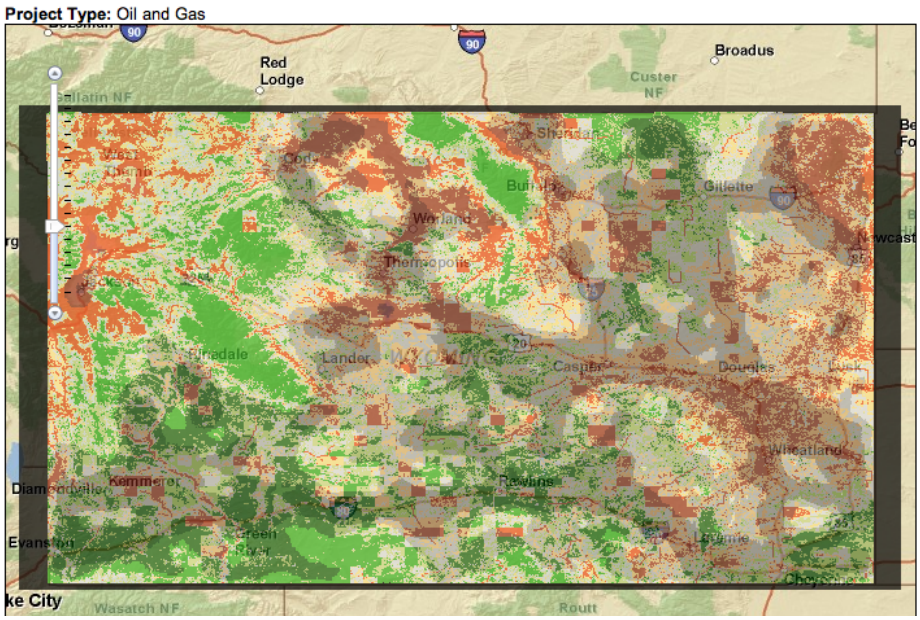
The FORT Applications Development Team is working with the USFWS Mountain-Prairie Region, the USFWS Washington Office, and NatureServe to build a way for USFWS Field Offices to perform and share landscape-vulnerability assessments. Working with the Landscape Energy Action Plan (LEAP), FORT developed methods to deliver office-specific base data to offices for assessments, and then provided a manageable repository for assessment outputs. FORT also designed and implemented ways to deliver the appropriate assessment results to USFWS portals. Project proponents can identify areas that are likely to be a regulatory problem before investing too many resources, and they can view the data that fed the assessment.

LEAP is built on the USGS ScienceBase project, an open-source Scientific Data Management and Integration system that employs Web-service communications to display and transfer data in a variety of formats. ScienceBase allows USFWS Field Offices to take advantage of both data discovery and management features developed for other user groups as well as data storage, delivery, and a GIS shared-work environment (GIS Share). LEAP extended the GIS Share to include geoprocessing capability, thereby refining the Web service outputs provide by ScienceBase.

The LEAP workflow employs some of the concepts developed for the Wyoming Landscape Conservation Initiative, stacking spatial data layers to develop resource-vulnerability scenarios. USFWS Field Offices submit model outputs and develop metadata using LEAP tools. USFWS portals allow project proponents to enter their project information and then query LEAP for assessments that overlap with the area and topic of concern. LEAP delivers both map and text outputs that can be embedded into USFWS portal pages.

Although this particular system was built for USFWS Field Offices and Web portals, the conceptual framework could be used for any landscape-assessment project.

LEAP augments ScienceBase capabilities, a core USGS Community for Data Integration project. The Wyoming Landscape Conservation Initiative (WLCI) and the Energy and Environment in the Rocky Mountain Area (EERMA) projects (see p. 65) both employ aspects of the capabilities developed through LEAP.



Screen capture from the Landscape Energy Action Plan. USGS image.

Contact: *Tim Kern*

Pinedale-Anticline Data Management System (PADMS)

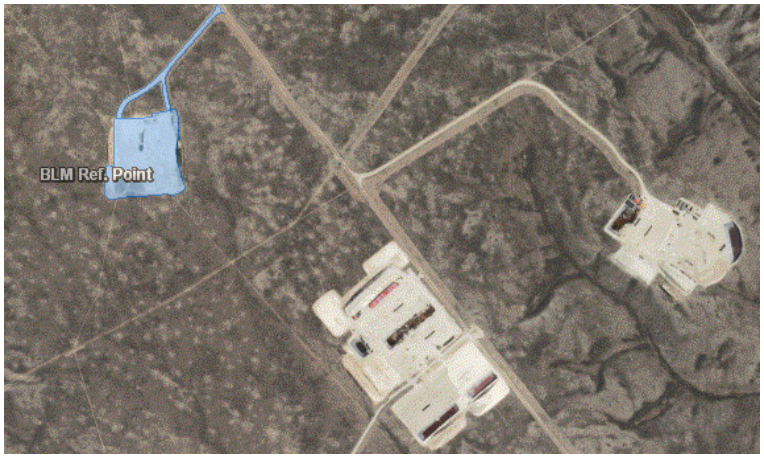
The Pinedale-Anticline Project Office manages almost 200,000 acres of sagebrush habitat in the Upper Green River basin in Wyoming. As the lead agency, the Bureau of Land Management (BLM) receives thousands of documents, datasets, images, and requests for information on natural gas extraction activities in the area. The BLM needs innovative ways to manage these items and track reclamation progress toward meeting natural resource goals.

To assist the BLM with this data-management challenge, the FORT Applications Development Team built a Web-based application that collects information the BLM will use to assess reclamation efforts and determine whether (1) interim and long-term requirements and criteria are being met, (2) reclamation and monitoring protocols are providing appropriate and sufficient information, and (3) data are being collected as specified. The system, the Pinedale-Anticline Disturbance Tracking System (PADMS), supports reclamation decisionmaking and trend evaluation associated with oil and gas activities in the Pinedale-Anticline fields in near real-time.

In addition to storing area-specific data, the application compiles summary information across all disturbed areas. This allows users to view information on a selected area, a selected gas company, and the entire field. These features will enable the BLM to evaluate large amounts of data and derive information that was previously unavailable, such as total acreage impacted, spatial changes over time, habitat fragmentation, stage of reclamation by pad or as a summary, and success of reclamation efforts.

The application employs a suite of open-source, Java-based products to allow users to upload batches of GIS datasets, spreadsheets, images, and support documents and to have these items automatically processed and spatially referenced. Users access the application through secure Internet and Web protocols. Authorized users can access data through their local ArcGIS via secure spatial Web services. This means that every BLM field office and partner organization can access and work with PADMS data using software tools on their own computers. Also, the public can view summary statistics and maps of disturbed and reclaimed areas.

The basis for this effort, automated batch spatial-dataset processing, is identical to the methods employed in the USGS ScienceBase platform. The data collected is available to all USGS researchers through the ScienceBase-integrated Web services.



Screen capture from the Pinedale-Anticline Data Management System. USGS image.

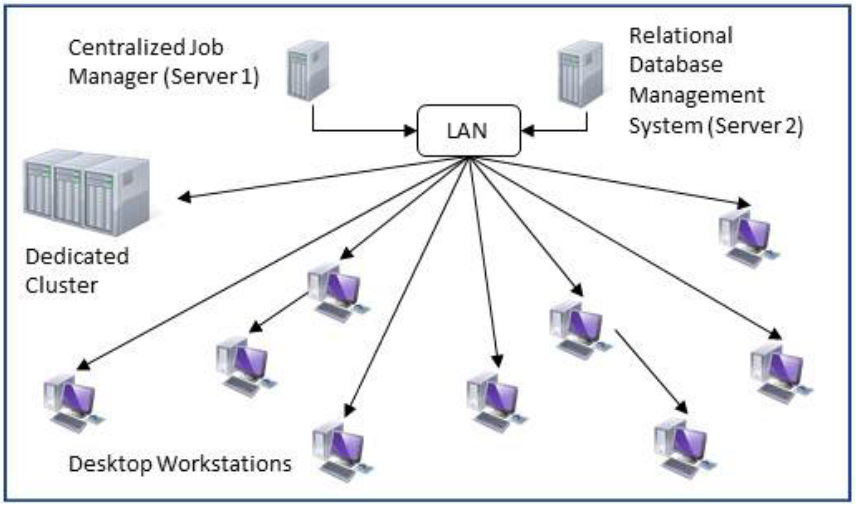
Contact: *Tim Kern*

The Use of High Throughput Computing for USGS Core Sciences Research

Public land management agencies continually face resource management problems that are exacerbated by climate warming, land-use change, and other human activities. As FORT works with managers in U.S. Department of the Interior (DOI) agencies and other Federal, State, and private entities, researchers are finding that the science needed to address their complex ecological questions across time and space produces substantial amounts of data. The additional data and the volume of computations needed to analyze it require expanded computing resources well beyond single- or even multiple-computer workstations. To meet this need for greater computational capacity, FORT investigated how to resolve the many computational shortfalls previously encountered when analyzing data for such projects.

We found a solution that uses high throughput computing (HTC) and high performance computing (HPC) systems to take advantage of unused computer processing units (CPUs) within a local area network in order to distribute and run highly complex analytical processes. HTC is a job-management and scheduling system that can execute independent jobs on standard workstations via a local network or the Internet. It is extremely useful for analyses that require a significant amount of calculations, data, or a combination of these. As management issues and the associated research questions grow more complicated and multi-dimensional, the use of HTC is proving invaluable in allowing us to undertake projects requiring extensive analyses.

In 2010–2011, FORT implemented an HTC system called Condor (*http://research.cs.wisc.edu/condor/*) with approximately 300 CPUs. We then evaluated the system for selected case studies: (1) species-distribution models using maximum entropy, (2) 2D/3D hydrodynamic numerical modeling, (3) species trend analysis and the effects of the surrounding environment, (4) development of bioclimatic variables, (5) landscape-scale ecological modeling, and (6) geostatistical simulations and statistical analysis. In using HTC for our selected case studies, we learned that HTC is both promising and scalable for many research applications. We were able to demonstrate the efficacy of HTC for a diverse and realistic set of projects, its effectiveness in substantially reducing overall computing time, and its ability to harness existing computer resources. HTC will not only meet DOI and USGS goals for enabling better research but also help meet computer-reduction initiatives, such as sharing computing resources and enabling power management and green computing. Thus far, HTC has allowed FORT scientists to complete many projects in a very short time that were initially believed impossible to accomplish due to the amount of processing time required.



Schematic illustrating how a centrally managed system of desktop workstations and servers can distribute and manage processes throughout a Local Area Network (LAN).

Product:

Wilson, J.T., and O'Donnell, M., 2011, High throughput computing—A solution for scientific analysis: Fort Collins, Colo., Fort Collins Science Center, Web feature, available at *http://www.fort.usgs.gov/Condor*.

Contact: *Michael O''Donnell*

The Development and Application of Derived Bioclimatic Variables from Climate Normals and Time-Series Data

All species are affected by both climatic and non-climatic factors. Climate changes can impose physiological constraints on species and therefore can affect species distributions to varying degrees. The relationship between climate and most species varies due to local adaptation and other factors limiting distribution, such as dispersion constraints related to habitat availability. Additionally, examining climate over time is useful when quantifying the effects of climate changes on species distributions for past, current, and forecasted climate scenarios.

To address historical and current scenarios, in FY11 FORT derived bioclimatic predictors (as defined by Nix, 1986) from GIS data for the conterminous United States. We used two climate data sources, one from Oregon State University (*www.prism.oregonstate.edu/)* and the other from Climate Source (*www.climatesource.com/*) to better represent the types of seasonal trends pertinent to the physiological constraints of different species. For example, wettest month and seasonal anomalies will generally capture broader biological trends better than the temperature or the amount of precipitation for a given day, due to the inherent variability associated with climate. Bioclimatic predictors capture information about annual (annual mean temperature, annual precipitation) and seasonal mean climate conditions (annual range in temperature and precipitation), as well as climate extremes and intra-year seasonality (temperature of the coldest and warmest months, precipitation of the wettest and driest quarters).

We used both time-series and climate "normals" data from multiple-scale (400-meter [m], 800-m, 2-kilometer [k], and 4-k) products between the years 1895 (min) and 2008 (max). Due to the volume, spatial extent, and spatial and temporal resolution of the data, FORT used High Throughput Computing (HTC) to manage the data processing via the Condor software (*http://research.cs.wisc.edu/condor/*). Each set of 20 bioclimatic predictors (20 products are derived for each calendar year) required the development of approximately 200 interim datasets, for a total of 576,000 datasets to obtain the final derived products. Further, all datasets required conversion to GIS data formats, conversion of units for precipitation and temperature using relevant scale factors, a defined map projection, and the importation and editing of metadata.

The bioclimatic variables derived from this process are an important source of biologically relevant climate data for ecologists. Researchers and land managers can use these variables to inform habitat management decisions in the present based on species relationships with climate and available habitat, while still considering future climate changes. These data generally are used in spatially explicit statistical models that provide mechanisms for either making predictions of species distributions or for building relationships that may suggest where and when species are more likely to respond to climate changes.

Reference:

Nix, H.A., 1986, A biogeographic analysis of Australian elapid snakes, in Longmore, R., Ed., Atlas of elapid snakes of Australia—Australian flora and Fauna Series 7: Canberra, Australia, Australian Government Publishing Service, p. 4–15.

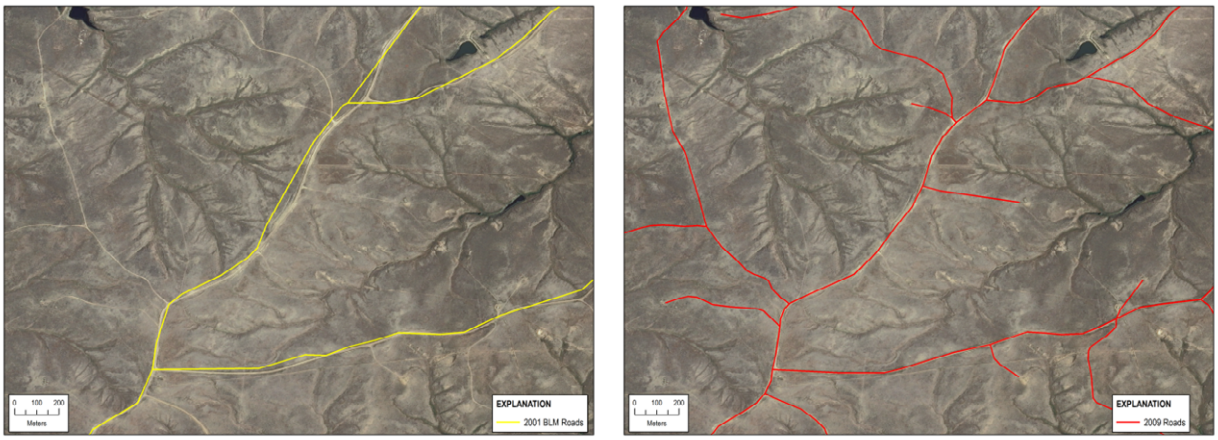
Contact: *Michael O'Donnell*

Geospatial Data Development of Wyoming Roads

The Wyoming State Office of the Bureau of Land Management (BLM) maintains a statewide GIS roads database for the State of Wyoming. In early 2010, FORT agreed to assist the BLM by updating their 2001 roads database to the 2009 National Agriculture Imagery Program (NAIP) imagery focusing on the 42 1:100,000-scale quadrangles that fall within a BLM-identified priority area.

In 2011, the FORT GIS team on-screen digitized road features from the August 2009 NAIP imagery using decision rules and a file geodatabase design that FORT and the BLM developed jointly. We systematically updated roads using a processing grid designed to facilitate digitization at a visual scale of 1:4,000. Each processing block was examined for omission and commission (select road classes only), spatial inaccuracy of 10 meters or greater, and classification inaccuracies. We then used a spatially stratified approach for sampling and assessing the accuracy of the updated features within the priority area. We conducted this evaluation to assess how accurate FORT technicians were when developing the updated transportation data layers. We also used this information to make corrections to all identified errors; therefore, the final version of the transportation data reflects all changes after errors were identified.

The updated roads layer will resolve known concerns with spatial and aspatial inaccuracies, inconsistencies of scale representation, and non-standard attribution. It also will make the data coincident with a single imagery source. The BLM needs these data for developing ecoregional assessments, environmental assessments, environmental impact statements, resource management plans, travel management plans, and records of decision, as well as for quantifying disturbances associated with wind energy, oil and gas activities, and anthropogenic land uses (see images below).



Digitized roads layer: pre-update (left) and post update (right) results. Images by Robert Waltermire, USGS.

Product:

ArcGIS file geodatabase with a single feature class representing road centerlines, the corresponding FGDC metadata, and supporting data layers used during database development.

Contact: *Tammy Fancher*

Rediscovering the Oregon, California, Mormon Pioneer, and Pony Express National Historic Trails

The National Park Service (NPS) National Trails System office based in Salt Lake City maintains a geographical information systems (GIS) database of the Oregon, California, Mormon Pioneer, and Pony Express National Historic Trails. The NPS continues to research and document the authentic segments of these trails before they are lost to new developments and land-use changes. A large part of the research behind this effort is based on historical paper maps, early twentieth-century aerial photographs, and written documentation by individuals who spent much of their career studying the national historic trails and associated landmarks.

FORT's GIS and Remote Sensing Team entered into an interagency agreement with the National Trails System office to assist with digitizing portions of the historic trails and providing research into the availability of historic aerial photography. In 2011, the team delivered three primary products and four value-added GIS databases. The first primary product was a GIS database of the Oregon Trail in the State of Oregon. The NPS provided (1) aerial photographs in digital format from the 1970s and (2) scans of USGS quadrangle maps containing annotation by Aubrey L. Haines, author of the book, *Historic Sites Along the Oregon Trail*. We produced a mosaic of the aerial photography, georeferenced the scanned USGS quadrangle maps, and then digitized the Oregon Trail from the aerial photo mosaic while referencing lines and annotation drawn on the USGS quadrangle maps. The resulting database included 14 information fields for each digitized arc and complete standards-compliant metadata.

The second primary product consisted of the Oregon, California, Mormon Pioneer, and Pony Express trails digitized in ArcGIS for the State of Wyoming. Based on small-scale digital data provided by the NPS (for reference) and 2009 National Agriculture Imagery Program images, this database contained 15 fields of information and complete standards-compliant metadata. The final primary product was a USGS Administrative Report that documented historical aerial photography in general (seven national programs with aerial photo acquisition), and specifically for three sites that were of particular interest to the NPS:

1. Working with the Wyoming State Office of the Bureau of Land Management (BLM), we were able to document the existence of aerial photographs from the BLM, Natural Resources Conservation Service, and the National Archives and Records Administration (NARA) for South Pass (Wyoming), with some dating back to 1937.
2. Working with NARA we documented aerial photographs going back to 1938 for the Plum Creek site in Nebraska.
3. Again working with NARA as well as Kansas State University, we documented aerial photography going back to 1936 for the Alcove Spring site in Kansas.

We also provided three value-added GIS products in 2011 based on records and publications by Mr. Haines. First, we digitized and attributed the 112 flight lines flown to acquire the aerial photographs used to create the mosaic of photos in Oregon mentioned above. These flight lines were originally drawn on USGS quadrangle maps by Mr. Haines. Second, we digitized and attributed lines and points that Mr. Haines had drawn on USGS quadrangle maps depicting the location of the historic trail in Oregon and associated historic sites. We included all of the lengthy annotation that Mr. Haines wrote on the maps. Third, we digitized and attributed 393 historical sites in Oregon that date back to 1841. These sites were based on locations documented in two books by Mr. Haines, *Historic Sites Along the Oregon Trail* and *Historic Resource Study* and *Historic Sites Along the Oregon Trail*. Finally, we developed a high-resolution GIS database of a section of the Oregon, California, Mormon Pioneer, and Pony Express historic trails in Wyoming for the BLM.

Products:

Waltermire, R.G., 2011, Aerial photography sources for delineating the Oregon, California, Mormon Pioneer, and Poly Express National Historic Trails in Kansas, Nebraska, Oregon, and Wyoming: U.S. Geological Survey, Administrative Report for the National Park Service, National Historic Trails System, 59 p.

Several GIS databases.

Contact: *Bob Waltermire*

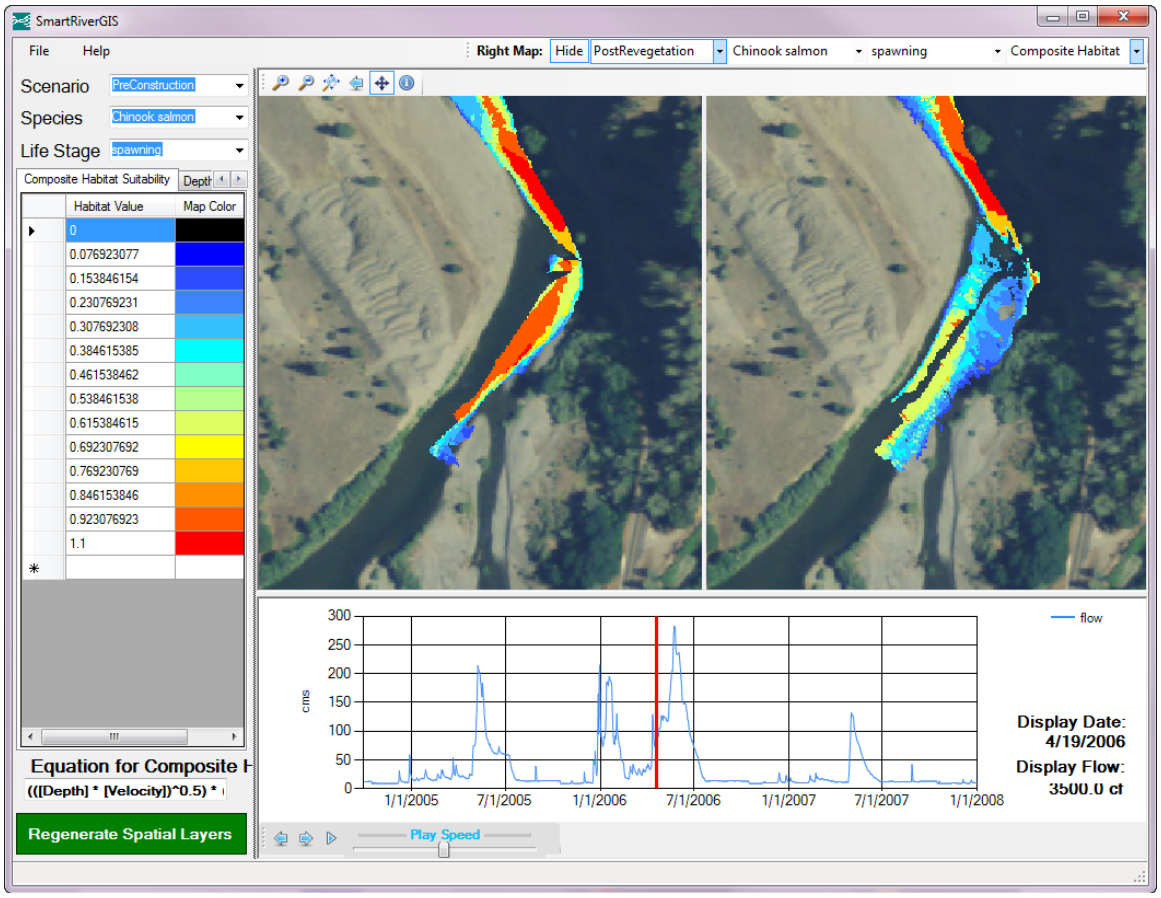
Ecosystems—Fisheries: Aquatic and Endangered Resources

Developing a SmartRiverGIS Application for 2D Aquatic Habitat Modeling

Aquatic two-dimensional (2D) habitat modeling is a complex process requiring numerous GIS inputs and outputs. A separate input and output is needed for each flow, habitat variable, species, and life-stage combination. This results in hundreds of inputs that must be classified, recombined, and processed to produce hundreds of output files. Current GIS processing and viewing software is capable of handling the data and processing needs. It also requires a high level of GIS expertise and can be cumbersome to use.

FORT scientists developed a desktop Windows application to allow decision makers and scientists to easily view and change the inputs and parameters used in aquatic 2D habitat modeling. This application has built-in GIS functionality for viewing inputs and visually inspecting how changes to instream flow and modeling parameters will affect model output. The user can dynamically change all modeling equations and parameters and then re-run the required geoprocessing. Habitat outputs can be viewed side by side and queried to investigate how individual parameters affect modeling results.

The initial application was developed with data for the Hocker Flat site on the Trinity River in northern California. Included in the initial analysis were three scenarios, four environmental covariates, and three species with approximately three life stages each. In 2011, we delivered the application and data to collaborators working on the Trinity River as a proof of concept. The application framework will be used as a template for creating spatially enabled decision-support tools for aquatic systems, starting with the Delaware River in FY12.



SmartRiverGIS desktop application screenshot comparing model output across two scenarios.

Contact: *Leanne Hanson*

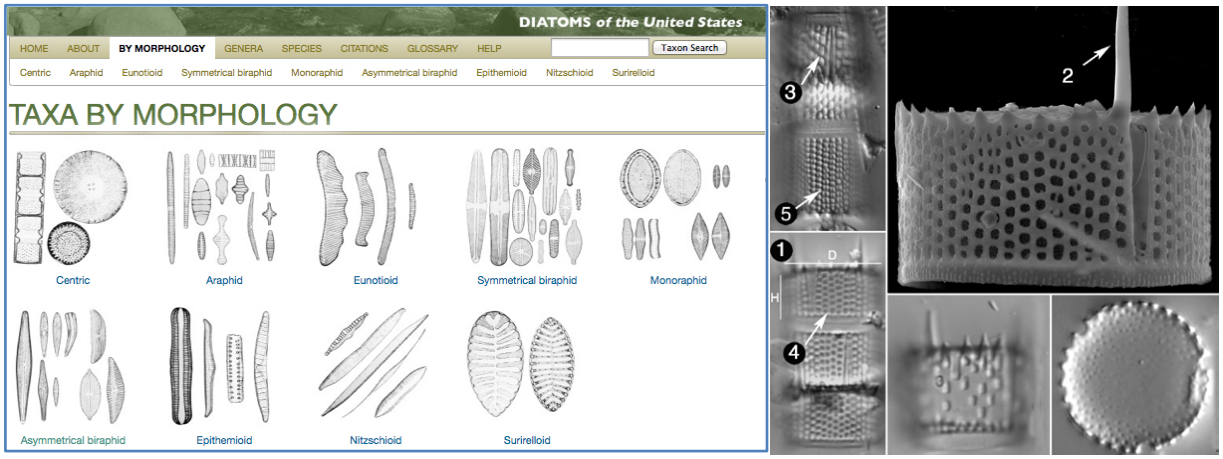
Developing a National Taxonomic and Ecological Database for Diatoms

Diatoms are a major lineage within the microbial eukaryotes. In terms of species diversity and ecological importance, they occupy a primary role as widespread, photosynthetic aquatic organisms. The use of diatoms as barometers of environmental status and change has secured them as necessary tools of community and ecosystem assessment. For example, each year in the United States, millions of dollars are spent by municipal, regional, tribal, State, and Federal agencies to evaluate diatom communities as an indication of environmental condition. The quality of diatom studies is wholly predicated upon accurate identification to a fine taxonomic level. Until now, however, a comprehensive taxonomic and geographic freshwater diatom flora of the United States did not exist.

The goal of this project is to complete a database of diatom flora of the United States by engaging the expert community through an open-access, online resource. This project is vaulting the capacity of diatom taxonomy, ecology, and biological assessment to a new level of excellence. The *Diatoms of the United States* interface includes visual keys to guide new users to genera based on morphological groups. Experienced users, including taxonomists and ecologists, gain access to species by search functions. Feedback from users has been enthusiastic and users report that "That is one terrific website!" and "I use the site for the superior images and updated nomenclature."

In 2011, in addition to overseeing the expansion of species pages on the site, the FORT principal investigator presented a summary to the National Water Quality Monitoring Council and received enthusiastic support. Content from the site is being reproduced by the Spanish Ministry of Environment for national guides for taxonomic literature, and the British Museum of Natural History is using the project as a model for a national flora for the United Kingdom. The database also was nominated for the Geoscience Information Society "Best Website" for 2011.

The project is funded by USGS NAWQA and includes expert contributors from academic and research institutions.



(L) Screen capture of the *Diatoms of the United States* Taxa by Morphology page. (R) closeup views of an example diatom species' structure. USGS images.

Product:

Spaulding, S.A., 2010, Diatoms of the United States: Boulder, Colo., Diatoms of the United States, available at *http://westerndiatoms.colorado.edu/* .

Contact: *Sarah Spaulding*

Processes and Patterns in Hydroscapes: Fragmentation, Domestication, and Consequences

"Hydroscape" refers to a type of landscape where water covers a large number of patches or large areas for long time periods. In hydroscapes, water plays a defining role in the formation of spatial patterns and the configuration of spatial processes, and water flow seems to be the determinant physical process that influences and determines other physical, chemical, and biological processes. Globally, humans have fundamentally altered the hydrological processes of freshwater systems and consequently many aquatic ecosystems. Water-control efforts have led to hydroscape fragmentation and hydroscape domestication (the loss of natural dynamics and behavior of water sources due to regulation and other human activities). Many hydroscapes have become human-dominated landscapes.

Historically in landscape ecology, a majority of studies have been conducted in terrestrial systems. Recently, aquatic studies have started to draw attention. Scientists at FORT believe that ecological studies of hydroscapes can offer great insights about the mechanistic links between processes and patterns because of the dominate role that water flow plays. Hydroscape ecology will be an emergent frontier in landscape ecology. In addition, hydroscape domestication will be an important issue in landscape ecology, land management, natural resource management, and ecosystem restoration.

We initiated an effort to synthesize the processes and patterns across seemingly diverse hydroscapes at multiple spatial scales: riverscape, lakescape, wetland landscape, and coastscape. A symposium was organized at the 8th World Congress on Landscape Ecology (held August 18–23, 2011, in Beijing, China) to bring together ecologists from universities and research institutions to present their studies of major types of hydroscapes. Speakers were invited to address two main questions:

1. What critical hydrologic features interact with other physical and biogeochemical processes to affect ecosystem processes and patterns, and how?
2. How do human activities influence these hydrologic features, their interplays, and consequent ecosystem processes and patterns?

The discussion and synthesis provided insight into how local human activities and natural processes interact with human influences and landscape patterns at hydroscape scales. The FORT principal investigator for this project chaired the symposium and will co-edit a special issue on the symposium in the journal, *Hydrology and Earth System Sciences*.

Products:

Dong, Q., 2011, Linear man-made structures, hydroscape domestication, and ecological consequences in 8th World Congress of International Association for Landscape Ecology, August 23–18, 2011, Beijing, China.

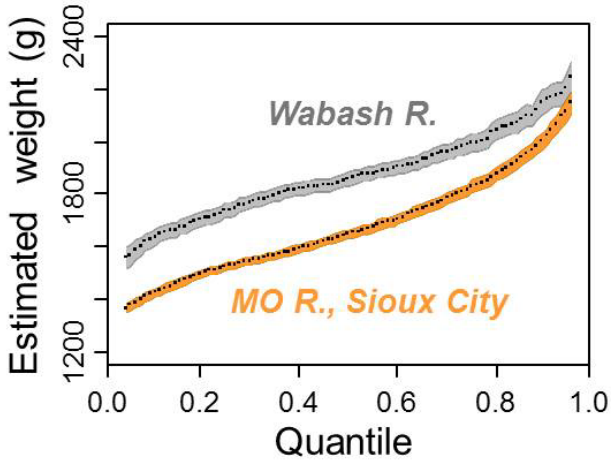
Dong, Q. 2011, Opening and concluding remarks for the symposium, "Processes and patterns in hydroscapes—Fragmentation, domestication, and consequences," in 8th World Congress of International Association for Landscape Ecology, August 23–18, 2011, Beijing, China.

Contact: *Quan Dong*

Statistical Improvements for Estimating Body Condition of Fish

Fish weight and length data are commonly collected by fisheries scientists to help evaluate differences in body condition of fish (weight and length) in different environments or under alternative management schemes. Following on prior efforts to evaluate and promote a more rigorous statistical approach based on quantile regression, FORT scientists and State cooperators refined the quantile regression approach and used it to evaluate the geographic variation in body condition of blue suckers, a threatened species inhabiting large rivers in the central United States (Cade and others, 2011). Blue suckers had better body condition at more southern locations. The quantile-regression approach models allometric growth of fish weight with length (similar to growth charts for children), allows for multiple forms of heterogeneity in growth, and provides estimates of percentiles of weight at length that can be compared among any factors included in the statistical model. In this way, the approach promotes assessment of fish condition in a manner consistent with that used for humans and avoids many of the statistical and interpretation issues associated with the use of condition indices, such as relative weight. Our 2011 publication includes statistical code for R that can be modified for other investigations of fish body condition. We will continue our efforts to promote this approach by developing online webinar training materials.

Cooperator, Ben C. Neely, Texas Parks and Wildlife, holds a large blue sucker. USGS photo.



Differences between percentiles of weights at 594-millimeter length for blue suckers in two rivers. USGS image.

Product:

Cade, B.S., Terrell, J.W., and Neely, B.C., 2011, *Estimating geographic variation on allometric growth and body condition of Blue Suckers with quantile regression*: Transactions of the American Fisheries Society, v. 140, p. 1657–1669.

Contact: *Brian Cade*

Ecosystems—Invasive Species

Control of Invasive Giant Constrictor Snakes in Florida

Invasive Burmese pythons (*Python molurus*) are established in the greater Everglades ecosystem and are expanding their range in southern Florida. These giant snakes (up to 20 feet and 250 pounds) are efficient predators of warm-blooded species ranging from wrens to deer, and represent a novel threat to which native species are poorly adapted. Since 2006, FORT scientists with expertise in control of invasive reptiles have worked with cooperating agencies to develop techniques to detect, capture, and control populations of giant constrictor snakes in Florida and elsewhere.

In FY2011, we continued development of capture tools for Burmese pythons in areas with high python densities outside Everglades National Park. To support conservation efforts for federally endangered mammals, the results of our work will be applied to detecting and capturing pythons as they invade Key Largo.

We continued to assist in identifying and delineating population control efforts and helped provide resources for genetic identification of samples (for example, shed skins) to figure out the extent of a newly discovered population of Northern African Pythons (*Python sebae*). We also analyzed a new trap type and monitoring tool to determine success of python capture rates. One of our team was appointed to the Boa and Python Specialist Group, part of the Species Survival Commission of the International Union for the Conservation of Nature (IUCN). Finally, we wrapped up a multi-year, collaborative study correlating Burmese python abundance with changes in abundance of certain mid-sized prey mammals. The resulting paper was published early online in 2012 (Dorcas and others, 2012).

Working with the USGS Southeast Ecological Science Center in Davie, Florida, cooperating agencies include the Endangered Species and National Wildlife Refuges branches of the U.S. Fish and Wildlife Service, National Park Service, South Florida Water Management District, Florida Department of Environmental Protection, University of Florida, and Florida Wildlife Commission.

(L) Python trap (behind) and Tegu trap (foreground). Photo by Ron Rozar, USGS. (R) Burmese python caught in trap near Key Largo, Fla. Photo by Scott Goetz, USGS.

Products:

Reed, R.N., Hart, K.M., Rodda, G.H., Mazzotti, F.J., Snow, R.W., Cherkiss, M.S., Rozar, R., and Goetz, S., 2011, *A field test of attractant traps for invasive Burmese Pythons (Python molurus bivittatus) in southern Florida*: Wildlife Research, v. 38, p. 114–121.

Dorcas, M.E., Willson, J.D., Snow, R.W., Rochford, M.R., Miller, M.A., Meshaka, W.E., Jr., Reed, R.N., Andreadis, P.T., Mazzotti, F.J., Romagosa, C.M., and Hart, K.M., 2012, *Severe mammal declines coincide with python proliferation in Everglades National Park:* Proceedings of the National Academy of Sciences U.S.A., v. 109, n.7. p. 2418–2422.

Contact: *Bob Reed*

Control and Prevention of the Invasive Brown Treesnake

The Brown Treesnake (BTS) is a highly destructive reptile species that has extirpated many native bird species on Guam, as well as bats and lizards. Visual searching is one technique currently used to detect and control BTS, especially incipient populations. The cost of an eradication program depends upon the least-capturable individual. Heterogeneity (analysis of capture variability) in visual-detection probabilities sets the cost for control efforts, particularly control programs directed at eradicating an incipient or nearly extirpated population. Visual searches and trapping efforts inside our closed population of BTS on Guam continue to provide data for many projects.

In FY2011, FORT scientists began analyzing trial results to determine absolute and relative effectiveness of bait tubes on small snakes in a BTS population in our 5-hectare (ha) snake enclosure facility on Guam. This included one trial in a prey-dense environment, as might be encountered in an accidental introduction of the snake to another island. We continued studies of analyzing visual-detection probability inside and outside the enclosed population. We also tested the effects of prey recovery in our enclosed population of BTS, due to the suppression of snake abundance. Results published in 2009 of food preferences in juvenile BTS led to further research in scent attractants, which is ongoing. In 2011, we published data from trials determining effectiveness of detector dogs in finding BTS in low-canopy forest (Savidge and others, 2011). Island-wide searches of BTS continued to determine spatial variability, size distributions, and characteristics of BTS to better inform landscape-level management plans and future suppression strategies. We continue to assist the U.S. Fish and Wildlife Service (USFWS) and the U.S. Department of Defense in snake barrier construction and maintenance plans related to the Habitat Management Unit, a 66-ha area on Guam, and a larger barrier on the Guam National Wildlife Refuge. Cooperators include U.S. Department of the Interior Office of Insular Affairs, USFWS, U.S. Navy, U.S. Air Force, Guam Division of Aquatic and Wildlife Resources, USDA Wildlife Services, Hawaii Department of Agriculture, Hawaii Department of Forestry and Wildlife, and Commonwealth of the Northern Mariana Islands Department of Fish and Wildlife.

Shane Siers weighs a trap-captured Brown Treesnake on Guam. Photo by Shane Siers, USGS.

Products:

Mason, L.C., Savidge, J.A., Rodda, G.H., and Yackel Adams, A.A., 2011, *Scented guide ropes as a method to enhance Brown Treesnake (Boiga irregularis) trap capture success on Guam*: Journal of Herpetology , v. 45, p. 308–312.

Savidge, J.A., Stanford, J.W., Reed, R.N., Haddock, G.R., Yackel Adams, A.A., 2011, *Canine detection of free-ranging brown treesnakes on Guam*: New Zealand Journal of Ecology, v. 35 p. 174–181.

Contact: *Bob Reed*

Brown Treesnake Rapid Response Team

Brown Treesnakes continue to cause major problems for the ecology, economy, and quality of life on Guam. In 2002, a multi-agency Rapid Response Team (RRT), led by USGS, was established to assist in detection and capture of Brown Treesnakes on recipient islands if a snake was accidentally transported from Guam. The RRT has incorporated research results from USGS, such as means to improve snake detectability at low densities, effectiveness of control tools in rodent-rich environments, and predicting movements of snakes translocated accidentally. Since its creation, the RRT has conducted 1–5 training courses annually and 22 field operations.

During 2011, one field operation was conducted on the island of Saipan in the Commonwealth of the Northern Mariana Islands (CNMI) at the request of the CNMI Department of Land and Natural Resources. This operation involved searching for non-native lizards with personnel from local agencies and USGS. The response was requested when a non-native species of lizard was captured by a resident and the agency was concerned that there may be an incipient population in the area. At the end of FY11, the RRT consisted of 90 members located throughout the Pacific region and the United States mainland. One 18-day RRT training course was conducted on Guam and Rota Islands for new team representatives from the Hawaiian Islands and Rota Island. In addition, numerous outreach and speaking engagements were conducted on Guam, including visits to the research lab by school groups, presentations at University of Guam venues, and running an invasive/native species booth with Guam Department of Agriculture at the local Earth Day celebration. Assistance was supplied to the National Invasive Species Council on the development of the Micronesia Biosecurity Plan (MBP), including MBP biological team support throughout the region.

Results from an FY10 field effort in Papua New Guinea were analyzed in cooperation with scientists at the USGS Western Ecological Research Center. The research was focused on native-range parasites as a potential control tool for Brown Treesnakes on Guam. Support to the USFWS continued in the Northern Mariana Islands, including assistance in the development of a quarantine barrier for the Island of Rota. Assistance was provided to the Micronesia Regional Invasive Species Council to host a workshop to develop emergency response documents for the Federated States of Micronesia (FSM) and the Council's strategic action plan for 2012–2017. Outreach materials were also created, including the Micronesian regional invasive-species calendar for distribution throughout Micronesia. Rapid Response Team efforts and brown treesnake prey findings were presented at the 11th annual Hawaii Conservation Conference.

Cooperators include the DOI Office of Insular Affairs, USFWS, U.S. Department of Defense, USDA Wildlife Services and APHIS, Guam Division of Aquatic and Wildlife Resources, Hawaii's Coordinating Group on Alien Pest Species and Invasive Species Committees, Hawaii Department of Agriculture, and Hawaii Department of Forestry and Wildlife. Additional quarantine, agriculture, and natural resources cooperators include officials from the FSM, the CNMI, the Republic of the Marshall Islands, and the Republic of Palau. Assistance was provided to USGS Western Ecological Research Center's San Diego Field Station in California.

Research cooperator and RRT member Bjorn Lardner (Colorado State University) capturing a brown treesnake on Guam. Photo by Shane Siers, USGS.

Contact: *James Stanford*

Potential Effects of Climate Change on Invasive and Native Riparian Plants in the U.S. West

Riparian forests contribute substantially to regional biodiversity, and they provide essential ecosystem functions and wildlife habitat in arid and semi-arid regions. The fate of woody riparian plants is closely tied to flow regime and ground water dynamics along rivers in the arid western United States, both of which are expected to change as a function of changing climate. Climate change is likely to alter riparian plant community structure and dynamics, by way of direct effects on plants and indirect effects via streamflow, biotic interactions, and human activities. Of particular interest to land and water managers is whether or not the distribution and abundance of invasive species are likely to increase. Our research addresses several knowledge gaps with respect to climate-change effects on riparian vegetation. It includes the following projects and accomplishments in FY11:

- We completed a literature synthesis summarizing expected and potential changes in climate, riparian hydrology, and riparian vegetation and animals in the arid and semi-arid western United States. This synthesis is now published online in the journal Global Change Biology. The manuscript was prepared with cooperators from Colorado State University and the Bureau of Reclamation.
- We developed a draft manuscript describing a greenhouse experiment designed to help us evaluate the potential for elevated CO_2 to offset negative effects of lower summer streamflows on recruitment by western woody riparian species, and to favor recruitment by some woody riparian species more than others. The experiment included five common woody riparian plant species (two native, three exotic). We will submit the manuscript to a peer-reviewed journal in FY12.
- We conducted a second year of field observations of seed release phenology of five woody riparian species (two exotic, three native) on snow-melt-driven rivers draining the Rocky Mountains, as part of a larger study examining potential effects of climate change on seed-release phenology, stream flow timing and magnitude, and differential responses of native and exotic riparian plants. Related hydrologic modeling of flow timing and magnitude, and linked climate-hydrology-riparian ecology modeling, will begin in FY12, in cooperation with scientists from the USGS Colorado Water Science Center and the USGS National Research Program.
- We conducted an analysis of stream-gage data to estimate potential shifts in riparian hydrology from perennial to non-perennial flow in the Upper Colorado River Basin as part of a larger study that will also include (1) development of a classification and regression tree model to estimate potential for flow regime shift on ungaged streams, and (2) an assessment of potential responses of riparian vegetation to perennial to non-perennial flow regime shifts. A manuscript describing the stream-gage analysis was completed and is in revision for the Journal of the American Water Resources Association. Also, funding was awarded by the Southern Rockies Landscape Conservation Initiative to Colorado State University collaborators Lindsay Reynolds and LeRoy Poff to continue this project in FY12 and FY13.
- We completed a greenhouse experiment examining the effects of water-table depth and groundwater temperature on establishment and first-year growth of a common native nitrogen-fixing herbaceous riparian perennial. Both groundwater warming and water-table decline are potential consequences of climate change. A manuscript describing this study was prepared in FY11 in collaboration with the Bureau of Reclamation and is currently in review at the journal, *Climatic Change*.

Products:

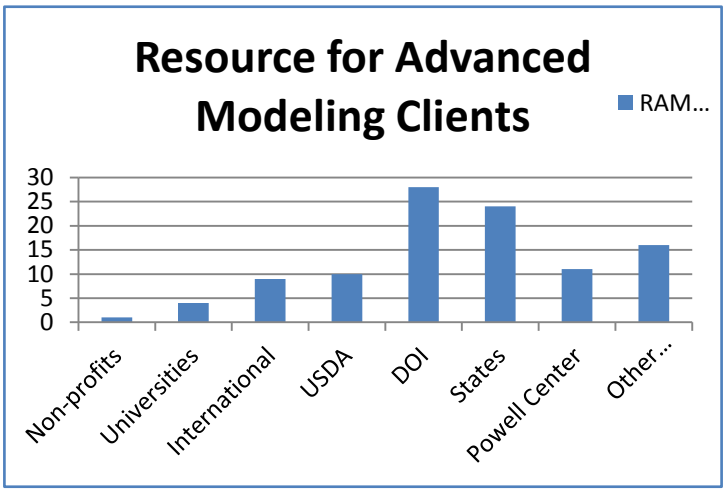
Perry, L.G., Andersen, D.C., Reynolds, L.V., Nelson, S.M., and Shafroth, P.B., 2012, *Vulnerability of riparian ecosystems to elevated CO2 and climate change in arid and semiarid western North Americ*a: Global Change Biology, DOI: 10.1111/j.1365-2486.2011.02588.x [Published online December 8, 2011.]

Reynolds, L.V., and Shafroth, P.B., in revision, Potential shifts in minimum flow stream hydrology in the Upper Colorado River Basin under a warmer, drier future climate—A streamgage analysis: Journal of the American Water Resources Association.

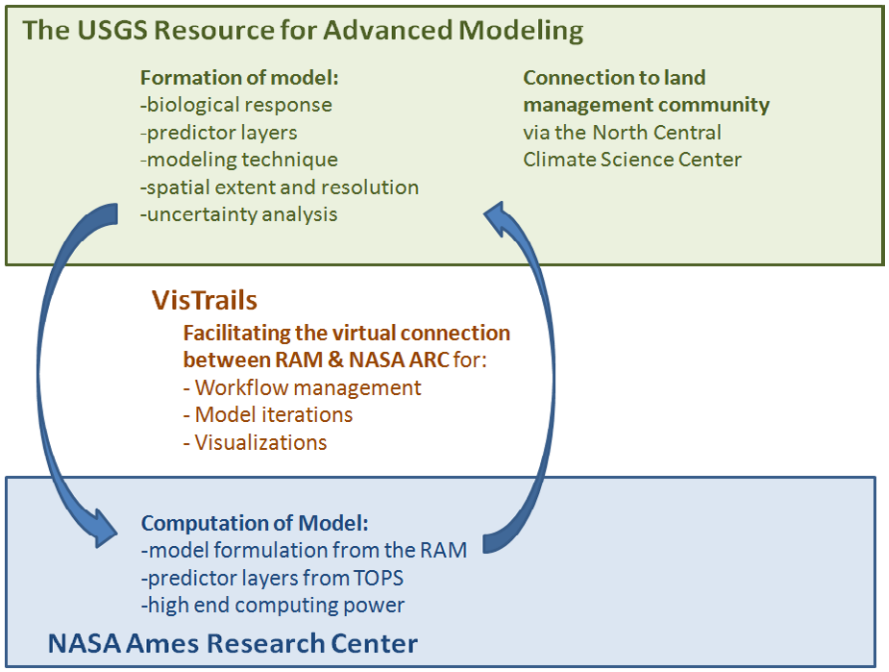
Contact: *Pat Shafroth*

Resource for Advanced Modeling and Software for Assisted Habitat Modeling

In 2011, FORT continued to maintain and invest in its Resource for Advanced Modeling (RAM). Established in 2009, this facility was recognized that year with a U.S. Department of the Interior (DOI) Partners in Conservation Award. The RAM continued to provide a collaborative working environment for scientists and land managers to work together on modeling activities and ecological studies. RAM logged 103 sessions in 2011 (see figure at right). These sessions included a variety of landscape ecology, species distribution modeling, and data synthesis studies across a wide range of taxa and spatial domains. The high number of users and array of studies highlight the high demand and utility of this facility.



In 2011, a collaborative proposal between FORT, the National Aeronautic and Space Agency's (NASA) Ames Research Center (ARC) in California, Colorado State University (CSU), and New York University Polytech (NYU Poly) successfully competed for NASA Earth Science funding directed at enhancing the modeling capabilities of the RAM. The project, funded at over $400,000 per year for four years, will use the input data layers and computation capacity at NASA ARC to better understand where species of concern (both endangered and invasive) are likely to thrive—now and under various future climate and land-use projections. The FORT/CSU team will ensure that the modeling efforts meet the needs of DOI land managers, particularly those articulated through the North Central Climate Science Center at CSU. NYU Poly is responsible for the VisTrails workflow and visualization software that will provide the "conduit" between the RAM and NASA ARC data and computational resources. The backbone for this effort is the Software for Assisted Habitat Modeling (SAHM). This RAM component is run through the VisTrails software. The SAHM modules were initiated during 2011. Version 1.0, a user guide and tutorial, and related peer-review publications are anticipated in mid-2012.



The role of the NASA Ames Research Center and VisTrails in the RAM process. "TOPS" is the Terrestrial Observation and Prediction System. USGS image.

Contact: *Jeff Morisette*

Ecosystems—Status and Trends of Biological Resources

Assessing Visitor Experience on National Wildlife Refuges

What activities are visitors participating in on refuges and how satisfied are they with their experiences? How much are they spending in the local community as part of their refuge visit? For the past year, FORT researchers have been exploring these and other questions as part of a survey of visitors to national wildlife refuges. The National Wildlife Refuge (NWR) Visitor Survey took place from July 2010 through July 2011 on 53 refuges across the country, from Kilauea Point NWR in Hawaii to Cabo Rojo NWR in Puerto Rico.

The survey, commissioned by the USFWS Division of Visitor Services and Communications, provides refuge managers, planners, and visitor services specialists with a better understanding of visitors':

- trip characteristics, such as where they are from, distance traveled, and time spent on refuges;
- opinions about the refuge they visited, from recreational opportunities to services provided by staff and volunteers;
- associated spending in the nearby communities; and
- opinions about larger issues facing the National Wildlife Refuge System (NWRS), including provision of alternative transportation and communication on climate change.

Nearly 15,000 visitors were contacted on site and asked to participate in the survey. The response rate was an overwhelming 71 percent. Preliminary results of the study indicate that nearly 90 percent of visitors find their refuge experience unique compared to other public lands they have visited. Visitors tend to enjoy and appreciate their refuge experiences, with at least 90 percent satisfied with not only the opportunities provided, but also the services provided by staff and volunteers.

As this iteration of the national survey wraps up, plans have begun for surveying visitors on an additional 22 refuges in FY12. In the meantime, USGS is creating individual station-specific reports from the 2010–2011 surveying effort via a USGS data series. Additionally, a national-level report is in preparation and forthcoming in FY12. This report will take a comprehensive look at the data across all the refuges in the study. This national-level view is important in tracking status and trends of visitors and their experiences over time, especially in light of the unprecedented challenges the NWRS is undertaking in its "Conserving the Future" vision.

Survey recruiter at Wertheim NWR contacting refuge visitors. Photo courtesy of Ann Bell, USFWS.

Product:

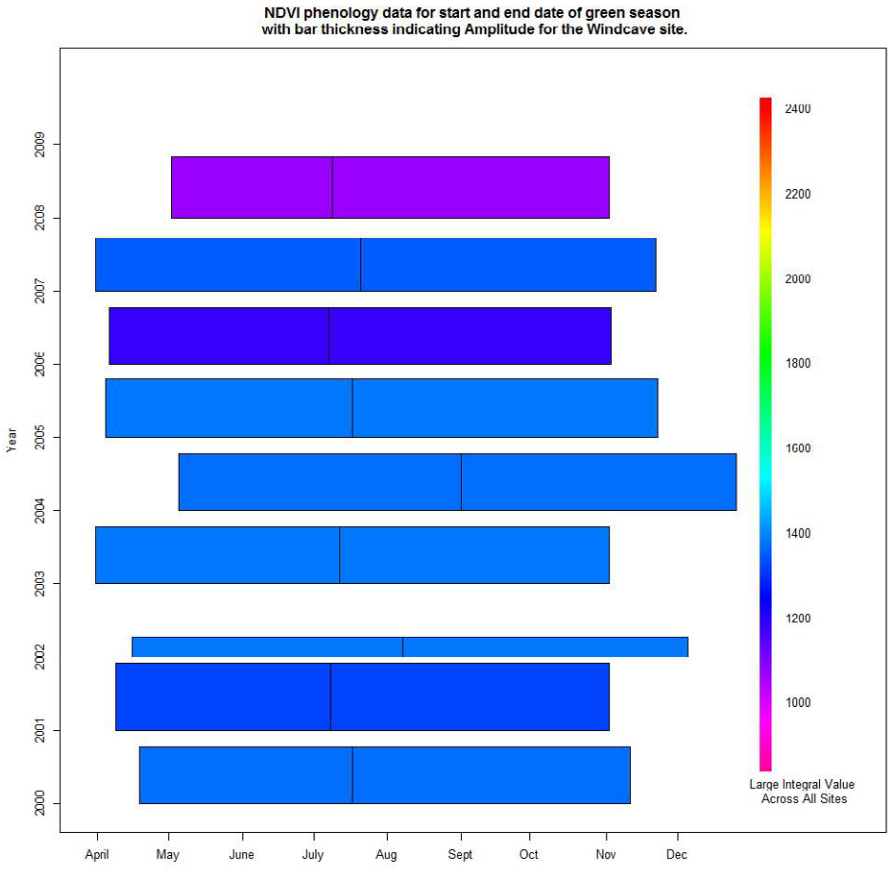
Sexton, N.R., Dietsch, A.M., Don Carlos, A.W., Koontz, L., Solomon, A. and Miller, H., 2011, *National Wildlife Refuge visitor survey 2010/2011—Individual refuge results: U.S. Geological Survey Data Series 643.* [Refuge-results reports are variously paginated.]

Contact: *Natalie Sexton*

Monitoring Seasonal Change: Using Remote Sensing to Measure Year-to-Year Vegetation Variation at National Parks

Seasonal change is important to consider when managing conservation areas at landscape scales. The study of such patterns throughout the year is referred to as phenology. Recurring life-cycle events that are initiated and driven by environmental factors include animal migration and plant flowering. Phenological events, such as fall color change in deciduous forests, the first flowering in spring, and for those with allergies, the start of the pollen season, capture public attention. These events can impact our daily lives, provide clues to help understand and manage ecosystems, and provide evidence of how climate variability can impact the natural cycle of plants and animals. Phenological observations can be gathered at a range of scale from plots smaller than an acre to landscapes of hundreds or thousands of acres. Linking these observations to diverse disciplines such as evolutionary biology or climate sciences can help further research in species and ecosystem responses to climate change scenarios at appropriate scales.

A cooperative study between the National Park Service, FORT, and NASA has been exploring how satellite information can be used to summarize phenological patterns observed at the park (or landscape) scale, and how those summaries can be presented to both park managers and visitors. This study specifically addressed seasonal changes in plants, including the onset of growth, photosynthesis in the spring, and the senescence of deciduous vegetation in the fall. The primary objective of the work is to demonstrate that seasonality, even in protected areas, can change considerably across years. The final phase of this project will occur in 2012. The project will culminate with a Web service that will enable users to select a spatial and temporal area of interest and dynamically generate a graphic like the one displayed below.



Variability in vegetation growing season characteristics at Wind Cave National Park in South Dakota can readily be assessed through visual inspection of the composite figure above. Each horizontal bar represents a single year (time sequence in months); bars are arranged by reporting year (2000–2008). Five different phenological metrics are presented and identified. The color of each bar indicates the large integral value (area under the curve), or the amount of green growth that was detected during the length of season as measured on the normalized difference vegetation index scale (NDVI). The bars are located with respect to start of season and end of season, with the bar thickness indicating the amplitude, or range, in greenness observed for that year. The black line in each bar represents the date of peak greenness. USGS image.

Contact: *Jeff Morisette*

Science in Support of Policy: Identifying Air-Pollutant Critical Loads for Lakes

Deposition of human-generated atmospheric pollutants, such as nitrogen (N), has reached levels that alter or are likely to alter the structure and function of many ecosystems across the United States. One approach for quantifying the deposition of a potentially harmful pollutant is to determine critical loads for it within a given system. A critical load is the input below which detrimental ecological effects are not observed to occur, based on present knowledge.

Most mountain lakes are situated upstream of human-generated land disturbances; therefore, their primary source of N input is atmospheric deposition. Moreover, many mountain lakes, especially those in the West, have few or no upstream pollutant traps, rendering them particularly vulnerable and sensitive to atmospheric deposition. FORT scientists are using several techniques to ascertain the critical loads of N deposition in mountain lakes in the Sierra Nevada, the Rocky Mountains, and New England. Prior efforts focused on reconstructing lake histories and using statistical procedures to characterize loads of deposition constituents in mountain lakes. Recently, we have used empirical correlations of lake N concentrations with atmospheric N deposition amounts.

We have presented critical loads for mountain lakes in a series of papers, published before and during 2011, stemming from long-term research and monitoring on ecological effects of atmospheric N deposition and critical loads in the Loch Vale watershed of Rocky Mountain National Park in Colorado. Critical loads are increasingly used by the National Park Service, U.S. Forest Service, and Environmental Protection Agency as guidelines for managing air pollutants. In Colorado, our critical-load values for lakes in Rocky Mountain National Park are being applied in the State's Nitrogen Deposition Reduction Plan.

Many western lakes have few upstream N traps due to low vegetation, steep slopes, and short growing seasons. Thus, they respond rapidly to N deposition. Photo by J.T. Elser.

Eastern lakes have suffered many decades of acid deposition. Photo by C.T. Driscoll.

Just finished reading your new BioScience paper, and had to tell you: WOW! This will be one of those classic papers that I refer lots of folks to, cite often, and use the thresholds for management purposes with confidence (since it's based on larger data sets than for some of the diatom studies). Nice work!

—Tamara Blett, Air Resources Division, National Park Service

Products:

Baron, J.S., Driscoll, C.T., Stoddard, J.L., and Richer E.E., 2011, *Empirical critical loads of atmospheric nitrogen deposition for nutrient enrichment and acidification of sensitive US lakes*: BioScience, v. 61, no. 8, p. 602–613.

Pardo, L.H, Fenn, M.E., Goodale, L., Geiser, L.H., Driscoll, C.T., Allen, E.B., Baron, J.S., Bobbink, R., Bowman, W.D., Clark, C.M., Emmett, B., Gilliam, F.S., Greaver, T.L., Hall, S.J., Lilleskov, E.A., Liu, L., Lynch, J.A., Nadelhoffer, K.J., Perakis, S.S., Robin-Abbott, M.J., Stoddard, J.L., Weathers, K.C., and Dennis, R.L., 2011, *Effects of nitrogen deposition and empirical nitrogen critical loads for ecoregions of the United States*: Ecological Applications, v. 8, p. 3049–3082.

Contact: *Jill Baron*

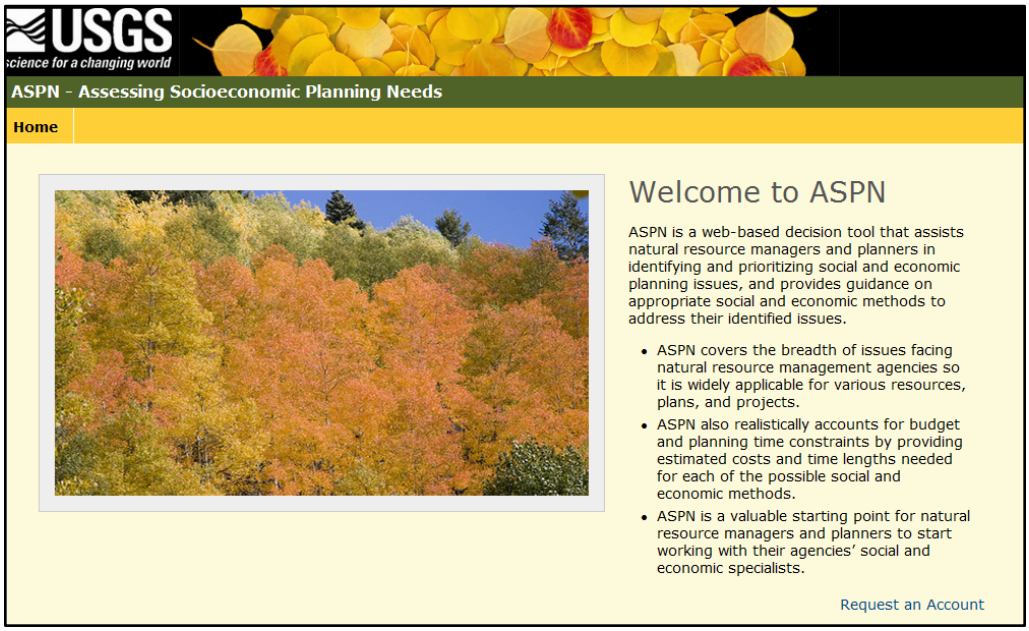
Assessing Socioeconomic Planning Needs (ASPN)

Land-management actions often have significant social and economic impacts. Over the years, there has been an increased need to address and analyze these impacts, given laws such as the National Environmental Policy Act, increased litigation and appeals on land-management decisions, as well as an overall better understanding by agencies of the range of effects that land-management actions have on society. However, there is often a lack of a consistent framework within each agency and across agencies regarding how to objectively and comprehensively identify and address the social and economic impacts of their management planning actions. In addition, resource planners and field staff may not be aware of the variety of social and economic methods that can be used to analyze these impacts. Further, agencies often have limited planning budgets and timeframes to conduct such analyses, requiring a prioritization of the most pressing issues.

In a collaborative effort with the Bureau of Land Management, the National Park Service, and the U.S. Forest Service, FORT social scientists have worked closely with FORT's Web Applications Team to develop a Web-based tool to address this analysis need. The product, called "Assessing Socioeconomic Planning Needs" (ASPN), is designed to:

1. provide various demographic data for the counties and states within an agency's specified planning area;
2. help decisionmakers identify and prioritize the social and economic issues that may need to be addressed given a specific land-management action;
3. highlight the range of applicable social and economic methods and analyses that are available to address these issues; and
4. guide project management of social and economic analyses.

ASPN provides a consistent framework to ensure that best science practices are used in the social- and economic-analysis components of land-management planning. Its development was driven by agency partners, resulting in an end product that reflects their needs. In FY11, we shepherded this tool to the final stages of development, and the program underwent the initial stages of review. We anticipate that ASPN will be available for agency use in the fall of 2012. It is expected that a broad range of users, including decisionmakers, on-the-ground managers, and regional planners, will find ASPN to be a helpful tool in their land-management planning efforts.



ASPN home page. USGS image.

Contact: *Jessica Montag*

Assessing the Economic Impacts of Perennial Habitat Lands to Nearby Rural Communities in the Prairies: Potential Rural Development in the Face of Global Economic and Climate Changes

Rural communities in much of the United States continue to witness declines in economic indicators that are vital to sustainable community health. Decreases in the available workforce, increases in farm consolidation, higher median age, and deteriorating infrastructure are observable trends. The Prairie Pothole Region (PPR) of the United States—incorporating portions of Montana, North Dakota, South Dakota, Minnesota, and Iowa—is home to many rural communities experiencing such conditions. The region is largely dependent on the agricultural sector, yet is also known for its ecological value to migratory waterfowl and other wildlife species. Given record-high commodity prices, renewable fuels initiatives, and potential legislative changes to conservation programs in the Farm Bill, land-use change in the region is imminent. Thus, it is important to understand the economic impacts that various land uses have on rural communities.

In 2011, the Plains and Prairie Pothole Land Conservation Cooperative (PPPLCC) asked FORT economists to investigate these economic linkages. Our study comprises three components:

1. Estimating the economic contribution of recreation and management activities taking place on perennial habitat lands in sub-regions of the PPR;
2. Conducting workshops with local county commissioners to discuss economic impacts of land-use change and community health indicators; and
3. Highlighting the economic value of various ecosystem services produced by perennial habitat lands in the PPR with respect to various land-use scenarios.

When complete, the findings of this study will help inform policymakers who are concerned with the impacts of land-use change in their local areas. The study will also qualitatively outline the economic impacts of habitat conservation in the PPR and its ties to rural community health.

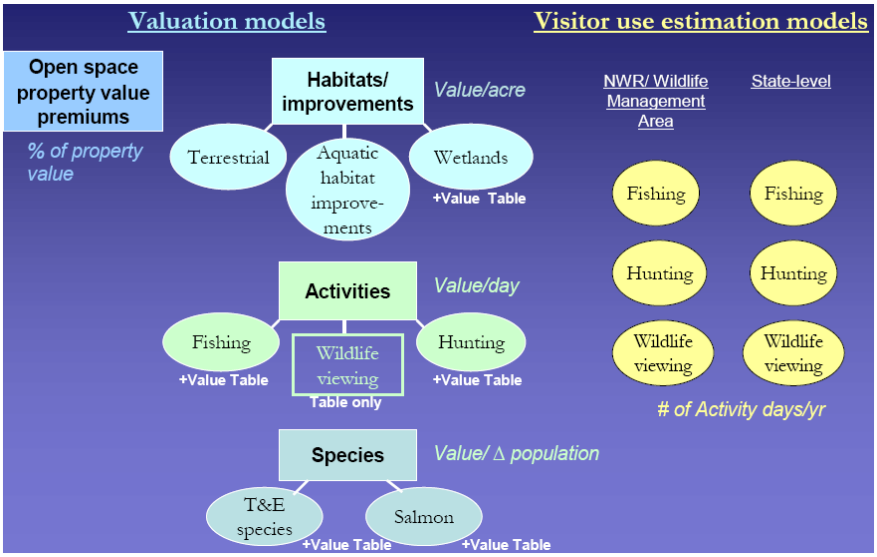
A buffered wetland on a rural farm in the Prairie Pothole Region. Photo by Mark Vandever, USGS.

Contact: *Billy Gascoigne*

The Benefit Transfer and Visitor-Use Estimating Models Toolkit

Our Nation's public and private lands provide a variety of ecosystem services and recreation opportunities. Determining how the public uses and values these services and opportunities is of increasing importance to natural resource managers. For instance, land management agencies are often required to evaluate and incorporate into the planning process the socioeconomic impacts of a management decision in compliance with National Environmental Policy Act guidelines. In addition, planners often wish to evaluate economic tradeoffs between alternative ways of managing natural resource use on public lands. To achieve these goals, two pieces of information often needed are:

1. estimates of the economic value held by the public for various ecosystem services and recreation opportunities, and
2. estimates of current visitor use or changes in visitor use associated with a management action.



Overview of estimation models currently contained in the toolkit. USGS image.

Collecting primary data to obtain this information is not always feasible given time or budget constraints, and may not be justified if resource impacts are expected to be low. Given the abundance of non-market valuation studies quantifying the economic value that the public places on various public goods and services, an alternative is to apply this existing data to unstudied policy sites, a practice referred to as "benefit transfer." In 2007, researchers at Colorado State University and Defenders of Wildlife created a simple, Web-based toolkit to help apply improvements in benefit-transfer methods by public agencies and consultants. This toolkit allows users to apply the benefit-transfer method to estimate the economic value to the public of wildlife-based recreation activities, wildlife habitats, wildlife species, and open space.

Specifically, the toolkit includes databases of non-market valuation studies and individual study values, average-value tables, and when possible, meta-analysis regression models to explain the variation in values obtained across studies. This allows public-land-management agencies, resource planners, and others to incorporate non-market values into their planning and decisionmaking without spending the time and money to obtain original data. In addition, the toolkit contains a set of models that allow users to estimate the number of current visitor-recreation-use days on national wildlife refuges. Users also can estimate changes in use days associated with a change in wildlife habitat acreage where the use is allowed. Finally, users can estimate the change in visitor-recreation-use days at the State level given a change in the acreage of a certain land type.

In 2011, FORT economists partnered with economists at the USGS Science and Decisions Center and Colorado State University to update and expand the toolkit. This is an ongoing effort that will result in visitor-use models as well as models to estimate economic values beyond those related to wildlife—all based on secondary data. When complete, the final product will be available online, with FORT supporting and maintaining it. We anticipate that agencies and other analysts will use the upgraded toolkit to quantify changes in annual economic values associated with potential management actions. The current toolkit is available at *http://dare.colostate.edu/tools/benefittransfer.aspx*.

Contact: *Leslie Richardson*

Economic Contribution of Federal Investments in Restoration of Degraded, Damaged, or Destroyed Ecosystems

Restoration projects are underway nationwide to mitigate environmental damages and improve the health and resilience of terrestrial, freshwater, and marine ecosystems via the American Restoration and Recovery Act and land-management agencies within the U.S. Department of the Interior (DOI) and U.S. Department of Agriculture (USDA). Federal investments in ecosystem restoration and monitoring protect Federal trust species, ensure public health and safety, and preserve and enhance essential ecosystem services; furthermore, these investments provide jobs. There is a need to better understand the connection between restoring the health and productivity of ecosystems and the resulting economic benefits to local communities.

Biomass material removed to improve forest and rangeland health and reduce hazardous fuels (as part of the BLM Gerber Stew Stewardship Contract) will be processed into clean chips. The chips are used to make hardboard by a nearby mill. BLM photo.

FORT economists are collaborating with economists from the DOI Office of Policy Analysis and the USGS Science and Decisions Center, and with economists, scientists, and land managers from Bureau of Land Management (BLM), National Park Service, U.S. Fish and Wildlife Service (USFWS), and U.S. Forest Service, to develop case studies to highlight the impacts of restoration to local economies. These case studies will be included in the FY12 Secretary of the Interior's Economic Report in a special chapter on restoration. The case studies include examples of collaboratively funded and managed projects to restore a wide range of degraded, damaged, or destroyed ecosystems. These case studies involve projects related to (1) an oil pipeline spill, (2) tidal marsh restoration, (3) river rechanneling, (4) invasive species mitigation, (5) wetland restoration, (6) grassland restoration, (7) forest stewardship, and (8) coral reef restoration.

The Nature Conservancy (TNC), in collaboration with the BLM, local governments, and tribes, is restoring natural channels and vegetation along the Lower Truckee River. These photos provide before-and-after views of one restoration site. Photos courtesy of TNC.

As a second phase, the USGS plans to conduct a nationwide survey to elicit information on expenditure patterns from a wide range of contractors that conduct restoration work for DOI and USDA. The objective of this survey is to develop a tool that will enable researchers and land managers to estimate the economic contributions in terms of jobs and income for any current or proposed restoration activity. This tool will support agency decisionmaking related to individual restoration projects, help prioritize spending across restoration projects, and enable agencies to meet internal guidelines for credible economic analyses.

The Nature Conservancy (TNC) is restoring the 24,000-acre Glacial Ridge property in Northern Minnesota. TNC will turn the property over to the USFWS to be included in the new Glacial Ridge National Wildlife Refuge. The project is the largest prairie grassland restoration project in U.S. history. Prairie photo courtesy of TNC; greater prairie chicken photo courtesy of Doug Dance.

Contact: *Lynne Koontz*

Assessment of Iowa CREP Wetland Buffers

For the USDA Conservation Reserve Enhancement Program (CREP), FORT is monitoring the establishment of wetland buffer vegetation to help quantify wildlife habitat quality, support wildlife models, and establish a baseline for long-term assessment of vegetative management. The primary objective of the CREP buffers is to provide soil stabilization. However, in this intensively farmed landscape, the buffers also may provide habitat for migratory waterfowl and shorebirds as well as year-round habitat for resident wildlife. The ability of CREP buffers to contribute to ecological sustainability is partly tied to programmatic restrictions such as buffer size, location, age, and management. However, management prescriptions for improving the resource have not fully been realized, and establishment of native vegetation and wildlife habitat are an added value to the landscape. To address this information need, in 2011 FORT scientists visited and sampled 18 CREP sites in the Des Moines Lobe of Iowa to identify the type and frequency of management needed for specific vegetation assemblages and successful buffer establishment. Although the existing Iowa CREP buffers represent a relatively small area of less than 500 ha (1,150 acres), the potential of this program to provide diverse plantings of native grasses and forbs to enhance wildlife habitat within this agriculturally dominated landscape appears promising.

Five-year-old CREP wetland and buffer in the Des Moines Lobe of Iowa. Photo by Mark Vandever, USGS.

Contact: *Mark Vandever*

Evaluation of Limited Grazing on CRP in the Shortgrass Steppe

The American shortgrass steppe is an immense and unique grassland with a long evolutionary history of grazing by bison and periodic drought. Grazing of the native shortgrass by cattle reduces abundances of exotic and early successional species compared with long-term ungrazed native grassland. The USDA's Conservation Reserve Program (CRP) has planted more than 6 million acres of native and introduced grasses in the shortgrass steppe over the last 25 years. These CRP plantings differ in composition and structure from native shortgrass steppe, and it was unknown how the CRP vegetation would respond to grazing treatments.

Our hypothesis was that grazing may be used to speed succession by removing highly competitive, taller weedy species in favor of grazing-tolerant, native shortgrass species. Collaborating with the USDA Farm Service Agency, Colorado State University, and a private landowner, FORT initiated a multi-faceted, long-term study evaluating the effects of limited grazing on CRP grassland species composition, soil erosion, and root production in the shortgrass steppe of eastern Colorado. Because of the geographic extent of the CRP throughout the shortgrass steppe, assessing how to successfully plant and manage these grasslands is a priority for the USDA and land managers. The results will help USDA better understand how to (1) employ grazing as a management tool to refine long-term management of CRP grasslands and (2) meet high-plains steppe ecological conditions and structural vegetative needs for wildlife species adapted to the shortgrass ecosystem.

Ungrazed (left of fence) and grazed (right of fence) treatments in an eastern Colorado Conservation Reserve Program field. Photo by Mark Vandever, USGS.

Products:

Milchunas, D.G., Vandever, M.W., Ball, L.O., and Hyberg, S., 2011, *Allelopathic Cover Crop Prior to Seeding Is More Important Than Subsequent Grazing/Mowing in Grassland Establishment*. Rangeland Ecology & Management, v. 64, no. 3, p. 291–300.

Milchunas, D.G., and Vandever, M.W., in review, Grazing Effects on Plant Community Succession of Early- and Mid-Seral CRP Seeded Grassland Compared to Undisturbed Shortgrass Steppe. Journal of Vegetation Science.

Contact: *Mark Vandever*

Do Natural or Restored Wetlands in Agricultural Landscapes Facilitate Source or Sink Amphibian Populations?

Natural landscapes are increasingly altered as human populations increase. The loss of habitat is the primary reason behind the decline in amphibian populations in altered landscapes. An example of a greatly altered landscape is the Des Moines Lobe of Iowa, which has lost over 95 percent of wetlands, largely to agriculture, since the late 19th century. This region has a rich history of amphibian presence, but habitat loss, agricultural practices, climate change, disease, and deformities have contributed to amphibian decline.

Working with the USDA Farm Service Agency, Iowa State University, and the Iowa Department of Agriculture and Land Stewardship (IDALS), FORT initiated a project to assess the utility of different wetlands (natural and restored) in providing habitat and landscape connectivity to amphibians in the Des Moines Lobe. The work involves examining water quality, testing for the presence of disease, and estimating survival and stress levels in two species of native frogs: leopard frogs (*Rana pipiens*) and chorus frogs (*Pseudacris triseriata*). The agricultural tiling system in the Des Moines Lobe is an extensive subsurface network of drains that carries excess precipitation off the landscape, making it possible to grow high-value crops such as corn and soybeans. Tile drains tend to reduce the transport of nutrients and pesticides to groundwater and increase their transport to streams—and eventually, to the Mississippi River. The Conservation Reserve Enhancement Program (CREP) is a collaborative Federal and State approach to construct and restore wetlands, and to do so in a way that addresses water-quality issues by removing nitrogen from the system while serving high-priority conservation needs (for example, creating habitat) on and around agricultural ecosystems.

Beginning in 2008, we used automated recording units at 41 CREP wetland sites to document amphibian presence. In 2011, we began the first phase of a longer-term project by securing funding for a master's student and conducting more intensive, hypothesis-driven research. At 18 of the selected CREP sites, we also sampled amphibian populations using capture-recapture techniques to determine inter-year survival rates, assess stress by measuring fluctuating asymmetry, and assess the presence of amphibian chytrid fungus. We are also sampling for water quality. Understanding the potential utility of restored and constructed wetlands and whether they are functioning as sources or sinks for amphibians in this landscape will be important to the USDA and IDALS in managing the program and the land for the future.

Conservation Reserve Enhancement Program wetland and Leopard frog (*Rana pipiens)* in the Des Moine Lobe of Iowa. Photos by Mark Vandever, USGS.

Contact: *Mark Vandever*

Assessment of the Mexican Wolf Reintroduction Project

The Mexican wolf (*Canis lupus baileyi)* was listed as endangered in 1976, and in March of 1997 the U.S. Fish and Wildlife Service (USFWS) was given approval by the U.S. Department of the Interior to restore Mexican wolves to the wild in Arizona and New Mexico. One year later, the USFWS and its cooperators released the first three family groups of wolves into the primary recovery zone on public lands in eastern Arizona. In 2002, White Mountain Apache Tribe became a formal cooperator and the first release of wolves on the Fort Apache Indian Reservation took place in 2003.

The Mexican wolf reintroduction project has been complicated by many events and the project has struggled to reach wolf population goals. The USFWS Southwest Regional Office (Region 2) contacted FORT social scientists to request a program evaluation so that they could identify programmatic barriers to project success. The timing of this request coincided with the selection of a new Mexican Wolf Recovery Coordinator who is interested in learning from past successes and difficulties as she steps into this position. Another important triggering event is that a Recovery Planning Team has begun work to identify recovery criteria, and a program evaluation could be helpful to their objectives as well.

The FORT principal investigator for this assessment conducted semi-structured interviews of 23 USFWS personnel who are current or former staff with the Mexican wolf program. Those individuals interviewed represented all levels of the program, from the Regional Director to field staff. The PI also visited one of the captive breeding facilities (located at Sevilleta National Wildlife Refuge, where wolves were released) to observe that operation. (A planned visit to the USFWS field office in Alpine, Ariz.., where wolves were released, was pre-empted by the June 2011 Wallow Fire that caused a temporary closure of that office.)

Interviewees were asked about their perceptions of communication, lines of authority, decisionmaking responsibility, budgetary issues, and other factors related to program performance. Most interviews lasted about two hours.

An administrative report of the 2011 assessment was provided to the USFWS for review in December 2011. The report includes perceptions of interviewees about obstacles to and opportunities for program success. As they move forward with Mexican wolf reintroduction and recovery, the USFWS intends to use this information to make adjustments to the program as needed.

Mexican wolf. Photo courtesy of Arizona Game and Fish Department.

Contact: *Nina Burkardt*

Negotiation Training

Negotiation is a part of everyday professional life for many employees of Federal and State natural resource management or science agencies. Many Federal statutes require agencies to engage with a variety of stakeholders, including other agencies, as management plans or regulations are developed. Scientists negotiate with their counterparts about what studies to conduct and how to interpret the data. Supervisors and those they oversee negotiate about performance plans and other matters. Public employees are required to achieve "good outcomes"—those that maximize service to the public, are efficient, and uphold agency missions. Developing negotiation skills is one way to increase the likelihood of successful outcomes.

FORT scientists have been conducting research on multi-party natural resource negotiation since the 1980s and using the findings from this research to develop negotiation classes that are targeted to meet the needs of Federal and State natural resource personnel. Currently, two classes are taught annually at FORT: Negotiation Skills for Natural Resource Professionals—Building a Foundation, and Strategies and Tactics for the Experienced Natural Resource Negotiator. Additionally, the FORT lead on this project also is an instructor for the "Negotiation and Conflict Resolution" segment of the USGS Leadership 101 class, taught twice per year at the National Conservation Training Center in West Virginia. She also assists in teaching negotiation classes sponsored by the Ruckelshaus Institute at the University of Wyoming.

The classes taught at FORT include participants from a wide variety of agencies and locations. For example, in 2011, our enrollees represented the Arizona Game and Fish Department, Bureau of Land Management, Bureau of Reclamation, Colorado Department of Public Health and Environment, Colorado Department of Transportation, Colorado State University, National Oceanic and Atmospheric Administration/National Marine Fisheries Service, National Park Service, Oregon Department of Fish and Wildlife, U.S. Forest Service, U.S. Fish and Wildlife Service, USGS, and Western Area Power Administration. The Leadership 101 classes include participants from all USGS Mission Areas and regions. One thing that we are often told by students is that it is highly beneficial for them to interact with those from other agencies and locations in a learning (as opposed to a decisionmaking) environment.

The negotiation classes are consistently rated very highly by students in the class evaluations.

"The instructor's communication with the group was very effective. I would recommend that all line officers (decisionmakers) take this course. People are in positions negotiating with no formal training."

"I gained insight into my personal negotiating tasks and responsibility because of this workshop—very much so!"

"The topics, materials, and exercises were very relevant to my work and how I need to be thinking about negotiation. I enjoyed the instructors' teaching styles and benefitted from their experience. I'm going to go back and encourage others in my organization to take this class! Thank you."

—Various course participants

Contact: *Nina Burkardt*

Ecosystems—Terrestrial, Freshwater, and Marine Environments

Sandhill Cranes in Colorado's San Luis Valley: Exploring New Technology for Improved Population Assessments

The U.S. Fish and Wildlife Service (USFWS), Division of Migratory Bird Management, seeks alternatives to manned, fixed-wing aerial surveys for some of their wildlife monitoring to reduce (1) costs, (2) the number of manned flights by having an alternative method for new survey efforts in the future, and (3) the amount of fuel needed to conduct surveys to lessen their carbon footprint. The USFWS has selected the sandhill crane (*Grus canidensis*) project for funding under the USGS Quick Response Program to explore new ways of assessing the bird's abundance on the Monte Vista National Wildlife Refuge (NWR), located in Colorado along the Central Flyway. In March 2011, FORT, USGS, and USFWS partners conducted daytime flights to determine (1) the applicability of the Raven-A, a small Unmanned Aerial System (sUAS), to detect cranes without disrupting them during various activities (roosting, loafing, and feeding), and (2) the efficacy of these data for population estimation.

The least amount of disturbance occurred during flights over roosting sites compared to sites where cranes were loafing or feeding. Ground-based counts were simultaneously conducted to compare methods of population estimates. The population estimate derived from the Raven sUAS (n=2,567) differed by 125 cranes (4.6 percent) compared with the population estimate derived from ground-based observations (n=2,692). The difference between the two methods is within acceptable error bounds associated with visual-estimation techniques for wildlife populations. These results will affect future wildlife-abundance projects well beyond this particular study. Both the USFWS and USGS staff involved were pleased with the project results. The Raven sUAS proved to be a non-intrusive, safe, and accurate way to estimate sandhill crane population abundance on roost sites. This project combines emerging technologies that may result in improved and safer wildlife-population survey techniques with a potentially cost-effective tool for monitoring cranes, and perhaps other species with similar (or larger) body size and behavior.

In October 2011, we received approval from the FAA to conduct night flights over multiple roost sites at Monte Vista National Wildlife Refuge. We are planning flights for mid-March 2012, which will provide a better population estimate for the USFWS. Collaborators and cooperators include the USGS Rocky Mountain Geographic Science Center, USFWS Region 6, USFWS Division of Migratory Bird Management, and Monte Vista NWR.

Conducting Raven sUAS flights at Monte Vista National Wildlife Refuge. Photos by USGS.

Products:

Wilson, J., and Hanson, L., 2011, Cranes and ravens—Strange airfellows? Fort Collins, Colo., USGS Fort Collins Science Center, Web feature, available at *http://www.fort.usgs.gov/RavenA/*

Hanson, L., 2011, Sandhill Cranes in Colorado's San Luis Valley—Exploring new technology for improved population assessments: Fort Collins, Colo., Fort Collins Science Center, Annual Report to U.S. Fish and Wildlife Service and USGS, 8 p.

Contact: *Leanne Hanson*

Landscape-Scale Sagebrush Habitat Mapping and Monitoring

Sagebrush ecosystems are among the most abundant and most threatened habitats in North America. Exotic plant invasions, oil and gas drilling, housing developments, altered fire patterns, over-grazing, climate change, and other factors are all contributing to degradation and fragmentation of sagebrush ecosystems. In turn, these changes can have detrimental effects on the species that depend on sagebrush, such as sage-grouse (*Centrocercus* spp.), pronghorn (*Antilocarpa americana*), pygmy rabbit (*Brachylagus idahoensis*), sage thrasher (*Oreoscoptes montanus*), and vesper sparrow (*Pooecetes gramineus*). Effective management and preservation of habitats often requires knowledge that is local in detail, landscape in scope, and long-term in time frame. Geographic information systems (GIS) informed by satellite imagery can provide such data, but traditionally sagebrush habitats have proven to be a difficult environment for remote sensing.

In 2006, in cooperation with the BLM, scientists with FORT and the USGS Earth Resources Observation Systems (EROS) Data Center began an effort to combine intensive, targeted field sampling with three resolutions of satellite imagery to produce detailed maps of sagebrush habitat characteristics for the entire State of Wyoming. Field sampling has occurred each year since then. In 2008, we began marking and resampling selected field sites to facilitate long-term monitoring efforts, particularly in conjunction with the Wyoming Landscape Conservation Initiative (WLCI). The WLCI is a multi-agency science-based effort to assess and preserve wildlife habitats while fostering responsible energy development in southwestern Wyoming.

The 2011 field effort consisted of resampling more than 500 marked transects divided among four clusters across southwestern Wyoming. The efficiency of our methods—field data gathered by a single experienced observer over the course of just two 2 months—allows production of detailed sagebrush habitat maps for an area about the size of Maryland (a single Landsat scene; the entire WLCI area is about the size of South Carolina). We published two papers describing the methodologies used in our novel modeling approach. A second paper assessing long-term changes in vegetation characteristics across southwestern Wyoming is in press.

Sagebrush overlooking the Killpecker Creek drainage, Sweetwater County, Wyoming. Photo credit: Spencer Schell, USGS.

Products:

Homer, C.G., Aldridge, C.L., Meyer, D.K., and Schell, S., 2012, *Multi-scale remote sensing sagebrush characterization with regression trees over Wyoming, USA—Laying a foundation for monitoring*: International Journal of Applied Earth Observation and Geoinformation, v. 14, no. 1, p. 233–244.

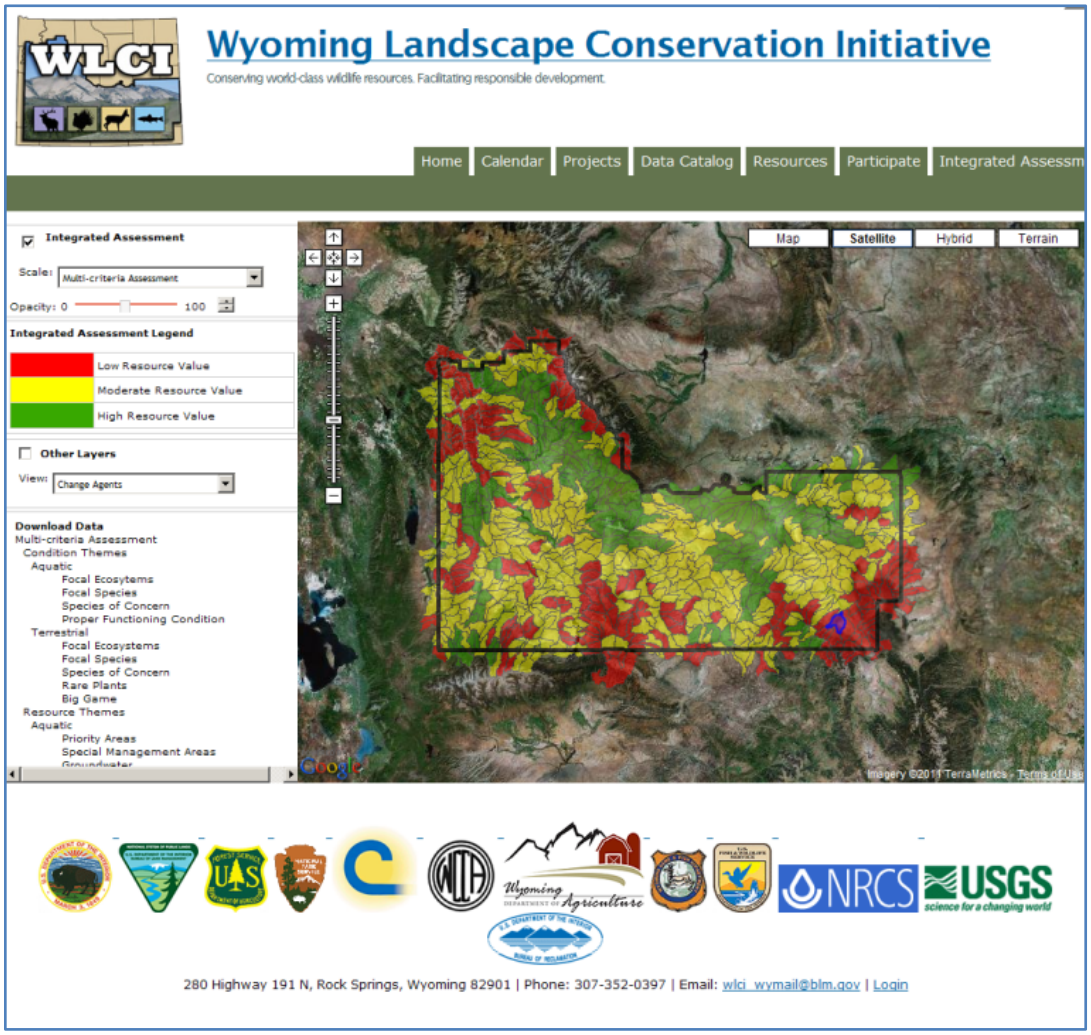
Xian, G., Homer, C.G., and Aldridge, C.L., 2012, *Assessing long-term variations of sagebrush habitat—Characterization of spatial extents and distribution patterns using multi-temporal satellite remote sensing data*: International Journal of Remote Sensing, v. 33, no. 7, pp. 2034–2058. Available early online at *http://www.tandfonline.com/doi/full/10.1080/01431161.2011.605085.*

Contact: *Cameron Aldridge*

Integrated Assessment for the Wyoming Landscape Conservation Initiative

The Wyoming Landscape Conservation Initiative (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, USGS, USFWS, the Wyoming Game and Fish Commission, the Wyoming Department of Agriculture, the USFS, six Wyoming County Commissions, and nine Wyoming Conservation Districts. The role of the USGS as a partner in the WLCI is to provide multidisciplinary scientific and technical assistance to WLCI partners and to advance the overall scientific understanding of ecosystems in southwestern Wyoming.

FORT and other USGS scientists, along with WLCI partners, developed the initial framework for a multi-resource Integrated Assessment (IA) for the WLCI area to inform planning and decisionmaking in southwestern Wyoming. The IA evaluates the natural, economic, and social context for energy development and other land uses, with a focus on informing conservation actions and decisions. Specifically, the IA will be used to identify areas with high potential for conservation, restoration, and/or development, based on current and potential land-use scenarios. This assessment takes into account both conventional and renewable energy resources, with special focus on natural gas and wind energy due to the current growth and future potential for developing them within Wyoming.



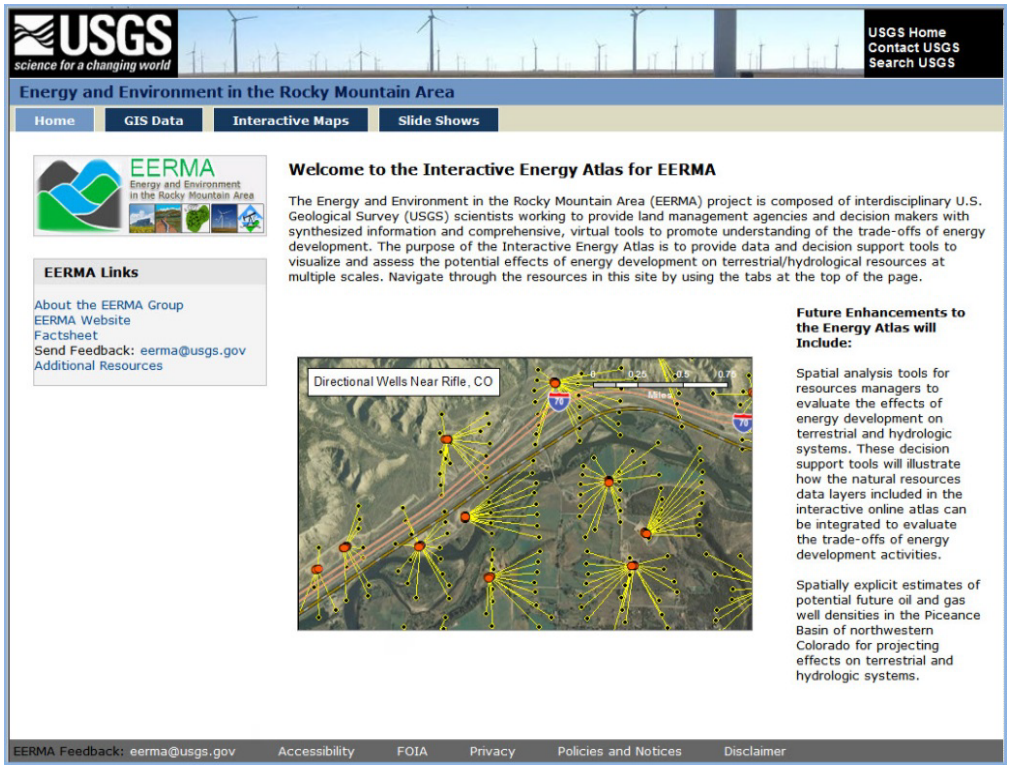
Screen capture of the Web application for the WLCI Integrated Assessment. The application allows users to view and explore results and download data used in the assessment.

Contact: *Zack Bowen*

Assessing Effects of Energy Development in Colorado and New Mexico

An interdisciplinary team of USGS scientists is working to provide land-management agencies and decisionmakers with synthesized information and comprehensive, virtual tools to promote an understanding of the tradeoffs of energy development. Increased demand for energy is driving rapid development of renewable and non-renewable energy throughout the western United States. Much of the development is occurring on public land, which constitutes about 40 percent of the land area in Colorado and New Mexico. Both of these states benefit from revenues generated by energy development, but resource managers and other decisionmakers must balance the benefits and potential effects of development on historic, scenic, recreational, and ecological resources.

The project entails compiling information on existing energy development and potential energy development. We digitized the location of wind turbines for Colorado and New Mexico and published this information in 2011 as a USGS Data Series report for each State. To provide this spatial information to decisionmakers and resource managers, we also created an online, interactive energy atlas. We are now in the process of developing an online toolbox that resource managers can use to evaluate the potential effects and tradeoffs of energy development on plant and wildlife communities as well as on hydrologic resources. Although the Bureau of Land Management is one of our primary stakeholders, the energy atlas will benefit other State and Federal agencies, the general public, and policymakers.



Home page of Interactive Online Energy Atlas for Colorado and New Mexico. The atlas provides GIS data and map packages for online viewing or downloading. USGS image.

Products:

Carr, N.B., Diffendorfer, J.E., Fancher, T.S., Latysh, N.E., Leib, K.J., Matherne, A.-M., and Turner, C., 2011, *Locations and attributes of wind turbines in Colorado, 2009*: U.S. Geological Survey Data Series 597.

Carr, N.B., Diffendorfer, J.E., Fancher, T.S., Latysh, N.E., Leib, K.J., Matherne, A.-M., and Turner, C., 2011, *Locations and attributes of wind turbines in New Mexico, 2009*: U.S. Geological Survey Data Series 596.

Carr, N.B., Diffendorfer, J.E., Latysh, N.E., Leib, K.J., Matherne, A.-M., and Turner, C., 2011, *Assessing effects of energy development in Colorado and New Mexico*: U.S. Geological Survey Fact Sheet 2011–3053, 2 p.

Contact: *Natasha Carr*

Reconstructing Flood History from Tree Rings

Shifts in river flow resulting from climate change are a major threat to water supplies and riverine ecosystems worldwide. Predicting flow changes and their effects on vegetation is essential to effective river management. The effects of human-induced climate change on river flow cannot be understood, however, unless they can be distinguished from the effects of natural climate variation and water management. Fluctuations in climate over the last century have caused flow shifts similar in magnitude to the effects of construction of major reservoirs. Therefore, there is a great need for studies of flow variation over the last few centuries to assist in detecting and adapting to the effects of global change. To address this need, FORT scientists reconstructed flow histories of rivers in the western United States, working in collaboration with the USGS Water Mission Area's National Research Program, the National Park Service Water Resources Division, and the University of Montana.

In the semi-arid western United States, reproduction of cottonwood trees is often limited to recently deposited sediment on river banks. As floods move a river channel across the flood plain, patches of trees are established to record former locations of the channel. Therefore, the pattern of tree ages on a flood plain can be used to reconstruct past channel migrations and flood history. Using cores of cottonwood trees collected in 2010, in FY11 we compared forest age distributions along several rivers in the U.S. West, including the Yellowstone River just downstream of Yellowstone National Park, the upper Green River, and the South Fork of the Snake River. Flood plains along all three of these rivers have surprisingly small areas of cottonwood forest established in the last 75–100 years. This pattern has previously been reported within Yellowstone National Park and attributed to intense grazing by elk following the removal of wolves from the park. Our observation of the same trend across a broader region, however, suggests that the 20th-century decrease in forest establishment is caused at least in part by a climate-induced decrease in peak flows. Our results are discussed in a 2011 paper to be included in the book cited below.

Cottonwood Forest in winter along the Little Missouri River in Theodore Roosevelt National Park, North Dakota. Tree ages record past history of channel changes. Photo by Jeff Hughes, National Park Service.

Product:

Merigliano, M.F., Friedman, J.M., and Scott, M.L., in press, Tree-ring records of variation in flow and channel geometry, *in* Shroder, J., Jr., Hupp, C.R., and Butler, D., eds., Treatise on geomorphology: San Diego, Calif., Academic Press.

Contact: *Jonathan Friedman*

Managing Public Access as an Adaptive Wildlife Management Tool: Impacts of OHV Use on Elk

A critical component in the successful management of elk (*Cervus elaphus*) populations is understanding their distribution, habitat preferences, and movements in relation to public and non-public lands. Within the Upper Gunnison Basin of Colorado, elk populations have increased, causing increased resource damage and escalating conflicts on both public and private lands. On public lands, elk compete with domestic livestock for available forage, potentially compete with Gunnison sage-grouse (*Centrocercus minimus*) for forage, and pose the threat of animal-vehicle collisions. On private lands they also compete with domestic livestock for available forage and can be the source of game-damage claims or conflicts.

Human activity, in various forms, plays an important role in determining the distribution of elk populations. Many studies have investigated the relationship between elk habitat use and distribution in relation to various human pressures like road density and use, which includes hunting access and motorized activities like logging and snowmobiling. General motorized vehicle use provides access to the majority of elk habitat on public lands, and in most cases off-highway vehicle (OHV) use provides the majority of motorized access. As of 2011, we have attempted to answer questions pertaining to the relationship between intensity of OHV use and elk habitat selection. We simultaneously collected data on vehicle use and elk locations, thereby providing complex and powerful datasets that increase the understanding of pertinent issues and inform land-management decisions. Methods were presented in 2011 and findings will be reported in 2012.

Elk taking advantage of the security provided by private lands for calving. Photo by Doug Ouren, USGS.

Responsibility for managing elk and elk habitat in the Upper Gunnison Basin is a responsibility shared by the National Park Service (Black Canyon of the Gunnison National Park and Curecanti National Recreation Area), the Bureau of Land Management (Uncompahgre Field Office), the U.S. Forest Service (Gunnison National Forest), and Colorado Parks and Wildlife. All of these agencies are participating in this research and adaptive management project.

Products:

Ouren, D., and Keim, J., submitted for 2012, Impacts of OHV use on elk distribution and habitat use: U.S. Geological Survey Open-File Report.

R.D. Watts, and Coffin, A.W., 2011, OOS 53-1: Beyond the pavement—Scientific methods for quantifying ecological response to off-highway vehicle use, *in* Technical Program of the 95th Annual Meeting of the Ecological Society of America, Pittsburgh, Penn., August 1–6, 2010: Washington D.C., Ecological Society of America. Abstract online at *http://eco.confex.com/eco/2010/techprogram/P22523.HTM*. 1 p.

Contact: *Doug Ouren*

Gunnison Sage-Grouse Habitat Use and Movement: The Crawford Population

In July 2000, the Gunnison sage-grouse (*Centrocercus minimus*) was officially recognized by the American Ornithologists' Union as a unique, endemic species, and it is listed as a "species of special concern" by all Federal and State natural resource management agencies throughout its range. Declines in Gunnison sage-grouse populations have been attributed primarily to loss and alteration of sage-steppe habitat. Now these birds exist in seven relatively small, isolated populations, primarily in Colorado and Utah. The largest population (fewer than 3,000 individuals) inhabits the Gunnison Basin in west-central Colorado. The Crawford population, estimated at 128 individuals, inhabits Black Canyon of the Gunnison National Park and the Gunnison Gorge National Conservation Area. Although this population is small, it is still considered a self-sustaining population, and its persistence and growth contributes directly to conservation of the species' genetic diversity. Prior to this project, there was only observational and anecdotal information about the range, movements, and seasonal habitat use of this population.

Gunnison sage-grouse with GPS backpack.
Photo by Doug Ouren, USGS.

To develop much-needed objective information on the Crawford population, the USGS, including FORT, has developed a multi-agency (National Park Service, Bureau of Land Management, U.S. Forest Service, and Colorado Parks and Wildlife) project to assess the following: (1) Gunnison sage-grouse seasonal habitat use and movement patterns, (2) effects of off-highway vehicle use on the birds' movements and distribution, (3) lek site probability (mapping), (4) effects of vegetation treatment on the species' movements and distribution, (5) historical use by the species in the Crawford area, and (6) nest predation. To address these topics, the USGS has been tagging Gunnison sage-grouse with GPS backpacks programmed to collect the birds' locations 14 times per day. Locations are emailed to the investigator every five days so that the data are readily available for analysis. In addition to the GPS monitoring, a 15-site OHV-monitoring network was established to monitor the intensity of motorized use in the area. Additionally in 2011, we developed a technique for assessing Gunnison sage-grouse habitat to help locate previously unknown lek sites, which will help to improve estimations of population trends. In 2012, the USGS and the BLM will launch a new project to study nest predation using video surveillance.

The multi-year USGS study of the impact of roads and traffic on Gunnison sage grouse has been the foundation of BLM's efforts to work collaboratively with Federal, State, County and private partners to protect, restore, and enhance Gunnison sage-grouse in the Gunnison Gorge National Conservation Area (GGNCA) and on surrounding private and public lands.

—Karen Tucker, Bureau of Land Management

Product:

Ouren, D.S., Childers, T., Siders, M., Tucker, K., Diamond, B., Homan, D., and Farmer, A., 2011, Gunnison sage-grouse habitat use and movement study—The Crawford population: Annual report provided to Black Canyon National Park, Gunnison, Colo., and the Bureau of Land Management, 6 p.

Contact: *Doug Ouren*

Developing a Public–Private Partnership to Support Potential Bison Restoration in the San Luis Valley, Colorado

The U.S. Department of the Interior recently initiated a Bison Conservation Initiative, which outlines conservation and restoration goals for North American plains bison (*Bison bison bison*) and wood bison (*B.b. athabascae*). Goals of the initiative include locating and determining suitable areas for new bison conservation herds for expansion of existing herds. The National Park Service (NPS) also identified 36 goals for their Centennial "Call to Action" (NPS, 2011), which outlines the direction of NPS for the next hundred years. One of their most important objectives is to "Return the American bison… to our country's landscape" (p. 18). One area considered for establishing a new conservation herd is the San Luis Valley in south-central Colorado. This landscape is home to a vast interconnected tract of Federal, State, and nongovernmental organization lands, including the Baca National Wildlife Refuge and Great Sand Dunes National Park, and is historic bison range.

Before restoring bison to the San Luis Valley, resource managers need scientifically based information to help them understand how bison will interact with both vegetation and elk in valley ecosystems. To address this need, FORT and the USGS Northern Rocky Mountain Science Center (NOROCK) initiated a public-private partnership (with three Federal agencies, The Nature Conservancy, and a private rancher) to investigate the potential to expand the existing bison population and ultimately establish a contiguous bison herd on the refuge, the park, and The Nature Conservancy lands.

Dr. Peter Gogan from the Northern Rocky Mountain Science Center (left) assisting our private-collaborator team members with implanting an ear chip in a small bison calf. Implants allow us to identify individuals, so we can track body weights and develop a model of fitness relative to climate conditions over time. Photo by Kate Schoenecker, USGS.

Previous research conducted by FORT in the San Luis Valley revealed some interesting dynamics among elk, bison, and vegetation. Our goal is to capitalize on this existing dataset to answer some key remaining questions and enhance our understanding of bison ecology in peripheral, arid habitats. Historically, the highest densities of bison occurred on the Great Plains; however, they also inhabited many areas outside the prairies, including desert and semi-desert, and little is known about their ecology and habitat interactions in these areas. Because global climate change is predicted to promote desertification, understanding function and species interactions in arid ecosystems is important for land managers tasked with responding to global climate change. We seek to understand the ecology of bison and their habitat relations in one of their peripheral but historic habitats: the cold desert.

In FY11, we initiated research and began field work in fall 2011 by implanting 1,400 bison with chips to allow us to identify individual animals. We are currently submitting proposals for funds to radio-collar bison and elk, and to measure vegetation. Research collaborators include NPS, the U.S. Fish and Wildlife Service, the Nature Conservancy, Zapata Partners (private rancher currently managing the bison), and NOROCK. Results and products of this project will provide resource managers with tools and information for making scientifically based decisions on bison restoration.

Reference: National Park Service, 2011, A call to action—Preparing for a second century of stewardship and engagement, Washington, D.C., National Park Service, p. 18.

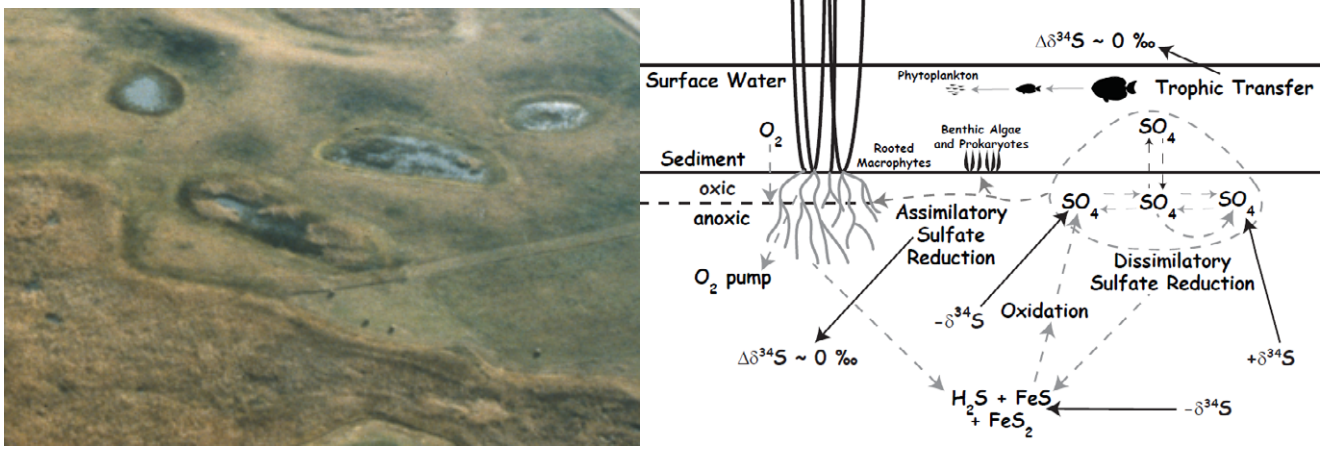
Contact: *Kate Schoenecker*

Sulfur Biogeochemistry of Aquatic Ecosystems

Nutrient cycling is a critical aspect of ecosystems, and a thorough understanding of such fundamental processes affords insight into controls on productivity and diversity. Sulfur is a redox-sensitive element that is a crucial building block in organic tissues. However, when in excess, sulfur is a pollutant of concern and plays a role in the methylation of mercury, a toxic form of mercury that concentrates in tissue progressively through higher trophic levels. FORT scientists have been studying the sulfur cycle in a variety of ecosystems using isotope techniques.

In 2011, we continued biogeochemical studies at the Cottonwood Lakes Area in North Dakota as part of the USGS Critical Zones project. The goal of this work is to better understand controls on water chemistry among individual wetlands within the landscape mosaic (see photo below at left). The glacial till soils are rich in sulfate, and isotopic data support the contention that oxygenated groundwater interacting with pyrite is the source of sulfate to wetland surface waters. The addition of geochemical context will inform land managers about water quality. Collaborators include USGS scientists from FORT, the Crustal Geophysics and Geochemistry Science Center, the Colorado Water Science Center, and the Northern Prairie Science Center.

Also in 2011, we completed a study detailing a mass-balance study of methylmercury production in natural and rice wetlands near Sacramento, Calif. Hydrologically managed wetlands are a dominant global landcover, with examples ranging from restored wetlands to seasonally flooded agricultural wetlands (such as those used in rice production). Seasonal flooding and dessication of soils contributes to a dynamic microbial ecology and, as a consequence, may also promote conditions where mercury, a contaminant of concern, is converted to the toxic methylmercury. The sulfur cycle has been shown to be involved in this process, and isotopic techniques have been very useful in detailing biogeochemical pathways (see figure below at right). This work was timely in providing important context for the development of a State-wide total daily maximum load for methylmercury. Collaborators include, among others, the Northern Prairie Science Center, the California Water Science Center, Moss Landing Marine Lab, and Battelle Marine Sciences.



(L) Prairie wetland landscape. (R) Isotope systematics of the sulfur cycle. USGS images.

Products:

Goldhaber, M.B., Mills, C., Stricker, C.A., and Morrison, J.M., 2011, *The role of critical zone processes in the evolution of the Prairie Pothole Region wetlands*: Applied Geochemistry , v. 26, p. S32–S35.

Mills, C.T., Goldhaber, M.B., Stricker, C.A., Holloway, J.M., Morrison, J.M., Ellefsen, K.J., Rosenberry, D.O., and Thurston, R.S., 2011, *Using stable isotopes to understand hydrochemical processes in and around a Prairie Pothole wetland in the Northern Great Plains, USA*: Applied Geochemistry, v. 26, p. S97–S100.

Contact: *Craig Stricker*

Ecosystems—Wildlife and Terrestrial Resources

Field Testing an Oral Plague Vaccine for Prairie Dogs

Plague, caused by the bacterium *Yersinia pestis,* is well-known for its capability to cause large-scale epidemics in humans and epizootics (animal epidemics) in rodents. Plague was introduced to North America around 1900 via trans-Pacific shipping. Though it is a disease that primarily affects rodents, it has infected more than 200 species of mammals. Plague has received much attention as a lethal human pathogen but relatively little investigation has been performed regarding its potential to modify the natural ecosystems it invades. During studies conducted by FORT biologists in Utah and Montana, plague management (via dusting with insecticides to reduce fleas that are vectors) improved annual prairie dog survival rates by an estimated 31–45 percent, even when epizootics of the disease were absent. In a similar study of enzootic (endemic to an area or population) plague, flea control or an experimental plague vaccine improved annual survival of the associated black-footed ferrets by more than 200 percent in Montana. Ferrets and prairie dogs are probably similarly susceptible to the disease (over 90-percent mortality), but the vulnerability of ferrets might be increased due to their much larger home ranges and exposure via infected carrion. Plague has had devastating impacts on several ferret reintroduction sites, but the most notable case occurred in 2007 with the invasion of the disease into the 26,000-acre Badlands/Conata Basin complex of prairie dogs that supported reintroduced ferrets in South Dakota. Annual dusting with deltamethrin has protected about 12,000 acres of the habitat, but prairie dog and ferret populations have collapsed on almost all habitat that has not been dusted.

A sylvatic plague vaccine (SPV), developed and tested jointly over several years (including FY11) by FORT, the USGS National Wildlife Health Center (NWHC), and University of Wisconsin, shows great promise as an effective preemptive method for controlling plague in prairie dogs without the disadvantages and potential collateral environmental effects of dusting with insecticides. This vaccine can be delivered via oral bait. The use of this vaccine to prevent plague outbreaks in targeted prairie dog complexes, particularly where black-footed ferrets have been released or where prairie dog conservation is a goal, could have both economic and environmental benefits. A plague vaccination program could enhance prairie dog and ferret recovery efforts, reduce pesticide use on public lands, allow managers to balance land-use needs (agriculture and development) with conservation efforts on other sites, and reduce the need to close public spaces and military sites due to plague.

The next step in developing a plague vaccination program is to work through the product registration process of the USDA Animal and Plant Health Inspection Service, which ensures that veterinary biologics—such as vaccines for the diagnosis, prevention, and treatment of animal diseases—are pure, safe, potent, and effective. FORT and NWHC scientists have joined biologists from other State and Federal agencies (Colorado Parks and Wildlife, U.S. Fish and Wildlife Service, National Park Service, Bureau of Land Management, U.S. Forest Service, and the Natural Resources Conservation Service) to form a "science advisory team" to help plan and oversee the required safety and efficacy trials of the vaccine in the field. Documents such as "Framework for field studies on oral plague vaccine for prairie dogs" and "Phase II field studies on sylvatic plague vaccine for prairie dogs" have been written to help guide the overall process and the specific field research that is needed. Safety trials and possibly some efficacy trials are expected to begin in 2012.

Plague is the most important biological impediment to conservation of prairie dogs (L) and black-footed ferrets (R). Photos by Dean Biggins, USGS.

Contact: *Dean Biggins*

Commemorating the 30th Anniversary of Re-discovery of Black-footed Ferrets

In 1851, two well-known American naturalists (Audubon and Bachman) first described the black-footed ferret (*Mustela nigripes*) to the scientific world, but by early in the next century, the black-footed ferret already was suffering from human persecution of the prairie dogs (*Cynomys* spp.) on which it depended. In 1929, E.T. Seton said, "Now that the big Demon of Commerce has declared war on the Prairie-dog, that merry little simpleton of the Plains must go...and with the passing of the Prairie-dog, the Ferret, too, will pass." Just 50 years later, Seton's prophecy was nearly fulfilled when the last black-footed ferret of the first captive-breeding effort died and free-ranging ferrets could no longer be found. But in September 1981, hope was restored when a ranch dog killed a black-footed ferret near Meeteetse, Wyo. Unfortunately, two diseases, plague and canine distemper, ravaged the Meeteetse population of prairie dogs and ferrets. The last 18 ferrets were rescued from Meeteetse during 1985–1987. FORT biologists were involved in capturing these remaining ferrets and the various aspects of captive breeding and reintroduction that followed to try to save the species from extinction. These efforts continue today.

Questions and problems that emerged during years of operational conservation of black-footed ferrets have been addressed by a wide variety of studies. Early results from such studies often were communicated orally during meetings of recovery groups and in written form using memoranda, unpublished reports, and theses. Most, but not all, of these studies were later published in journals. During 2010–2011, the FORT principal investigator for ferret studies aggregated and updated previous unpublished but seminal studies that tell the story of research milestones affecting ferret recovery. This dedicated collection of papers, published in the August 2011 issue of the *Journal of Mammalogy*, commemorates the 30th anniversary of rediscovery of the black-footed ferret at Meeteetse. The issue contains eight papers that summarize data collected over most of the 30 years. FORT scientist Dean Biggins is co-author on seven of the eight papers and provides the opening remarks for this special issue. His titles in that volume (92[4]) include the following:

Biggins, D.E., Livieri, T.M., and Breck, S.W., *The interface between black-footed ferret research and operational conservation*, p. 699–704.

Fagerstone, K.A, and Biggins, D.E., *Black-footed ferret areas of activity during late summer and fall at Meeteetse, Wyoming*, p. 705–509.

Biggins, D.E., Hanebury, L.R., Miller, B.J., and Powell, R.A., *Black-footed ferrets and Siberian polecats as ecological surrogates and ecological equivalents*, p. 710-720.

Biggins, D.E., Miller, B.J., Hanebury, L.R., and Powell, R.A., *Mortality of Siberian polecats and black-footed ferrets released onto prairie dog colonies*, p. 721–731.

Poessel, S.A., Breck, S.W., Biggins, D.E., Livieri, T.M., Crooks, K.R., and Angeloni, L., *Landscape features influence postrelease predation on endangered black-footed ferrets*, p. 732–741.

Biggins, D.E., Godbey, J.L., Horton, B.M., and Livieri, T.M., *Movements and survival of black-footed ferrets associated with an experimental translocation in South Dakota*, p. 742–750.

Cover photo of the August 2011 issue of the Journal of Mammology.

Eads, D.A., Millspaugh, J.J., Biggins, D.E., Livieri, T.M., and Jachowski, D.S., *Post-breeding resource selection by adult black-footed ferrets in the Conata Basin, South Dakota*, p. 760–770.

Contact: *Dean Biggins*

Evaluating Habitat Objectives in Comprehensive Conservation Plans for National Wildlife Refuges

FORT scientists have provided technical assistance to the U.S. Fish and Wildlife Service (USFWS) for developing Comprehensive Conservation Plans (CCPs). These plans, required by the 1997 National Wildlife Refuge System Improvement Act, commonly include specific numerical criteria for habitat-management objectives. Refuges are collecting vegetation data to monitor their habitats, but they have had little guidance on quantitative approaches to evaluate whether habitat-management objectives are being met. A FORT scientist and USFWS biologist used recent advances coupling quantile regression and equivalence testing (Cade, 2011) to evaluate compliance with habitat objectives specified in the CCP for Arapaho National Wildlife Refuge in northern Colorado. The analyses and procedures used relied on the first four years of monitoring data collected at the refuge. This approach provided both conservative and liberal interpretations of sampling variability for estimated proportions of the habitat that met specified objectives. The analyses were useful both for evaluating the current state of the refuge with respect to desired conditions and for providing feedback on how to improve the specification of habitat objectives. The quantile equivalence framework can be readily extended to other refuges and to other objectives that are specified as intervals of desirable values. Our experiences with developing CCPs and evaluating compliance with habitat-management objectives are continuing with a project to provide assistance to the USFWS to revise their CCP for the San Luis Valley complex of refuges (Alamosa, Monte Vista, and Baca) in southern Colorado.

Refuge biologists taking habitat measurements. USFWS photo.

Products:

Cade, B.S., and Johnson, P.R., 2011, *Quantile equivalence to evaluate compliance with habitat management objectives*: Journal of Fish and Wildlife Management, v. 2, no. 2, p. 169–182.

Cade, B.S., 2011, *Estimating equivalence with quantile regression*: Ecological Applications, v. 21, no. 1, p. 281–289.

Contact: *Brian Cade*

Ecological Investigations of White-Nose Syndrome in Bats

White-nose syndrome (WNS) is an emerging disease of hibernating bats that is causing unprecedented population declines in multiple species of bats in North America. WNS has spread during the past five winters from a small area of New York to a region now covering at least 16 states and 4 Canadian provinces. WNS is caused by a highly invasive fungus (*Geomyces destructans*) that infects the skin of bats. During FY11, FORT scientists continued participating in efforts to coordinate the national response to this wildlife emergency, provided support to disease researchers at the USGS National Wildlife Health Center (NWHC), and expanded a field study into causes and consequences of the disease. This video-monitoring project, in cooperation with the National Park Service (NPS) and the University of Tennessee, involves investigating the hypothesis that skin infection by *G. destructans* triggers unsustainable aberrant behaviors in bats during hibernation, thus causing death. The project is also identifying environmental conditions under which effects of disease occur. Four custom-made, surveillance-camera systems capable of monitoring the behaviors of hibernating bats in deep, dark caves and mines over the entire hibernation period were deployed in four states. The high-resolution video imagery will help determine whether behavioral changes associated with skin infection by the cold-growing fungus are the likely cause of mortality in bats affected by WNS. This information will help resource managers know when and where to target efforts to minimize disease effects. Additional WNS activities at FORT include using habitat-association modeling to predict the potential spread of WNS (with Colorado State University), investigating electrolyte imbalance in affected bats (with the NPS, NWHC, Bucknell University, Pennsylvania Game Commission), and developing an online database for tracking WNS (with the U.S. Fish and Wildlife Service).

Screen capture of video imagery gathered by remote surveillance cameras deep within a bat hibernation cave. Photo by Paul Cryan, USGS.

Products:

Lorch, J.M., Meteyer, C.U., Behr, J., Boyles, J.G., Cryan, P.M., Hicks, A.C., Ballmann, A.E., Coleman, J.T.H., Redell, D.N., Reeder, D.M., and Blehert, D.S., 2011, *Experimental infection of bats with Geomyces destructans causes white-nose syndrome:* Nature, v. 480, p. 376–378.

Foley, J., Clifford, D., Castle, K., Cryan, P., and Ostfeld, R.S., 2011, *Investigating and managing the rapid emergence of white-nose syndrome, a novel, fatal, infectious disease of hibernating bats*: Conservation Biology, v. 25, p. 223–231.

Blehert, D.S., Lorch, J.M., Ballman, A.E., Cryan, P.M., and Meteyer, C.U., 2011, *Bat white-nose syndrome in North America*: Microbe, v. 6, p. 267–273.

Cryan, P.M., Meteyer, C.U., Boyles, J.G., and Blehert, D.S., 2010, *Wing pathology associated with white-nose syndrome in bats suggests life-threatening disruption of physiology*: BMC Biology, v. 8, no. 135, p. 1–8.

Contact: *Paul Cryan*

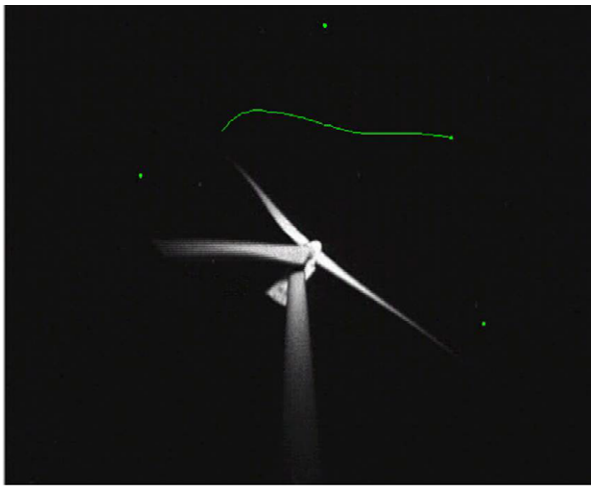
Investigating Causes and Consequences of Bats Fatalities at Wind Turbines

Wind energy is one of the fastest-growing energy industries in the world and is an important step toward reducing dependence on non-renewable sources of energy. However, turbines are causing unprecedented mortality of migratory tree-roosting bats during late summer and early autumn. Causes of bat collisions with turbines remain unknown. Current USGS research is building upon earlier studies by the FORT and other agencies. These studies examined the natural histories of the affected species to help determine such things as the origins of bats killed by turbines, whether bats are attracted to turbines, whether mating and/or feeding behaviors play a role in fatalities, and how risk to bats might be predicted before turbines are built.

During 2011, scientists from FORT and four other USGS science centers initiated a project to combine and compare different methods of monitoring bat activity and fatality at wind turbines, including carcass searches (FRESC), mobile radar (NOROCK), acoustic monitoring (NPWRC), and video surveillance (PIERC). FORT and PIERC scientists developed a new infrared video system capable of remotely imaging bats and birds flying in the dark at the heights of wind turbines (greater than 100 m) and are now developing computer programs capable of automatically detecting bat activity of interest in the recorded imagery. Video imaging holds promise for assessing bat fatality at turbines as well as directly observing behaviors that may explain susceptibility. By identifying and substantiating the causes of bat mortality, solutions may be possible in the future to reduce bat mortality while minimizing costs to the wind-energy industry.

In collaboration with the University of Pretoria (South Africa), University of Tennessee, and Boston University, FORT scientists also co-authored a paper in *Science* that was the first assessment of the economic importance of the pest control services provided by bats at a national scale. The authors' intent was to highlight the importance of conserving bat populations that are confronting two new and very different threats: wind turbines and white-nose syndrome.

Biologists from the USGS Fort Collins Science Center and Hawaii Cooperative Studies Unit set up a video monitoring system for field testing at a wind energy facility in Pennsylvania during August 2011. Photo by Paul Cryan, USGS.



Snapshot from infrared video. The green line shows the motion analysis program detecting and tracking the flight trajectory of a bat passing a turbine approximately 80 m above the ground. Photo by Mark Hayes, CSG.

Products:

Cryan, P.M., 2011, *Wind turbines as landscape impediments to the migratory connectivity of bats*: Environmental Law, v. 41, no. 355–370.

Boyles, J.G., Cryan, P.M., McCracken, G.F., and Kunz, T.H., 2011, *Economic importance of bats in agriculture*: Science, v. 332, p. 41–42.

Contact: *Paul Cryan*

Bats of Ouray National Wildlife Refuge, Utah

Ouray National Wildlife Refuge (NWR) is located in the northeastern corner of Utah along the Green River and is part of the Upper Colorado River System and the Colorado Plateau. Nineteen different species of bats call the Colorado Plateau home, 18 of which have been documented in the State of Utah. Except for a single silver-haired bat (*Lasionycteris noctivagans*) caught on the refuge in 2009, the managers at Ouray NWR did not know which of those 18 species of bats would be found using the refuge. FORT initiated a field study in collaboration with U.S. Fish and Wildlife Service and Quick Response Program (QRP) funds to inventory the bats at the refuge during the summer of 2010. FORT scientists captured and identified bats at water sites and flyways and collected echo-location activity of bats to augment species occurrence information. The report for this study was issued in February 2011 (Ellison 2011).

A diverse bat fauna was found at Ouray NWR. Nine species of bats were captured using mist nets and an additional four species were identified based on recordings of unique vocalizations. All of these species were previously undocumented for the refuge. Only 36 individual bats were captured in mist nets because of the prevalence of water on the refuge; however, more than 22,000 acoustic recordings were collected. The two most commonly captured species in mist nets were the pallid bat (*Antrozous pallidus*) and the big brown bat (*Eptesicus fuscus*). Conversely, the largest number of bat recordings identified to species was from the canyon bat (*Parastrellus hesperus*) and the big free-tailed bat (*Nyctinomops macrotis*).

There have been relatively few surveys of the bat fauna within specific land management areas, especially in the state of Utah. Bats are notoriously difficult to survey due to their nocturnal activity, secretive daytime habits, and their mobility across the landscape. If mist netting alone was used to survey for bats at Ouray NWR during this field study, only nine species would have been documented. By including acoustical monitoring, the species list was increased by 4 for a total of 13 species known to occur on the refuge. This field study illustrated the need to use multiple field techniques in order to identify the bat fauna of a particular land management area.

An acoustic monitoring station at Ouray NWR. Anabat ultrasonic bat detectors were fitted inside metal cases and affixed to steel posts. Photo by Laura E. Ellison.

Product:

Ellison, L.E., 2011, *Bats of Ouray National Wildlife Refuge, Utah*: U.S. Geological Survey Open-File Report 2011–1032, 51 p.

Contact: *Laura Ellison*

The Ecological Role of Bats as Reservoirs of Rabies Viruses: Final Mathematical Model

Big brown bat (*Eptesicus fuscus*). Colorado State University photo.

Bats are known to serve as natural reservoirs for the rabies virus, but the ecological mechanisms by which rabies is maintained within bat populations remain a mystery. The big brown bat (*Eptesicus fuscus*) is the most highly commensal bat in the United States, occurs nationwide, and is the most commonly submitted bat for rabies diagnostic examinations nationally (more people are potentially exposed to rabies from this bat than from any other species). Working with Colorado State University and the Centers for Disease Control and Prevention, in FY11 FORT scientists completed an intensive study of population dynamics and rabies prevalence in big brown bats with publication of a final mathematical model of the host and virus dynamics. The model describes the cycle of rabies virus infection and persistence in big brown bats by focusing on seasonal bat mortality rates, acquired immunity, virus dormancy in winter, and bat reproduction.

In the resulting publication, we report that decreased bat metabolism and cold temperatures slow viral development during hibernation, which is followed by a pulse of births as warmer weather returns. It was found that the winter interruption of viral incubation time allowed infected bats to enter hibernation and survive long enough to pass the virus on to the next year's cohort of susceptible juveniles, thereby continuing the cycle of infection. The model's predicted timing of peak bat rabies infections corresponded with an actual peak in reported cases of rabies through public-health surveillance. Finally, simulations of the model that omitted the hibernation period showed that the infected bat population would have crashed without winter dormancy.

These results have important implications for public-health programs and for conservation of bat populations. Results show that rabies exposure is widespread in bats and that the disease is enzootic (endemic), not epizootic (epidemic). Large-scale outbreaks and mass public exposure due to irruptions of rabies in bats are unlikely; instead, public health authorities can continue to expect a low number of cases annually. Bats have a limited degree of natural "herd immunity" from low-level exposure to rabies from other bats of their own species, and vaccination control programs would not only be impractical, but probably unnecessary. Similarly, die-offs due to rabies are unlikely to occur in endangered species of bats. The host-population dynamics explored in the study are important in planning conservation management strategies for bats because they demonstrate that the most important demographic parameter for positive bat population growth is high adult survival. This study also sets the stage for better understanding the potential range of host-virus parameters that may be important to the emergence of other viruses in bats, a topic of increasing concern: bats have been the source of viruses leading to certain diseases with human health consequences, such as Ebola, SARS, and Nipah. In addition to publication of the final model, this project has produced 21 publications in journals and books, 4 master's theses, and 1 doctoral dissertation.

Product:

George, D.B., Webb, C.T.. Farnsworth, M.L., O'Shea, T.J., Bowen, R.A., Smith, D.L., Stanley, T.R., Ellison, L.E., and Rupprecht, C.E., 2011, *Host and viral ecology determine bat rabies seasonality and maintenance*: Proceedings of the National Academy of Science, v. 108, p. 10208–10213.

Contact: *Tom O'Shea*

Population Size of Island Loggerhead Shrikes on Santa Rosa and Santa Cruz Islands

Island loggerhead shrikes (*Lanius ludovicianus anthonyi*) are an endemic, genetically distinct subspecies of loggerhead shrike with breeding populations on three of the eight California Channel Islands: Santa Rosa Island, Santa Cruz Island, and Santa Catalina Island. Anecdotal accounts suggest that shrikes were once common on these islands but have decreased in abundance. Unfortunately, despite several recent attempts to quantify the abundance of shrikes, poor study design and incomplete sampling have produced unreliable estimates of the number of remaining shrikes.

Despite the absence of satisfactory abundance estimates for shrikes, it is believed that in 2006 there were only 15–30 shrikes on Santa Rosa Island and 20–30 shrikes on Santa Cruz Island, so *L. l. anthonyi* was listed as a Species of Special Concern by the California Department of Fish and Game. A petition to federally list *L. l. anthonyi* as an endangered subspecies was submitted in 2006. In the event of such a listing, a formal recovery plan will be required. Therefore, a rigorous estimate of the number of remaining shrikes on the islands is urgently needed. FORT's objective in this study was to obtain an accurate estimate of shrike abundance on the two islands, which are part of Channel Islands National Park.

During the 2009 and 2010 breeding seasons, biologists from FORT, the National Park Service, the University of California Santa Barbara, and the Western Foundation for Vertebrate Zoology surveyed sample units for shrikes on Santa Rosa and Santa Cruz Islands using a statistically rigorous sampling design. In a manuscript completed and submitted to four publications in FY11, we estimated shrike abundance to be 169 in 2009 and 240 in 2010 for Santa Rosa Island, and 35 in 2009 and 42 in 2010 for Santa Cruz Island. These numbers are higher than previously reported, especially for Santa Rosa Island, but nevertheless are still low.

Our abundance estimates represent a baseline against which land managers will evaluate the effectiveness of their management efforts, and the interannual variability in abundance that is estimable from our data will be used to develop target abundance levels for each island that account for environmental variation.

The island loggerhead shrike is a predatory songbird that occurs on Santa Rosa and Santa Cruz Islands, Calif., which are part of Channel Islands National Park. Photo by Andrew Fisher.

Product:

Stanley, T.R., Teel, S., Hall, L., Dye, L., and Laughrin, L. 2012, *Population size of island loggerhead shrikes on Santa Rosa and Santa Cruz islands*: Wildlife Society Bulletin, v. 36, no. 1, p. 61–69.

Contact: *Tom Stanley*

Science in Support of Wild Horse Management

With passage of The Wild Free-Roaming Horses and Burros Act of 1971 (Public Law 92-175), the Bureau of Land Management (BLM) was given primary responsibility for management of wild horses on rangelands of the western United States. Since that time, the BLM has faced two primary management challenges. First, given the protection afforded by the Act and a general lack of natural predators in most areas, wild horse populations can double every 3–5 years and rapidly exceed the carrying capacities of their ranges. Second, depending on terrain, weather, and other factors, it can be very difficult to estimate the number of wild horses in a population, which leaves the advisability of any subsequent management action open to question.

For about a decade, FORT has been working with the BLM to help address their horse management challenges. This work has entailed two primary foci: (1) developing fertility control measures to help slow population growth rates, and (2) developing techniques to provide more reliable estimates of population size. To evaluate fertility controls, we treated mares with a contraceptive, porcine zona pellucida (PZP), at the Little Book Cliffs Wild Horse Range in Colorado, the McCullough Peaks Herd Management Area in Wyoming, and the Pryor Mountain Wild Horse Range in Wyoming and Montana. These treatments involved two formulations of PZP: (1) a liquid form thought to be effective for 1 year and (2) a time-release, pelleted form thought to be effective for 22 months. In FY 2011, a journal article was published detailing the results of this work (Ransom and others, 2011).

Also in FY 2011, we expanded our work by contracting with Oregon State University to study the safety and mechanism of action for a third form of PZP known as SpayVac® (Immunovaccine Inc., Halifax, Nova Scotia). Using both aqueous and non-aqueous forms of SpayVac®, we treated 30 captive mares with each of the 2 formulations, and 30 mares served as untreated controls. The mares are being monitored for both antibody titers and pregnancy. In cooperation with Colorado State University and the National Park Service, we also conducted a field trial on wild horses with another type of contraceptive, Gonacon™, at Theodore Roosevelt National Park. Results of these new aspects of our work will be submitted for publication in FY 2012. Finally, we conducted a training course for BLM personnel on how to collect aerial survey data using either of two established methods for accurately estimating ungulate populations. The BLM will use the results of our contraception and population-estimation studies to inform management of wild horse populations on western ranges within their jurisdiction.

Wild horses at Pryor Mountain Wild Horse Range have been treated with the immunocontraceptive porcine zona pellucida (PZP) to reduce fertility in females. Photo credit: Jason Ransom, USGS.

Product:

Ransom, J.I., Roelle, J.E., Cade, B.S., Coates-Markle, L., and Kane, A.J., 2011, *Foaling rates in feral horses treated with the immunocontraceptive porcine zona pellucida*: Wildlife Society Bulletin, v. 35, no. 4, p. 343–352.

Contact: *Butch Roelle*

Food Webs and Nutrition Inferred from Stable Isotopes

Understanding the trophic structure and nutritional basis of food webs is critical to the management of fish and wildlife populations. Additionally, perturbations such as species introductions, habitat degradation, pollution, and climate change can have significant impacts at the ecosystem level, yet the short- and long-term consequences on individual species can be complicated due to functional dependencies within the food web. Further, the nutritional basis of species capable of long-distance movements poses a unique challenge, especially when movements transcend traditional ecosystem boundaries. FORT scientists have been employing stable isotope techniques to better understand the trophic relationships and nutritional basis for a broad array of species from a variety of ecosystems. Examples of ongoing work in 2011 include the following:

- The western stock of the Steller sea lion (*Eumetopias jubatus*), which ranges from the Gulf of Alaska to the Kuril Islands, has declined in recent decades and is listed as endangered under the Federal Endangered Species Act. The decline is thought to reflect, at least in part, decreased juvenile survival rates. Decreased survival may reflect an inability of adult females to deliver adequate milk to large late-lactation pups, or an inability of newly weaned pups and juveniles to acquire sufficient food while foraging. The effects of nutritional stress might be expressed in shorter nursing times, changes in times of weaning, and changes in foraging behavior by young. FORT scientists, in collaboration with the Alaska Department of Fish and Game and the University of Colorado, are testing this nutritional stress hypothesis by applying stable isotope techniques to reconstruct diet and estimate age of weaning.
- As top predators, bottlenose dolphins (*Tursiops truncatus*) consume a wide variety of prey items across numerous habitats, serving as sentinels of ecosystem change. In 1995, a state-wide ban on inshore commercial fishing nets was imposed. Working with Mote Marine Laboratory, Sarasota Bay Dolphin Research Program, Michigan State University, and the Chicago Zoological Society, FORT scientists are evaluating the effects of this ban on bottlenose dolphins. Using teeth collected over a span of roughly 40 years, stable isotope analysis of tooth dentin (annually deposited layers) is being used to assess changes in foraging habits (trophic level and foraging location).
- The Chukchi Sea population of polar bears (*Ursus maritimus*), jointly managed by the United States and Russia, is threatened by some of the highest rates of sea ice loss in the arctic and may be subject to high levels of illegal killing. Furthermore, the area is being explored for potential oil and gas extraction off the U.S. coastline. Compounding these threats is the recent listing of polar bears as a threatened species, which further highlights the conservation concern for this species. Working with the U.S. Fish and Wildlife Service and Washington State University, FORT is using stable isotope techniques to constrain current foraging habits of Chukchi Sea polar bears, providing important context from which future changes due to habitat loss can be inferred.

From left to right: Bottlenose dolphin, Steller's sea lion, polar bear. USFWS photos.

Contact: *Craig Stricker*

Re-examining Genetic Patterns in Sage-Grouse Using Genomic Methods

In the past, conservation genetics has tried to understand the genetic consequences associated with small population size. These consequences, such as inbreeding, are usually linked to lower fitness and reduced ability to adapt to environmental change. Traditional conservation genetics approaches have used available methods (small numbers of neutral genetic markers) to investigate and document these processes. These methods are limiting because (1) they only examine a small fraction of the genome and (2) the areas they examine are neutral (they do not code for genes that might be under selection). New genomic approaches allow us to greatly expand the amount of the genome that we can investigate and also identify genes under selection that may provide a mechanism for a species to adapt to varying environments.

In 2011, in collaboration with other scientists at the USGS Western Ecological Research Center, Colorado Parks and Wildlife, and the U.S. Fish and Wildlife Service, FORT scientists re-examined genetic variation in sage-grouse using such genomic methods. Sage-grouse have been split into two species (greater and Gunnison sage-grouse; *Centrocercus urophasianus* and *Centrocercus minimus,* respectively) based on genetic differences as well as morphology (physical characteristics) and behavior. Within the greater sage-grouse range, however, is a population along the border between California and Nevada (the "bi-state" population) that has been shown to be genetically unique, such that some experts question whether this might be a distinct species. However, unlike Gunnison sage-grouse, the bi-state birds are behaviorally and morphologically similar to other greater sage-grouse.

The genetic data collected from both species using previous genetics methods characterized these divisions using a small number of genetic markers. When USGS researchers re-examined those divisions using a genomic approach (with its many thousands more markers spread throughout the genome), they found that the bi-state population, though still genetically different from the rest of the greater sage-grouse population in some ways, is not different in the genes that are under selection—genes that code for things like behavior and morphology. This is a much clearer distinction that explains why the Gunnison sage-grouse may be truly a unique species, and why the bi-state population is not. This analysis demonstrates the promise of genomic methods for providing more comprehensive information to issues facing natural resource managers today.

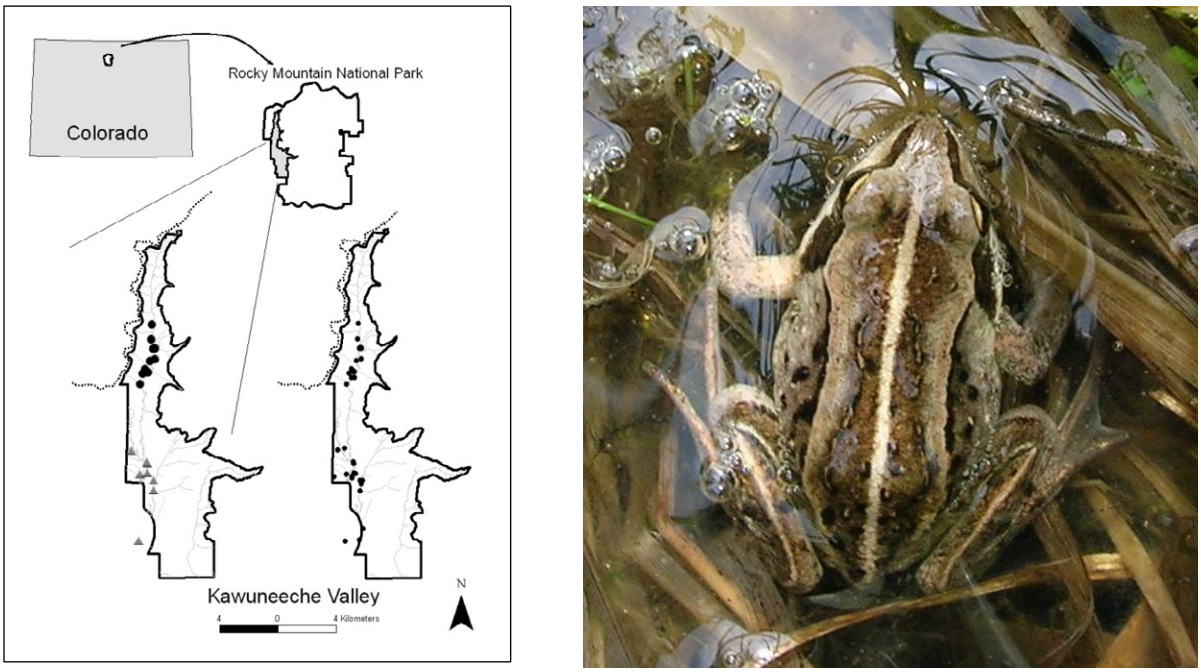
(L) Gunnison sage-grouse and (R) greater sage-grouse. Photos courtesy of Gerritt Vyn and Stephen Ting, respectively.

Contact: *Sara Oyler-McCance*

Landscape Genetics: Integrating Population Genetics and Landscape Ecology

Landscape genetics is a quickly evolving multidisciplinary field that brings together aspects of population genetics and landscape ecology. The goal of this new field is to quantify the effects of landscape features on gene flow and spatial genetic variation. In a sense, this new focus of research allows scientists to determine the degree to which landscape features (both natural and human-made) facilitate or deter the movement of organisms. The landscape genetic approach provides a better understanding of population connectivity that ultimately will facilitate more cohesive management strategies for species of conservation concern (taking into account genetic distinctiveness), and can be based in part on a clearer understanding of the entire genetic landscape of a species. Ultimately, this will add to the scientific knowledge of a species, increase the efficiency with which management decisions can be made, and support conservation strategies.

FORT scientists are embracing this new field with several research projects. In cooperation with the Bureau of Land Management, we are conducting a state-wide landscape genetic analysis of greater sage-grouse (*Centrocercus urophasianus*) in Wyoming. This ongoing project represents the most comprehensive, fine-scale genetic analysis of sage-grouse connectivity to date. The genetic data are being integrated with seasonal sage-grouse habitat models to provide a better understanding of the relationship and connectivity between important areas of sage-grouse habitat and sage-grouse populations. Tiering off of this analysis, in FY11 we began laying the groundwork for a range-wide landscape genetic analysis of greater sage-grouse and a similar effort for Gunnison sage-grouse (*Centrocercus minimus*). In collaboration with National Park Service, we are also conducting landscape genetic analyses on wood frogs (*Rana sylvatica*) in Rocky Mountain National Park to investigate the impact of altered hydrology (from natural or anthropogenic causes) on the distribution of wood frog genetic variation in the Kawuneeche Valley of Rocky Mountain National Park.



(L) Map of wood frog sampling locations in the Kawuneeche Valley. USGS image. (R) Wood frog. Photo courtesy of R. Scherer.

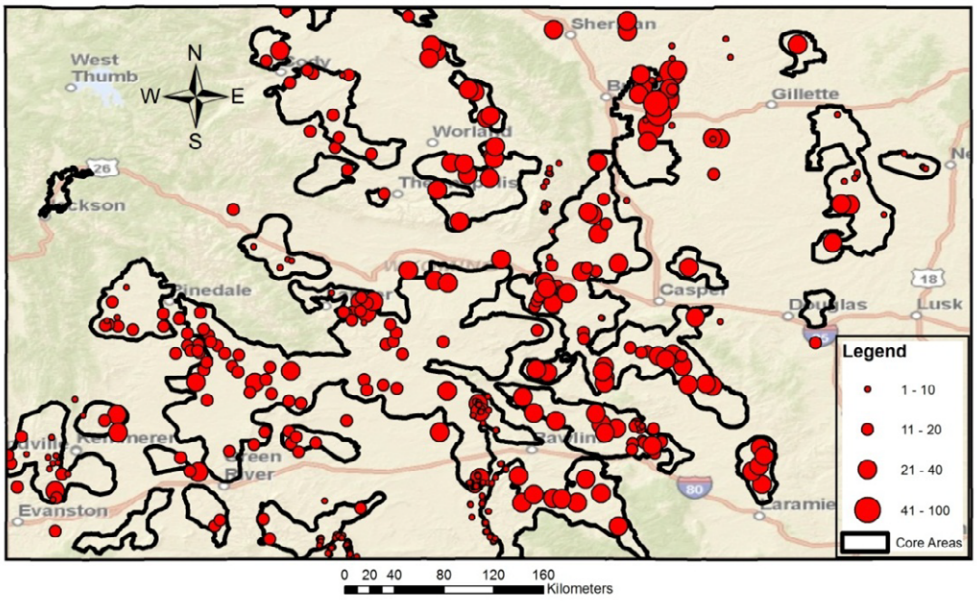
Contact: *Sara Oyler-McCance*

Assessing Greater Sage-Grouse Population Connectivity Using Genetic Approaches

The movement of animals among populations is often essential for population persistence. However, movement among populations can be hindered by various landscape features. For several grouse species, patches of unsuitable or poor habitat above a particular size threshold can prevent successful movement of individuals between populations. The resulting population isolation can threaten population persistence. Thus, identifying populations and connectivity levels among them can help guide prioritization of habitats for conservation and identify habitat and anthropogenic features that impair the connectivity among populations. The U.S. Fish and Wildlife Service recently concluded that greater sage-grouse are "warranted but precluded" for listing under the Federal Endangered Species Act. Population connectivity—the ability of individuals from one population to disperse and intermingle or breed with individuals from a different population—is an important issue for the conservation of this species.

Population connectivity can be measured in terms of habitat connectivity as well as species connectivity. Understanding habitat connectivity typically involves quantifying suitable habitats for a species. For sage-grouse, it is crucial to consider the configuration of important landscape components, such as vegetation (for example, sagebrush and herbaceous cover) and levels of human disturbance. However, habitat connectivity is only a proxy for species connectivity, which measures the actual breeding consequences of movement. It is often unknown whether animals actually use the habitat corridors and patches that an analysis of habitat connectivity identifies.

In 2011, in cooperation with the Wyoming Game and Fish Department and the Bureau of Land Management, FORT scientists coordinated collection of greater sage-grouse feather samples from across Wyoming for genetic analysis to assess population connectivity. We also established collaborative relationships with biologists pursuing similar questions about sage-grouse population connectivity in Montana and the Dakotas. We extracted genetic information from approximately 2,000 feather samples at FORT's Molecular Ecology Laboratory; sample analyses will take place during FY12. The results of our work will provide natural resource managers with the information and tools needed to help guide their efforts to maintain connectivity between greater sage-grouse populations and, ultimately, help to ensure the species' persistence.



Location and number of feather samples collected throughout Wyoming for genetic analysis of greater sage-grouse population connectivity.

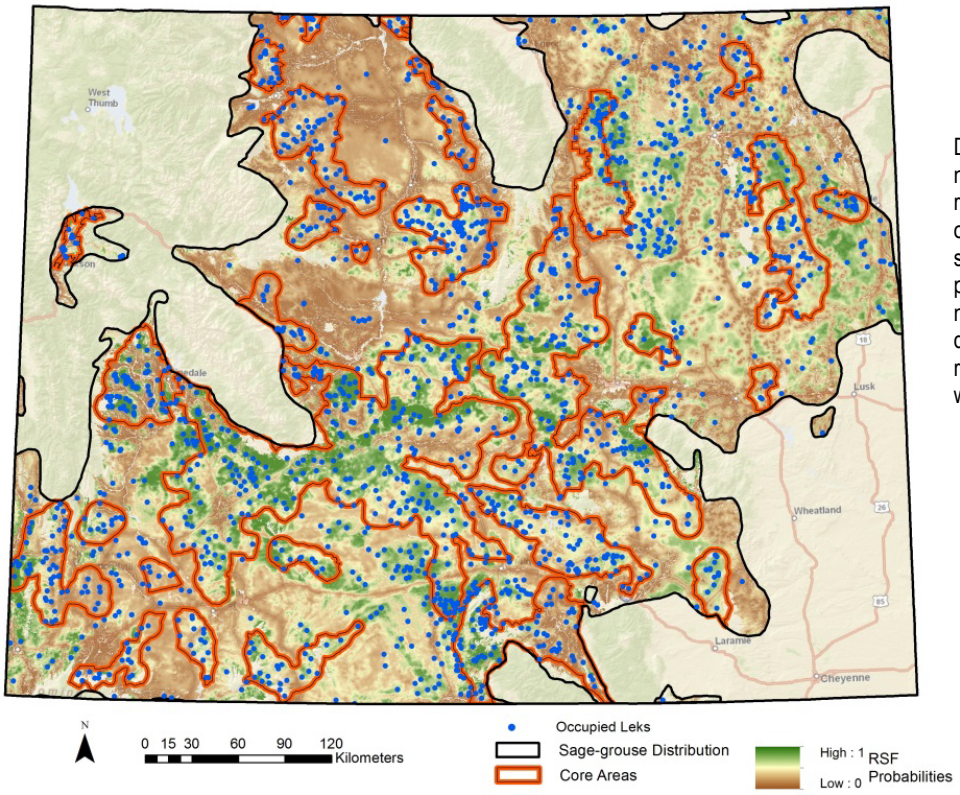
Contact: *Sara Oyler-McCance*

Mapping Seasonal Habitats for Greater Sage-Grouse in Wyoming

The conservation of animal populations requires preserving necessary habitats. However, it is often difficult to determine *which* landscape conditions represent necessary habitats and *where* these habitats are located. Furthermore, identifying *when* (season) particular habitats are used is important in managing for population persistence. The causes for conservation concern regarding greater sage-grouse are well documented, and efforts to prioritize habitats could benefit greatly from a detailed understanding of the *which, where,* and *when* of habitat use by sage-grouse. To address these questions, FORT scientists are developing seasonal habitat-selection models for greater sage-grouse (*Centrocercus urophasianus*).

To develop the models, we used data from telemetry studies conducted across Wyoming. The data allowed us to examine how landscape conditions at multiple scales influence habitat suitability. Our predictive modeling approach has proven to be accurate at a state-wide scale (see map below). Preliminary results from 2011 suggest that our planned (FY12) development of regional-scale models will further increase our predictive capabilities. Our sage-grouse seasonal habitat models capture the species' needs for all three critical life stages, including nesting, late-summer brood-rearing, and wintering . Ultimately, these models will be used to associate habitat requirements with ongoing genetic analyses to assess population connectivity throughout Wyoming.

The spatially explicit habitat-selection models will provide resource managers at the Bureau of Land Management, U.S. Fish and Wildlife Service, and Wyoming Game and Fish Department with practical tools to guide conservation planning across Wyoming. The DOI and State partners can use these models and maps to help them guide future energy development while also planning conservation of important sage-grouse habitats.



Draft predictive model of sage-grouse nesting in Wyoming. Green areas represent high probability of nest occurrence. Predictions are based on state-wide data and likely will improve in performance with ongoing regional modeling efforts at FORT. Lek sites are displayed as blue circles and represent a reasonable proxy for nest locations where nest data do not exist.

Product:

Fedy, B., 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 press, Interseasonal movements of greater sage-grouse, migratory behavior, and an assessment of the core regions concept in Wyoming: Journal of Wildlife Management, v. 76.

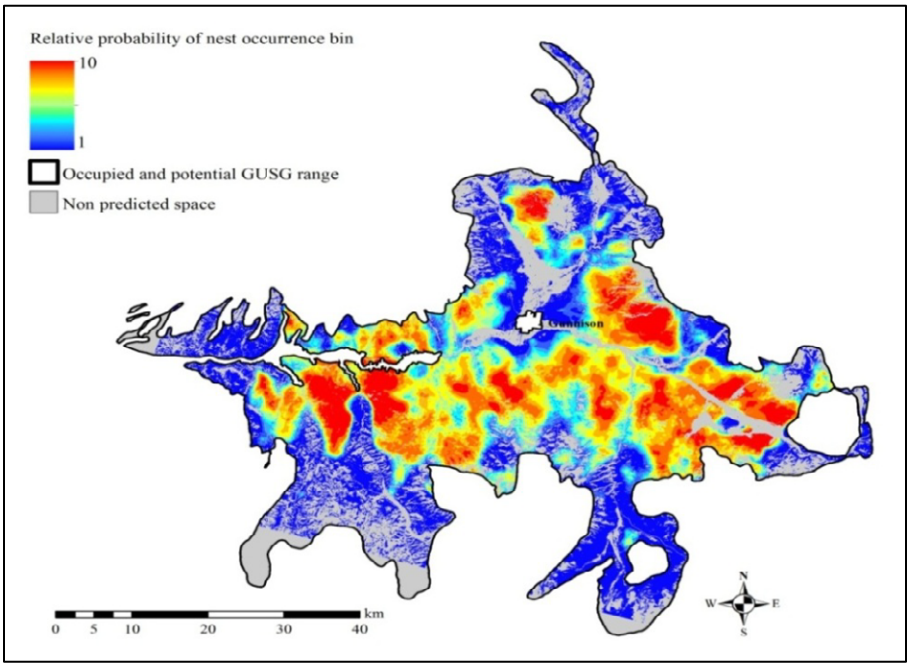
Contact: *Brad Fedy*

Identifying Crucial Nesting Habitat for Gunnison Sage-Grouse

Only seven small, disjunct populations of Gunnison sage-grouse (*Centrocercus minimus*) remain, all in Colorado and Utah. Consequently, the species is being petitioned for listing under the Endangered Species Act. Previous research has shown that loss and fragmentation of sagebrush landscapes on which the species depends have resulted in a drastic contraction of its range and population sizes. The largest remaining population inhabits the Gunnison Basin in west-central Colorado, where the sagebrush habitats are at risk from exurban development. If the population is to remain viable, Federal, State, and local resource managers need to identify, protect, and carefully manage crucial habitats required by the Gunnison sage-grouse. To accomplish this, they need spatially explicit information on crucial habitats.

Gunnison sage-grouse require suitable habitat for three key life stages—nesting, brood-rearing, and wintering—and connectivity between these key habitat types must be maintained. However, until now there were no published spatial habitat assessments for this species. In 2000, the National Park Service (NPS) began radio-marking Gunnison sage-grouse in the western portion of the Gunnison Basin to begin collecting data on their habitat use. In 2006, the NPS teamed up with the U.S. Geological Survey and the U.S. Fish and Wildlife Service to enhance the data collection and seek expertise on sage-grouse and spatial modeling. Continued monitoring of radio-marked birds during 2006–2010, combined with acquisition and creation of numerous spatial data layers, has allowed our research team to develop detailed habitat models in 2011 that identify critical nesting habitat for Gunnison sage-grouse. Two other models related to brood rearing and winter habitat are continuing into 2012.

The models are proving to be extremely useful for informing both management and planning efforts, including planning the species' Candidate Conservation Agreement. Models geographically depict where Gunnison sage-grouse nests have the greatest likelihood of occurrence and illustrate to managers how specific habitat characteristics and anthropogenic features affect habitat quality. In our initial publication (Aldridge and others, 2012), we more explicitly identify thresholds above which development begins to have negative effects on nesting habitat. These measures provide managers with a unique planning tool. Ongoing work to identify crucial brood-rearing and wintering habitat should be complete within the next year. Subsequently, it will be possible to identify habitat needs across the basin for all key life stages and to assess their connectivity.



Spatial map predicting crucial nesting habitat for Gunnison Sage-Grouse across the Gunnison Basin landscape (from Aldridge and others, 2012).

Product:

Aldridge, C.L., Saher, D.J., Childers, T.M., Stahlnecker, K.E., and Bowen, Z.H., 2012, Crucial nesting habitat for Gunnison Sage-grouse—A spatially explicit hierarchical approach: Journal of Wildlife Management, v. 76, no. 2, p. 391–406. Available online at *http://onlinelibrary.wiley.com/doi/10.1002/jwmg.268/abstract*.

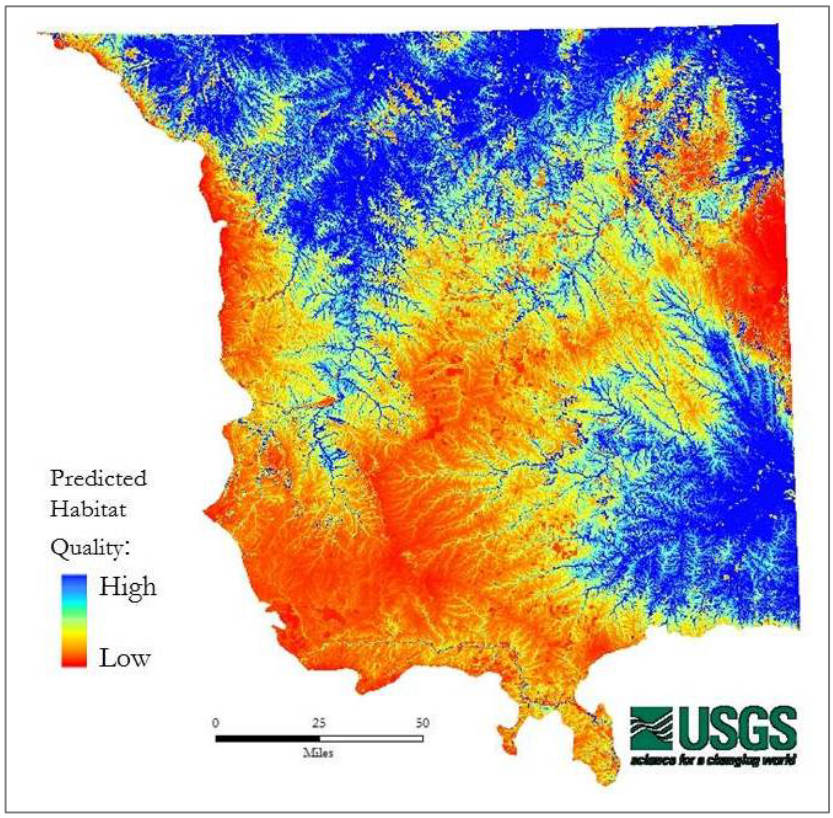
Contact: *Cameron Aldridge*

NEW Raptors and Wind Development: Developing Science-based Conservation Tools

Land-use change across the North American West is a primary threat to wildlife populations. Energy development is a major driver of habitat loss and fragmentation in some of the last large and connected landscapes. Development of renewable energy poses a difficult challenge for conservation, because proliferating emission-neutral energy sources expand the human footprint in previously undeveloped areas. Raptors are of particular concern with wind energy development because wind turbines are a known source of raptor mortality, and these otherwise long-lived species have low reproductive capacities. Effects of development can be cumulative to raptors and their prey base as roads, transmission lines, and increased noise and human use rise in concert with development. Balancing the need to achieve energy independence through renewable sources while maintaining robust wildlife populations requires the development of tools for proactive conservation planning.

Working with State, Federal, and non-governmental entities, in 2011 FORT investigators collected extensive records of raptor nest locations across Wyoming. Using FORT's spatial data library, we extracted and created data layers representing features that raptors key in on when choosing nest sites, including topographic indices, land cover, and human use. Combining spatial data with statistical models helps to reveal relationships between landscape features and raptor nest-site selection, allowing for predictions of relative habitat quality in a GIS.

These models are valuable tools for multiple-species conservation planning at the largest spatial scales available to date, and they form the basis for collaborating with other FORT projects in Wyoming. Also, overlaying spatial data layers that represent habitat quality with layers representing likely energy-development scenarios will provide agencies with the most rigorous planning tool available to date. Partners, including the U.S. Fish and Wildlife Service, also can use the models to guide energy-development companies with project-siting decisions at the project level.



Draft model of nesting habitat selection by golden eagles in Northeast Wyoming. Landscapes of high value to raptors can be transposed against areas with high value for energy development to identify where to target conservation. USGS image.

Contact: *Brad Fedy*

Using LiDAR to Measure Sagebrush Vegetation

LiDAR (Light Detecting And Ranging) is a remote sensing tool that emits pulses of light from a laser mounted on a plane or satellite to estimate the position, size, and other characteristics of objects on the ground. The targets are measured by the return rates of pulsed laser light reflected from the surface. LiDAR has proven useful in measuring plant heights and spacing in forests and woodlands, but it has not been clear whether it can accurately estimate plant heights and spacing in sagebrush or other rangeland systems.

To address this question, we collaborated with scientists from the USGS Northern Prairie Wildlife Research Center to collect LiDAR data from low-flying aircraft over a 500-square-mile area north of Rock Springs, Wyo., and evaluated how accurately LiDAR measured key characteristics of sagebrush vegetation structure. To test the LiDAR data, we measured vegetative characteristics on the ground in 83 0.25-hectare plots spread throughout the image-acquisition area. Vegetation characteristics measured by both methods included maximum and minimum canopy height, canopy volume, percent live canopy, and shrub densities in six shrub-height classes. We then used regression analysis to evaluate the strength of the relationship between ground-truthed and LiDAR-derived shrub measurements. The data, presented to the Wyoming Landscape Conservation Initiative's Executive Committee in July 2011, are valuable to natural resource managers who require accurate information on vegetation structure, and these data have shown promise for predicting spatial distributions of sagebrush-obligate wildlife species such as songbirds, pygmy rabbits, and greater sage-grouse. Future products will describe the relations between LiDAR-characterized and ground-truthed vegetation characteristics as well as wildlife relations with LiDAR-characterized vegetation.

Patches of taller sagebrush surrounded by short shrubs and grasses. Minute variation in return rates of light beams broadcast from overhead aircraft allow accurate estimation of vegetation heights in shrubsteppe habitats. In this photo, a female mountain bluebird (center) perches on sagebrush. Photo by Steve Germaine, USGS.

Product:

Germaine, S.S., 2011, Presentation to the Wyoming Landscape Conservation Initiative Executive Committee, July 2011.

Contact: *Steve Germaine*

Pygmy Rabbits and Gas Field Development in Wyoming

Currently, operational gas fields cover more than 1,000 square miles ($mi^{2)}$ of land in western Wyoming, and further development is projected for the next 25 or more years. However, information on the effects of gas-field development is lacking for most of Wyoming's wildlife Species of Greatest Conservation Need that occur in sagebrush ecosystems. The pygmy rabbit (*Brachylagus idahoensis*) is one of these in which there is high conservation interest. We are conducting two studies to examine the relationship between gas fields and pygmy rabbit occurrence patterns in southwestern Wyoming.

Study 1: The Normally Pressured Lance (NPL) gas field in Sublette County is scheduled for development in 2014, and by 2024 there may be up to 3,500 operational gas wells in a 220-mi^2 area. In 2010 and 2011, we conducted pre-development, site-occupancy surveys for pygmy rabbits at 150 plots distributed evenly across the NPL and three adjacent control areas. We will compare the pre-development occurrence rates on the NPL with rates we ascertain after development of the NPL is underway.

Study 2: We began evaluating the influence of gas well and road density on pygmy rabbit occurrence rates on the Atlantic Rim, Jonah, and Pinedale Anticline Project Area gas fields. Using GIS maps of gas wells and roads, high-resolution imagery, and a current pygmy rabbit habitat map, we located 26 survey plots on each gas field and surveyed each plot for pygmy rabbit sign twice during summer of 2011. We will continue data collection in 2012 and 2013 and then use the data to identify threshold densities of roads and gas wells below which pygmy rabbit site occupancy remains unaffected. These data will be used to guide development of future gas fields in Wyoming and elsewhere. Cooperators and collaborators include the Bureau of Land Management's Pinedale and Rock Springs Field Offices and the Wyoming Game and Fish Department.

Left: Pygmy rabbit under a big sagebrush plant. Right: Jonah gas field, 2007, Sublette County, Wyo. Photo credits: Jeff Kemper, USGS, and Stephen Germaine, USGS, respectively.

Contact: *Steve Germaine*

Integrated Monitoring to Support the Wyoming Landscape Conservation Initiative

The Wyoming Landscape Conservation Initiative (WLCI) is a multi-partner, landscape-scale project to scientifically address concerns associated with rapid energy development and other land uses in southwestern Wyoming, where some of the Nation's largest extant wildlife and outdoor resources exist. To address these concerns effectively, our many partners—the Bureau of Land Management, U.S. Fish and Wildlife Service, Wyoming Game and Fish Commission, Wyoming Department of Agriculture, U.S. Forest Service, six Wyoming County Commissions, nine Conservation Districts in Wyoming, the Pinedale Anticline Project Office—and myriad other stakeholders urgently need information and tools to help guide management decisions that facilitate responsible energy development while conserving important natural resources.

The USGS, including FORT, continues to conduct the science for the WLCI effort, including development of long-term, integrated resource monitoring across the WLCI region—sagebrush ecosystems in particular. Using a multi-faceted approach, USGS has been building on decades of work in semi-arid systems to address the cumulative impacts of expanding human activities. Our two primary goals are to understand (1) the distribution and dynamics of habitat conditions across the landscape and (2) the relations between habitat conditions and wildlife population dynamics. Using a combination of remote sensing, GIS, and field-based, replicated sampling, we have developed techniques for using remote sensing products to map and detect changes in resource conditions at multiple scales. Additionally, we are compiling a comprehensive resource-monitoring scheme for integrating data and supporting coordinated monitoring into the future.

Several parallel projects contribute to this effort, including projects to map and monitor the cover and distribution of sagebrush and shrub-steppe communities, monitor the effects of habitat treatments, and assess the relationships between land-use and both native and invasive species. To identify wildlife responses to habitat changes, we are conducting several related projects to evaluate distributions and dynamics of wildlife populations—including greater sage-grouse, songbirds, pygmy rabbits, and ungulates—as they relate to local and regional environmental patterns. Because USGS does not monitor all important resources within the WLCI region, an interagency team led by USGS scientists also is developing a database for compiling monitoring information and coordinating data collection and analyses to provide long-term monitoring perspectives.

Although the integrated monitoring project is centered on the northern sagebrush steppe of Wyoming, our work has extended across environmental gradients and into similar community types in Montana, Colorado, Utah, and Idaho, providing a revealing multiple-variable analysis. With a clarified picture of sagebrush distribution, we can begin to address questions about the condition and productivity of these systems. To that end, in 2011 we mapped and monitored vegetation cover and investigated the distribution of two landscape-scale drivers of change within natural and managed areas: biotic invasions induced by land use, and management activities that intentionally altered habitat conditions. Together, these projects provide important information required for regional planning and adaptive management. Overall, this and related projects provide the crucial data and techniques required for monitoring habitat and wildlife conditions across vast landscapes at multiple scales.

Products: Manier, D.J., Aldridge, C., Anderson, P., Chong, G., Homer, C., O'Donnell, M., and Schell, S., 2011, Land use and habitat conditions across the southwestern Wyoming sagebrush steppe—Development impacts, management effectiveness and the distribution of invasive plants, *in* Monaco, T., and others, eds., Wildland Shrub Symposium—Threats to Shrubland Ecosystem Integrity, Logan, Utah, May 18–20, 2010, Proceedings: Logan, Utah, S.J. and Jessie E. Quinney Natural Resources Research Library, Natural Resources and Environmental Issues, Volume 17.

Homer, C.G., Aldridge, C.L., Meyer, D.K., and Schell, S., 2012, *Multi-scale remote sensing sagebrush characterization with regression trees over Wyoming, USA—Laying a foundation for monitoring*: International Journal of Applied Earth Observation and Geoinformation, v. 14, no. 1, p. 233–244.

Xian, G., Homer, C.G., and Aldridge, C.L., 2012, *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. 33, no. 7 [early online].

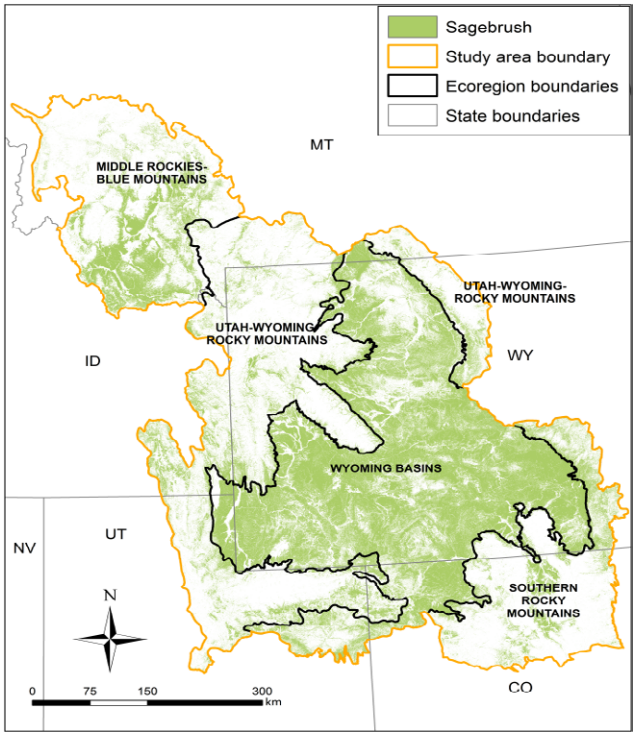
Contact: *Cameron Aldridge*

Wyoming Basins Ecoregional Assessment

The Wyoming Basins is a priority ecoregion for conservation planning because it contains approximately 24 percent of all remaining sagebrush habitats in the United States. It supports 65 species of concern and is an important stronghold for greater sage-grouse, which is listed as "warranted but precluded" under the Federal Endangered Species Act. However, numerous factors, including rapid energy development for oil and gas and wind, threaten sagebrush habitats in the Wyoming Basins. The ecoregion contains roughly 41 percent of the known U.S. domestic reserves of natural gas; thus, as the predicted 50 percent increase in energy demand is realized over the next 20 years, energy-development activities in the Wyoming Basins are expected to increase as well. Within this context, our ecoregional assessment was developed to (1) provide an integrated process for delineating and quantifying the magnitude of threats to sagebrush ecosystems and associated species of conservation concern in the Wyoming Basins, and (2) produce information necessary for broad-scale natural resource management and planning to help meet future development and energy demands while also conserving sagebrush habitats.

In prior years of the project, field surveys were conducted to identify species relationships with land cover, abiotic features (like soils and climate), and anthropogenic features on the landscape. Subsequently, we modeled the distribution and abundance of species of conservation concern, as explained by environmental relationships, and developed spatial predictions (maps) of species' abundances on the landscape that can be used to guide future management actions. In FY 2011, the work culminated in publication of a book addressing sagebrush ecosystem conservation and management (Hanser and others, 2011).

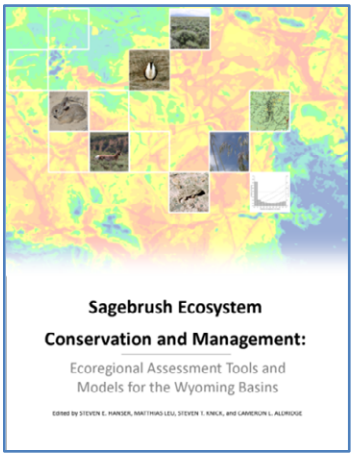
The outcomes of this project will be useful to many resource management agencies—including the BLM, USFS, and the State fish and wildlife agencies of Wyoming, Montana, Colorado, Utah, and Idaho—for addressing large-scale, regional factors likely to (1) affect the well-being of species of concern, (2) guide the development of management plans to reduce further loss or degradation of habitats, and (3) establish a basis for restoring habitats in the most timely, cost-effective ways possible. The project was led by USGS scientists at FORT and the Forest and Rangeland Ecosystem Science Center. Partners included Colorado State University and the U.S. Forest Service, and the work was supported by the Bureau of Land Management.



Map of the Wyoming Basins study area showing specifc ecoregions and the distribution of sagebrush (from Hanser et al. 2011).

Product:

Hanser, S.E., Leu, M., Knick, S.T., and Aldridge, C.L., 2011, *Sagebrush ecosystem conservation and management—Ecoregional assessment tools and models for the Wyoming Basin*: Lawrence, Kans., Allen Press.



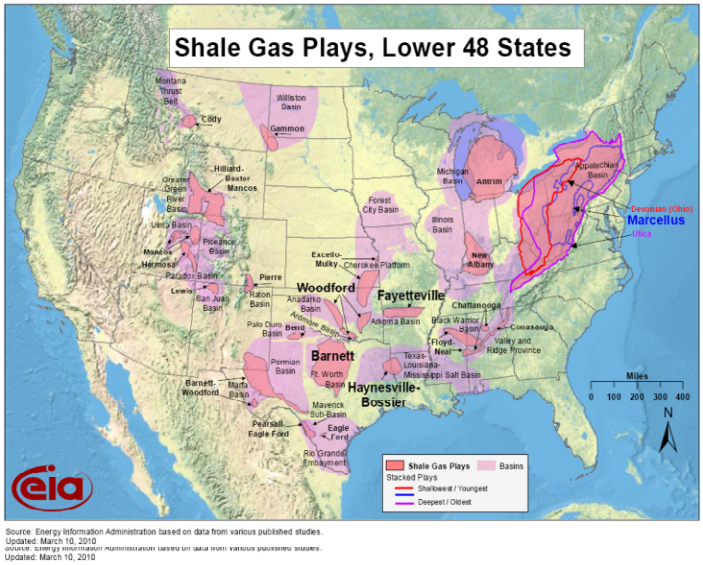
Contact: *Cameron Aldridge*

Energy and Minerals, and Environmental Health

Assessing Potential Effects of Hydraulic Fracturing for Energy Development on Water Resources

Production of oil and gas from "unconventional" plays (low-permeability reservoirs of shale gas, shale oil, and tight-sands gas) is increasing in the United States. Extracting hydrocarbons from an unconventional play requires increasing its permeability by drilling horizontal wells through the play and using explosives to fracture it. Subsequently, the fractures are expanded by injecting fluids under high pressure, and then propped open by sands suspended in the fluids. This requires large volumes of water and involves various chemical additives, penetration of aquifers, and waste-product disposal. News sources report many claims that hydraulic fracturing has deleterious effects on water quality and quantity. There is little scientifically based information, however, that confirms or refutes these claims. Without it, policymakers and decisionmakers are unable to meaningfully address the concerns.

To help fill this data gap, FORT received a grant from the USGS John Wesley Powell Center for Analysis and Synthesis to lead the first broad-scale, data-based assessment of hydraulic fracturing's potential effects on water resources in the United States. FORT initiated the project by hosting a scoping workshop in FY11 attended by 29 hydrologists and other physical scientists, who represent 14 USGS water science centers, the National Center, the National Research Program, the Central Energy Resources Center, the Central Region National Water-Quality Assessment Program, the Columbia Environmental Research Center, Duke University, and an eastern Colorado water conservation district. Participants presented their expertise and interest as it relates to this project, then identified possible approaches for using existing high-quality, robust databases to address possible effects of hydraulic fracturing on water resources.



Location and extent of shale gas plays in the United States. Shale gas is one of several "unconventional" (low-permeability) sources of natural gas that require hydraulic fracturing to release the gas. Map created by the Energy Information Administration.

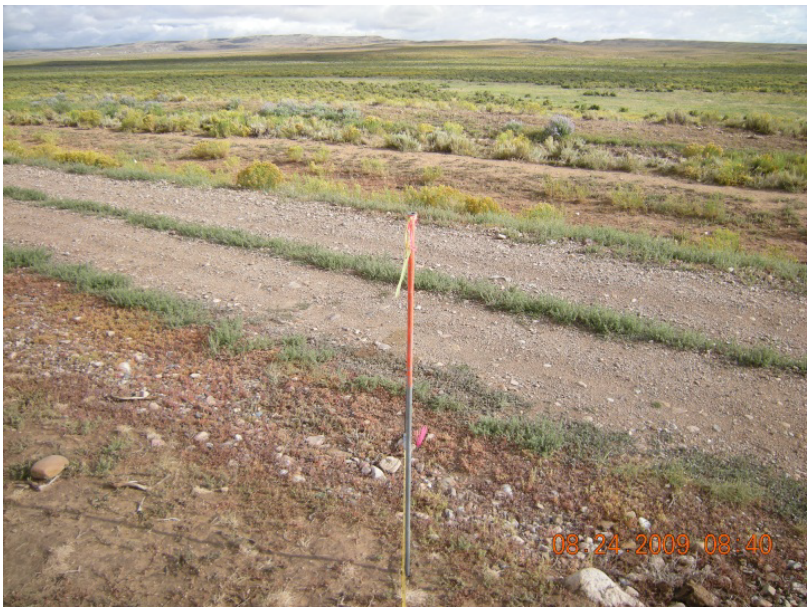
A core team of 12 people was formed to conduct the analyses, syntheses, and product development. The team has pulled national water-quality data, by unconventional play, from the USGS National Water Information System database and the Environmental Protection Agency (EPA) STORET data warehouse. The pulled data, representing a total of 344 groundwater wells and 16,752 stream gages, were downloaded and centralized on myUSGS (a secure science-sharing Web site for USGS scientists and their partners). The team also identified and began downloading regional and local datasets, identified potential project products, and developed a product-development schedule. Planned products include (1) a project factsheet, (2) a report summarizing unconventional oil and gas development in the United States, (3) an atlas that details features and associated water-quality issues of each play, and (4) high-impact journal articles detailing important findings of this project. The products will target a range of audiences, from policymakers and agencies (for example, the EPA and State- and watershed-level boards or commissions) charged with regulating activities that potentially impact water resources, to other scientists and potential clients seeking to address related questions, to the general public. It is expected that results of the analyses will help to identify not only any water-quality problems associated with hydraulic fracturing, but also areas of research needed to better address questions regarding the effects of hydraulic fracturing on water resources in the United States.

Contact: *Zack Bowen*

Distribution of Infrastructure and Invasive Plants in Southwestern Wyoming

Herbicides and other treatments used to control invasive plants are applied prolifically by State, Federal and private entities, but invasive plants continue to expand. To improve treatment effectiveness, natural and agricultural resource managers need better information regarding which species occur within a given management unit and where they are likely to occur. The goal of this project was to increase our understanding of how land use, energy development, habitat treatments, and environmental gradients influence the distribution and spread of invasive species, at both landscape and local scales. The objectives were to display (map) and describe (interpret statistical results) the distribution of invasive plants in the Wyoming Landscape Conservation Initiative (WLCI) study area of southwestern Wyoming (see photo). In turn, mapped and interpreted distributions of invasive plants may be used by resource managers to design strategic actions, such as targeting invasion hot-spots, implementing a coordinated assault around the perimeter of a plant population, and protecting valued resources.

Our approach first entailed field sampling to document which invasive plant species currently occur on the WLCI landscape. We then conducted statistical analyses and distribution modeling to describe relations between the most common invasive species and predictive variables that are useful for modeling and offering insights into the habits and control of those species. In FY11, two modeling techniques were used to map projected distributions for each of 10 species at local and regional scales. These maps are available for use in a GIS by land managers and other stakeholders to represent potential species distributions across the region. The maps also can be used within smaller management units to support identification and prioritization of potential treatment areas. This project culminated in FY11 with the submission of two manuscripts to professional peer-reviewed journals.



A sample unit adjacent to a road and pipeline where the invasive plants *Halogeton glomeratus* and *Kochia* species (among others) are found in great abundance within the sagebrush sea of southwestern Wyoming. Photo by Spencer Schell, USGS.

This project was a cooperative venture between the Fort Collins and Forest and Range Ecology science centers. Although primary beneficiaries of products from this project are the Bureau of Land Management's State and Field Offices in Wyoming, benefit also accrues to agricultural interests, county governments, and local landowners. Furthermore, as long as suitable field-based data are available, the methods developed for this project are readily transferable to other species and regions.

Product:

Manier, D.J., Aldridge, C., Anderson, P., Chong, G., Homer, C., O'Donnell, M., and Schell, S., 2011, Land use and habitat conditions across the southwestern Wyoming sagebrush steppe—Development impacts, management effectiveness and the distribution of invasive plants, *in* Monaco, T., and others, eds., Proceedings of the Wildland Shrub Symposium—Threats to Shrubland Ecosystem Integrity, May 18–20, 2010, Logan, UT. S.J. and Jessie E. Quinney Natural Resources Research Library, Natural Resources and Environmental Issues, v. 17.

Contact: *Dan Manier*

Aquatic Experimental Laboratory Capabilities Developed at FORT

Scientists at FORT have developed an aquatic laboratory facility for conducting a variety of experiments on lake, stream, and riparian ecosystems. Components of the system include:

- "Living streams," 400 liter (L) recirculating, climate-controlled artificial streams;
- Stream mesocosms, 6 L recirculating miniature streams (left image, below); and
- Rearing systems for culturing algae and aquatic invertebrates such as midges and mayflies.

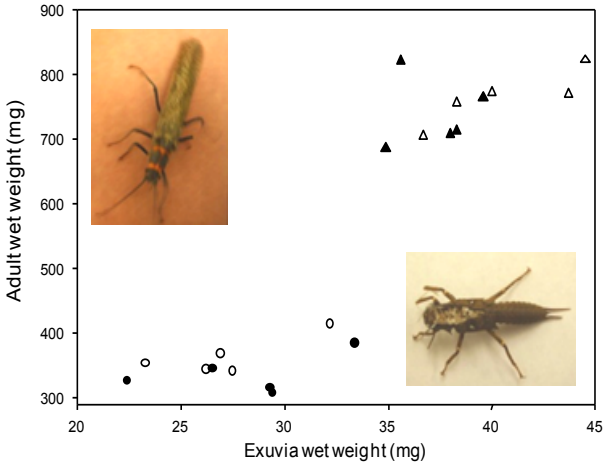
Our primary goal is to use this lab to identify mechanistic processes underpinning the patterns in nature that we at FORT and others have observed through field studies. We will address a broad array of resource management issues related to stream ecology, ecological exposure and food webs, climate change, aquatic-riparian linkages, and invertebrate taxonomy. Our research questions include:

- What are the effects of trophic transfer (dietary consumption), growth, and metamorphosis on chemical signatures in the environment?
- What are the effects of climate change on mineral weathering, stream chemistry, and chemical exposure on stream communities?
- What are the main pathways of organism and contaminant movement between aquatic and riparian ecosystems, and how big are these fluxes?

In 2011, we conducted our first preliminary trial, using the facility to raise aquatic insect larvae collected from rivers in Colorado. This experiment is part of a larger study investigating the ecological importance of adult aquatic insects to terrestrial predators and riparian food webs. Here, we raised giant salmonflies (an iconic insect of western rivers and trout streams) to help quantify the amount of energy these organisms transfer from rivers to neighboring terrestrial habitats (right image, below).

USGS laboratory collaborators include scientists at FORT, the Colorado Water Science Center, and the Crustal Geophysics and Geochemistry Science Center. External collaborators include the National Park Service and Colorado Parks and Wildlife.

Experimental aquatic mesocosms at the FORT Aquatics Laboratory. Photo by David Walters, USGS.



Relationship between exuvia and adult weight (mg wet) for female (triangles) and male (circles) giant salmonflies from the Gunnison (open symbols) and Frasier (filled symbols) Rivers. Inset photos are an adult salmonfly (upper left) and its exuvia (lower right). Photos obtained from rearing salmonfly larvae at the FORT Aquatics Laboratory. Graphic image by David Walters, USGS.

Contact: *David Walters*

Quantifying Biological Fluxes of Stream Metals to Terrestrial Food Webs

Trace-metal contamination of aquatic ecosystems is a major health and environmental concern globally, leading to altered aquatic communities, decreased fisheries, and bioaccumulation in higher trophic levels. In the Rocky Mountains, metals that are mobilized from the mineralized bedrock underlying watersheds constitute one of the major factors shaping aquatic communities in perennial streams.

The geologic processes that affect distribution of metals within central Colorado streams, such as mining and mineralization, are well characterized, but little is known about the repercussions of these effects for neighboring terrestrial ecosystems. Aquatic insects in their larval form make up a large component of stream food webs. When they emerge from streams as adults, they are consumed by terrestrial predators, such as spiders. Thus, insects can transport metals from aquatic to terrestrial food webs by carrying them within their adult bodies.

FORT is conducting research to (1) establish the relationship between metal accumulation in riparian predators (spiders), stream trace-metal concentrations, and underlying rock type; (2) measure insect emergence, production, and metal flux during the growing season; and (3) test how fish, an important top predator, alter metal flux to riparian food webs in contaminated streams. We hypothesized that since trace metals directly reduce the abundance of aquatic insects in streams, metal flux to terrestrial ecosystems may be counterintuitively lower in areas of highest contamination. In FY11, we conducted a large-scale field study of 40 sites and presented the initial results at two professional meetings (Kraus and others, 2011).

Data from this multi-disciplinary, multi-science-center study (involving FORT and the USGS Crustal Geophysics and Geochemistry Science Center) will be used to construct a predictive framework based on geology, toxicology, and ecology for understanding when and where fluxes of aquatically derived metals to terrestrial food webs are important. The outcomes of this research will have large implications for stream restoration and management in the national forests and parks where this study is taking place, since decisions regarding aquatic ecosystems could have ramifications for terrestrial ecosystems as well.

Collecting emerging aquatic insects and spiders near mineralized streams in the Colorado Rocky Mountains. Photos by J. Kraus, USGS.

Product:

Kraus, J.M., Wanty, R.B., Schmidt, T.S., Walters, D.M., Zuellig, R.E., Stricker, C.A., and Lamothe, P.J., 2011, Transfer of stream metals to terrestrial food webs by emerging aquatic insects, *presented* at Society of Environmental Toxicology and Chemistry (SETAC) North America, Boston; and Rocky Mountain SETAC, Denver.

Contact: *Joanna Kraus*

Using Spiders to Track Ecosystem Exposure to Contaminants

FORT scientists are measuring contaminant exposure in riparian food webs of the lower Manistique River and Harbor (Michigan) using sentinel species such as spiders. Manistique River and Harbor is one of the Great Lakes Areas of Concern (AOCs). These AOCs are heavily contaminated sites around the Great Lakes that are prioritized for remediation and restoration by the U.S. Environmental Protection Agency (EPA). Manistique River is contaminated with polychlorinated biphenyls (PCBs) released into the environment decades ago.

Riparian spiders are important mediators of contaminant transfer from aquatic systems to nearby terrestrial habitats. Aquatic insects accumulate contaminants in their larval form, and transport these contaminants to terrestrial ecosystems in their adult bodies. Spiders are a key predator of aquatic insects, and many species feed almost exclusively on adult aquatic insects. Spider concentrations closely track ambient sediment concentrations, making them ideal indicators of exposure and suitable endpoints for monitoring changes in sediment concentrations. At Manistique, we are using tetragnathids (long-jawed spiders) and araneids (orb-weaving spiders), traditional species for contaminant-exposure studies.

We began field studies in FY11 to characterize the complex hydrology of the site and investigate the extent and magnitude of PCB contamination in aquatic sediments and in spiders living next to aquatic habitats. The site is a complex mosaic of connected river, backwater, harbor, and lake environments, and we are using chemical tracers like dissolved metals, stable isotopes, and nutrients to understand hydrological linkages among these habitats. In addition, we collected sediment and spider samples from these various habitats to characterize ongoing levels of PCB contamination among them.

Our results will be used to evaluate the relationship between sediment contamination and adverse biological exposures. More importantly, these data will establish baseline conditions to assess future remedial actions at the site. Currently, a multi-agency task force (EPA, NOAA, USFWS, USGS, and various State agencies) is planning a $30-million remediation of the site, scheduled for FY12. Data collected by FORT are already informing this massive restoration effort.

Sampling contaminated sediments in a backwater of the Manistique River, Mich. Aquatic insects accumulate contaminants like PCBs in their tissues as larvae, then transform them to predators such as spiders when they emerge from the water. USGS photo.

Product:

Walters, D.M., and Mills, M.A., 2011, Riparian indicators of contaminant exposure in Manistique River and Harbor, *data* presentation for Manistique River AOC Multi-Agency Task Force, Webinar, December, 2011.

Contact: *David Walters*

Natural Hazards (Earthquake Hazards)

USGS Twitter Earthquake Dispatcher (@USGSted)

The mission of the National Earthquake Information Center (NEIC) is to determine the location and size of all destructive earthquakes worldwide and to immediately disseminate this information to concerned national and international agencies, scientists, and the general public. The NEIC determined that, in populated regions, Twitter reports often precede the USGS's publicly released, scientifically verified earthquake alerts. For earthquakes in sparsely instrumented regions, these detections could provide an initial alert that an earthquake may have occurred. The challenge faced by the NEIC is how to harness the power of social networks like Twitter to get earthquake information out to the public.

When citizens feel shaking activity, they often use the popular social-media application, Twitter, to "tweet" what they are experiencing. In 2011, the FORT Applications Development Team worked with NEIC to build the USGS Twitter Earthquake Dispatch (@USGSted). This application distributes Twitter (*www.twitter.com*) alerts for earthquakes worldwide with magnitudes of 5.5 and above. The @USGSted application searches for tweets that contain the word "earthquake" or certain related terms and stores these messages to a database. From this database, scientists at NEIC can then produce maps of locations and discern how severe an earthquake event might be as soon as tweets are received, which is almost instantly after an earthquake begins. Anyone can track or report significant earthquake activity by logging into Twitter.com and searching for "@USGSted."

Using Twitter's application programming interface, the FORT developers wrote code that reads the Twitter stream in real-time, requests tweets that contain a keyword (for example, "earthquake"), and stores that data in a database. Because earthquakes are a global natural event, the keywords include international terms like "temblor" (see image below) and "terremoto." One of the advantages for the science community of retrieving data from Twitter is that each tweet contains a geospatial string of the tweet's origin. The application decodes the location string from Twitter to a latitude and longitude that can be plotted on a map to visualize the areas of impact.

Mapping earthquake-related "tweets" from Central America. USGS image.

When a major event occurs, Twitter produces a high level of data for a short period of time. The application evaluates the incoming data load, and if it is higher than a specified threshold, defers decoding of locations. These values are filled at a later time when the incoming tweet rate is below the threshold. FORT also created a separate process to recover tweets lost due to network interruptions. By filling in any gaps, the application provides a more consistent and complete dataset to the scientist.

The USGS Community for Data Integration is adopting @USGSted as the basis for a number of other field-observation and notification efforts, including the new species-observations platform.

Contact: *Tim Kern*

Appendix 2. FORT Publications and Other Products Issued in FY2011

Table 2-1. FORT Publications Released in FY 2011.

Publication Type	Citation
Core Science Systems	
Science Feature	Kern, T., J.T. Wilson, S. Bristol, and S. Tekell. 2010. Tailor made: Web applications for natural resources science and management. Web feature. *http://www.fort.usgs.gov/WebApps/*
Journal	Jarnevich, C.S., T.R. Holcombe, D.T. Barnett, T.J. Stohlgren, and J. Kartesz. 2010. Forecasting weed distributions using climate data: A GIS early warning tool. Invasive Plant Science and Management 3(4): 365-375.
Science Feature	O'Donnell, M. 2011. High throughput computing: A solution for scientific analysis. Web feature. *http://www.fort.usgs.gov/Condor/*.
Open-File Report	Wilson, J.T. (compiler). 2011. Fort Collins Science Center: Fiscal year 2010 science accomplishments. U.S. Geological Survey Open-File Report 2011–1114. 62 p.
Science Feature	Wilson, J. and C. Allen. 2011. Seeing the forest *and* the trees: USGS scientist links local changes to global scale. Web feature. *http://fort.usgs.gov/callen/default.asp*.
Science Feature	Wilson, J. and L. Hanson. 2011. Cranes and drones: Strange airfellows? *http://www.fort.usgs.gov/RavenA/*.
Climate and Land-Use Change	
Report Chapter	Baron, J.S., C.T. Driscoll, and J.L. Stoddard. 2011. Inland surface water [Chapter 18]. Pages 209-227 in L.H. Pardo, M.J. Robin-Abbott, and C.T. Driscoll (eds.). Assessment of N deposition effects and empirical critical loads of N for ecoregions of the United States. General Technical Report NRS-80. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.
Journal	Hussey, A.M., B.A. Kimball, and J.M. Friedman. 2011. Assessment of tannin variation in tamarisk foliage across a latitudinal gradient. The Open Environmental & Biological Monitoring Journal 4: 32-35.
Report Chapter	Pardo, L.H., L.H. Geiser, M.E. Fenn, C.T. Driscoll, C.L. Goodale, E.B. Allen, J.S. Baron, R. Bobbink, W.D. Bowman, C. Clark, B. Emmett, F.S. Gilliam, T. Greaver, S.J. Hall, E.A. Lilleskov, L. Liu, and J.A. Lynch. 2011. Synthesis [Chapter 19]. Pages 229-284 in L.H. Pardo, M.J. Robin-Abbott, and C.T. Driscoll (eds.). Assessment of N deposition effects and empirical critical loads of N for ecoregions of the United States. General Technical Report NRS-80. Newtown Square, PA: Department of Agriculture, Forest Service, Northern Research Station.
Open-File Report	Richer, E.E. and J.S. Baron. 2011. Loch Vale Watershed Long-Term Ecological Research and Monitoring Program—Quality assurance report, 2003–09. U.S. Geological Survey Open-File Report 2011–1137. 22 p.
Journal	Williams, A.P., C.D. Allen, C.I. Millar, T.W. Swetnam, J. Michaelsen, C.J. Still, and S.W. Leavitt. 2010. Forest responses to increasing aridity and warmth in the southwestern United States. Proceedings of the National Academy of Sciences, USA (PNAS) 107(50): 21289-21294.

Ecosystems—Fisheries: Aquatic Endangered Resources	
Presentation	Daniels, J.S. 2011. Treatment wetlands for nitrogen removal. In: Water Quality Forum, March 21, 2011. Fort Collins, CO: Colorado Department of Health and Environment and the Colorado Water Institute. 23 slides.
Report Chapter	Magirl, C.S., C.A. Curran, R.W. Sheibley, J.A. Warrick, J.A. Czuba, C.R. Czuba, A.S. Gendaszek, P.B. Shafroth, J.J. Duda, and J.R. Foreman. 2011. Baseline hydrologic studies in the lower Elwha River prior to dam removal [Chapter 4]. Pages 75-110 in J.J. Duda, J.A. Warrick, and C.S. Magirl (eds.). Coastal habitats of the Elwha River, Washington—Biological and physical patterns and processes prior to dam removal. U.S. Geological Survey Scientific Investigations Report 2011–5120.
Journal	Sanders T.G., Jr., B.A. Biddanda, C.A. Stricker, and S.C. Nold. 2011. Benthic macroinvertebrate and fish communities in Lake Huron are linked to submerged groundwater vents. Aquatic Biology 12(1): 1-11.
Report Chapter	Shafroth, P.B., T.L. Fuentes, C. Pritekel, M.M. Beirne, and V.B. Beauchamp. 2011. Vegetation of the Elwha River Estuary [Chapter 8]. Pages 225-248 in J.J. Duda, J.A. Warrick, and C.S. Magirl (eds.). Coastal habitats of the Elwha River, Washington— Biological and physical patterns and processes prior to dam removal. U.S. Geological Survey Scientific Investigations Report 2011–5120.
Book Chapter	Spaulding, S.A., C. Kilroy, and M.B. Edlund. 2010. Diatoms as non-native species [Chapter 32]. Pages 560-569 in J.P. Smol and E.F. Stoermer (eds.). The Diatoms: Applications for the environmental and earth sciences. New York: Cambridge University Press.
Ecosystems—Invasive Species	
Journal	Beauchamp, V.B. and P.B. Shafroth. 2011. Floristic composition, beta diversity, and nestedness of reference sites for restoration of xeroriparian areas. Ecological Applications 21(2): 465-476.
Journal	Bromberg, J.E., S. Kumar, and T.J. Stohlgren. 2011. Distributional changes and range predictions of downy brome (*Bromus tectorum*) in Rocky Mountain National Park. Invasive Plant Science and Management 4(2): 173-182.
Journal	Crall, A.W., G.J. Newman, C.S. Jarnevich, T.J. Stohlgren, D.M. Waller, and J. Graham. 2010. Improving and integrating data on invasive species collected by citizen scientists. Biological Invasions 12(10): 3419-3428.
Journal	Evangelista, P.H., S. Kumar, T.J. Stohlgren, and N.E. Young. 2011. Assessing forest vulnerability and the potential distribution of pine beetles under current and future climate scenarios in the Interior West of the US. Forest Ecology and Management 262(3): 307-316.
Presentation	Frid, L., K. Bryan, T. Holcombe, A. Olsson, and A. Hall. 2011. Developing a decision support model for buffelgrass management in Southern Arizona. Poster for Invasion of the Aliens. Williams Lake, BC, Canada: Invasive Plant Council of British Columbia.
Journal	Garner, T.W.J., J.-M. Hero, R. Jehle, F. Kraus, E. Muths, R.N. Reed, R.C. Vogt, and W. Hodl. 2010. The World Congress of Herpetology and Animal Conservation: Excerpts from the 6th World Congress. Animal Conservation 13 (Supp.): 1-2.
Journal	Graham, J., C. Jarnevich, N. Young, G. Newman, and T. Stohlgren. 2011. How will climate change affect the potential distribution of Eurasian Tree Sparrows *Passer montanus* in North America? Current Zoology 57(5): 648-654.
Journal	Graham, J., C.S Jarnevich, A. Simpson, G.J. Newman, and T.J. Stohlgren. 2011. Federated or cached searches: Providing expected performance from multiple invasive species databases. Frontiers of Earth Science 5(2): 111-119.
Journal	Graham, J., G. Newman, S. Kumar, C. Jarnevich, N. Young, A. Crall, T.J. Stohlgren, and P. Evangelista. 2010. Bringing modeling to the masses: A web based system to predict potential species distributions. Future Internet 2(4): 624-634.
Fact Sheet	Holcombe, T.R. 2011. Buffelgrass—Integrated modeling of an invasive plant. U.S. Geological Survey Fact Sheet 2011–3022. 2 p.
Data Series	Jarnevich, C.S., G.H. Rodda, and R.N. Reed. 2011. Data for giant constrictors—Biological management profiles and an establishment risk assessment for nine large species of pythons, anacondas, and the boa constrictor. U.S. Geological Survey Data Series 579.

Abstract	Jarnevich, C.S., W.E. Esaias, P. Ma, J.T. Morisette, J.E. Nickeson, T.J. Stohlgren, and T. Holcombe. 2011. Using phenology in predicting the northward expansion of the Africanized honey bee. Abs. in 96th Ecological Society of America Annual Meeting, , Austin, TX, 7–12 August 2011. Washington, DC: Ecological Society of America.
Journal	Jarnevich, C.S., P. Evangelista, T.J. Stohlgren, and J. Morisette. 2011. Improving national-scale invasion maps: Tamarisk in the western United States. Western North American Naturalist 71(2): 164-175.
Journal	Jarnevich, C.S. and M.K. Laubhan. 2011. Balancing energy development and conservation: A method utilizing species distribution models. Environmental Management 47(5): 926-936.
Journal	Jarnevich, C.S. and L.V. Reynolds. 2011. Challenges of predicting the potential distribution of a slow-spreading invader: A habitat suitability map for an invasive riparian tree. Biological Invasions 13(1): 153-163.
Journal	Lardner, B., J.A. Savidge, R.N. Reed, G.H Rodda. 2011. *Boiga irregularis* (Brown Treesnake). Predation attempt by praying mantis. Herpetological Review 42(3): 435-436.
Journal	Lardner, B., J.A. Savidge, T.J. Hinkle, E. Wostl, S.R. Siers, R.N. Reed, G.H. Rodda. 2011. *Boiga irregularis* (Brown Treesnake). Predation attempt by crab. Herpetological Review 42(3): 434-435.
Journal	Liang, C.T. and T.J. Stohlgren. 2011. Habitat suitability of patch types: A case study of the Yosemite toad. Frontiers of Earth Science 5(2): 217-228.
Journal	Morisette, J.T., J. Nightingale, and J. Nickeson. 2010. Assessing the accuracy of landscape-scale phenology products: An international workshop on the validation of satellite-based phenology products. Dublin, Ireland, 18 June 2010. EOS 91(44): 407-408.
Book Chapter	Morisette, J.T., M.D. Schwartz, and C.M. Hogan. 2011. Phenology. Page 5 in C.J. Cleveland (ed.). The Encyclopedia of Earth. Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment.
Journal	Newman, G., A. Crall, M. Laituri, J. Graham, T. Stohlgren, J.C. Moore, K. Kodrich, and K. Holfelder. 2010. Teaching citizen science skills online: Implications for invasive species training programs. Applied Environmental Education and Communication 9(4): 276-286.
Book Chapter	Perry, G. and G.H. Rodda. 2011. Brown Treesnake. Pages 78-81 in D. Simberloff and M. Rejmanek (eds.). Encyclopedia of biological invasions. Berkeley, CA: University of California Press.
Journal	Reed, R.N., D. Giardina, T. Pernas, D. Hazelton, J.G. Dozier, J. Prieto, R.W. Snow, and K.L. Krysko. 2011. *Python sebae* (Northern African Python or African Rock Python). Size. Herpetological Review 42(2): 303.
Journal	Reed, R.N., K.M. Hart, G.H. Rodda, F.J. Mazzotti, R.W. Snow, M. Cherkiss, R. Rozar, and S. Goetz. 2011. A field test of attractant traps for invasive Burmese pythons (*Python molurus bivittatus*) in southern Florida. Journal of Wildlife Management 38(2): 114-121.
Journal	Reed, R.N. and F. Kraus. 2010. Invasive reptiles and amphibians: Global perspectives and local solutions. Animal Conservation 13 (Supp.): 3-4.
Book Chapter	Reed, R.N. and G.H. Rodda. 2011. Burmese Pythons and other giant constrictors. Pages 85-91 in D. Simberloff and M. Rejmanek (eds.). Encyclopedia of biological invasions. Berkeley, CA: University of California Press.
Journal	Rodda, G.H., C.S. Jarnevich, and R.N. Reed. 2011. Challenges in identifying sites climatically matched to the native ranges of animal invaders. PLoSOne 6(2): 1-18.
Journal	Stohlgren, T.J., C.S. Jarnevich, W. Esaias, and J.T. Morisette. 2011. Bounding species distribution models. Current Zoology 57(5): 642-647.

Abstract	Stohlgren T.J., C.S. Jarnevich, and J.T. Morisette. 2011. Predicting kudzu in the US and Canada in response to climate change and other factors. Abs. in 96th Ecological Society of America Annual Meeting, Austin, TX, 7–12 August 2011. Washington, DC: Ecological Society of America.
Journal	Stohlgren, T.J., S. Kumar, D.T. Barnett, and P.H. Evangelista. 2011. Using maximum entropy modeling for optimal selection of sampling sites for monitoring networks. Diversity 3(2): 252-261.
Journal	Stohlgren, T.J., P. Pysek, J. Kartesz, M. Nashino, A. Pauchard, M. Winter, J. Pino, D.M. Richardson, J.R.U. Wilson, B.R. Murray, M.L. Phillips, L. Ming-Yang, L. Celesti-Grapow, and X. Font. 2011. Widespread plant species: Natives versus aliens in our changing world. Biological Invasions 13(9): 1931-1944.
Journal	Tan, B., J.T. Morisette, R.E. Wolfe, F. Gao, G.A. Ederer, J. Nightingale, and J.A. Pedelty. 2011. An enhanced TIMESAT algorithm for estimating vegetation phenology metrics from MODIS data. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 4(2): 361-371.
Journal	Wostl, E., T.J. Hinkle, B. Lardner, and R.N. Reed. 2011. *Boiga Irregularis* (Brown Treesnake) predation and diet. Herpetological Review 42(2): 282.
Journal	Yackel Adams, A.A., J.W. Stanford, A.S. Wiewel, and G.H. Rodda. 2011. Modelling detectability of kiore (*Rattus exulans*) on Aguiguan, Mariana Islands, to inform possible eradication and monitoring efforts. New Zealand Journal of Ecology 35(2): 145-152.
Ecosystems—Status and Trends of Biological Resources	
Journal	Cade, B.S. 2011. Estimating equivalence with quantile regression. Ecological Applications 21(1): 281-289.
Open-File Report	Ellison, L.E. 2011. Bats of Ouray National Wildlife Refuge, Utah. U.S. Geological Survey Open-File Report 2011–1032. 51 p.
Journal	Fedy, B.C. and K.E. Doherty. 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 165(4): 915-924.
Abstract	Gascoigne W.R. 2011. Valuation of Rangeland Ecosystem Services. Abs. in California Rangelands Policy and Research Dialogue, Stanford, CA, 13 May 2011. Stanford, CA: Stanford University, Woods Institute for the Environment.
Abstract	Gascoigne, W., D. Hoag, L. Koontz, B. Tangen, T. Shaffer, and R. Gleason. 2010. Valuing ecosystem and economic services across land-use scenarios in the prairie potholes. Abs. in ACES: A Community on Ecosystem Services, Phoenix, AZ, 6–9 December 2010. Gainesville, FL: University of Florida.
Abstract	Jarrell, G.H., C.A. Ramotnik, and D.L. McDonald. 2010. ARCTOS: A relational database relating specimens, specimen-based science, and archival documentation. Abs. in 2010 Geological Society of America Annual Meeting, Denver, CO, 31 October–3 November 2010. Washington, DC: Geological Society of America.
Scientific Investigations Report	McDonald, L.L., T.R. Stanley, D.L. Otis, D.E. Biggins, P.D. Stevens, J.L. Koprowski, and W. Ballard. 2011. Recommended methods for range-wide monitoring of prairie dogs in the United States. U.S. Geological Survey Scientific Investigations Report 2011–5063. 36 p.
Journal	Milchunas, D.G., M.W. Vandever, L.O. Ball, and S. Hyberg. 2011. Allelopathic cover crop prior to seeding is more important than subsequent grazing/mowing in grassland establishment. Rangeland Ecology and Management 64(3): 291-300.
Science Feature	Miller, H., N. Sexton, and L. Koontz. 2011. Landsat imagery: A unique resource. *http://www.fort.usgs.gov/LandsatSurvey*
Open-File Report	Miller, H.M., N.R. Sexton, L. Koontz, J. Loomis, S.R. Koontz, and C. Hermans. 2011. The users, uses, and value of Landsat and other moderate-resolution satellite imagery in the United States—Executive report. U.S. Geological Survey Open-File Report 2011–1031. 42 p.

Open-File Report	Montag, J.M., C.J. Willis, and L.W. Glavin. 2011. Abbreviated bibliography on energy development—A focus on the Rocky Mountain region. U.S. Geological Survey Open-File Report 2011–1206. 316 p.
Admin. Report	Muths, E. 2010. Bent's Old Fort National Historic Site—Reptile/amphibian inventory, 2007–2008. U.S. Geological Survey Administrative Report. 12 p.
Open-File Report	Ponds, P.D. and R.M. Schuster. 2011. The constraints of connecting children with nature—A research literature review. U.S. Geological Survey Open-File Report 2011–1139. 54 p.
Report	Ramotnik, C.A. and M.A. Bogan. 2011. U.S. Geological Survey. Pages 109-117 in T. Turner (ed.). 2010 Annual Report—Museum of Southwestern Biology. Albuquerque, NM: University of New Mexico.
Open-File Report	Ratz, J.M. and S.J. Conk. 2010. Use of wildlife webcams—Literature review and annotated bibliography. U.S. Geological Survey Open-File Report 2010–1306. 42 p.
Open-File Report	Ratz, J.M. and R.M. Schuster. 2011. Constraints to connecting children with nature—Survey of U.S. Fish and Wildlife Service employees sponsored by the National Conservation Training Center, Division of Education Outreach. U.S. Geological Survey Open-File Report 2011–1192. 46 p.
Open-File Report	Ratz, J.M. and R.M. Schuster. 2011. A survey of U.S. Fish and Wildlife Service employees regarding constraints to connecting children with nature—Summary report to respondents. U.S. Geological Survey Open-File Report 2011–1025. 40 p.
Open-File Report	Ratz, J.M., R.M. Schuster, and A.H. Marcy. 2011. The effect of offering distance education on enrollment in onsite training at the National Conservation Training Center. U.S. Geological Survey Open-File Report 2011–1138. 35 p.
Open-File Report	Ratz, J.M., R.M. Schuster, and A.H. Marcy. 2011. A study of topics for distance education—A survey of U.S. Fish and Wildlife Service employees. U.S. Geological Survey Open-File Report 2011–1075. 66 p.
Open-File Report	Ratz, J.M., R.M. Schuster, and A.H. Marcy. 2011. A survey of U.S. Fish and Wildlife Service employees regarding topics for distance education—Summary report to respondents. U.S. Geological Survey Open File Report 2011–1021. 38 p.
Science Feature	Ruth, J.M. 2011. Herding sparrows for science: They're not just "LBJs." *http://www.fort.usgs.gov/HerdingSparrows/*.
Abstract	Ruth, J.M., R.H. Diehl, and R.K. Felix. 2011. Bird migration and stopover habitat use in the Southwest. Abs. in New Mexico Ornithological Society 49th Annual Meeting, Las Cruces, NM, 9 April 2011. Albuquerque, NM: New Mexico Ornithological Society.
Open-File Report	Ruth, J.M., R.K. Felix, Jr., and R.H. Diehl. 2010. Bird migration patterns in the arid Southwest—Final report. U.S. Geological Survey Open-File Report 2010–1271. 51 p.
Journal	Sexton, N.R., H.M. Miller, and A.M. Dietsch. 2011. Appropriate uses and considerations for online surveying in human dimensions research. Human Dimensions of Wildlife 16(3): 154-163.
Journal	Skagen, S.K. and A.A. Yackel Adams. 2011. Potential misuse of avian density as a conservation metric. Conservation Biology 25(1): 48-55.
Abstract	Stanley, T., S. Teel, L. Hall, L. Dye, and L. Laughrin. 2010. Estimating the population size of island loggerhead shrikes on Santa Rosa and Santa Cruz Islands, USA. Abs. in The Wildlife Society 17th Annual Conference, Snowbird, UT, 2–6 October 2010. Washington, DC: The Wildlife Society.
Admin. Report	Valdez, E. 2011. Population assessment of the Mariana fruit bat (*Pteropus mariannus mariannus*) on Anatahan, Sraigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, and Maug, 15 June–10 July 2010. U.S. Geological Survey Administrative Report. 48 p.
Admin. Report	Valdez, E.W. and L.E. Ellison. 2011. Review of "State of Texas Mine: A Comparison of 2010 Modified Cupola and Cable-net Video Surveys" and supporting data, prepared by WestLand Resources, Inc. and Arizona Game and Fish Department, 2010. U.S. Geological Survey Administrative Report. 76 p.

Journal	Valdez, E.W., G.J. Wiles, and T.J. O'Shea. 2011. Diets of the sympatric Pacific sheath-tailed bat (*Emballonura semicaudata rotensis*) and Mariana swiftlet (*Aerodramus bartschi*) on Aguiguan, Mariana Islands. Pacific Science 65(3): 301-309.
Admin. Report	Waltermire, R.G. 2011. Aerial photography sources for delineating the Oregon, California, Mormon, Pioneer, and Pony Express National Historic Trails in Kansas, Nebraska, Oregon, and Wyoming. U.S. Geological Survey Administrative Report. 59 p.
Journal	Westbrook, C.J., D.J. Cooper, and B.W. Baker. 2011. Beaver-assisted river valley formation. River Research and Applications 27(2): 247-256.
Ecosystems—Terrestrial, Freshwater, and Marine Ecosystems	
Journal	Andersen, D.C., P.B. Shafroth, C.M. Pritekel, and M.W. O'Neill. 2011. Managed flood effects on beaver pond habitat in a desert riverine ecosystem, Bill Williams River, Arizona USA. Wetlands 31(2): 195-206.
Journal	Baron, J.S., C.T. Driscoll, J.L. Stoddard, and E.E. Richer. 2011. Empirical critical loads of atmospheric nitrogen deposition for nutrient enrichment and acidification of sensitive US lakes. BioScience 61(8): 602-613.
Open-File Report	Bowen, Z.H., C.L. Aldridge, P.J. Anderson, T.J. Assal, L.R.H. Biewick, S.W. Blecker, G.K. Boughton, S. Bristol, N.B. Carr, A.D. Chalfoun, G.W. Chong, M.L. Clark, J.E. Diffendorfer, B.C. Fedy, K. Foster, S.L. Garman, S. Germaine, et al. 2011. U.S. Geological Survey Science for the Wyoming Landscape Conservation Initiative—2010 Annual Report. U.S. Geological Survey Open-File Report 2011–1219. 147 p.
Open-File Report	Bowen, Z.H., C.L. Aldridge, P.J. Anderson, T.J. Assal, L.R.H. Biewick, S.W. Blecker, S. Bristol, N.B. Carr, A.D. Chalfoun, G.W. Chong, et al. 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.
Report Chapter	Bowman, W.D., J.S. Baron, L. Geiser, M.E. Fenn, and E.A. Lilleskov. 2011. Northwestern Forested Mountains [Chapter 8]. Pages 75-88 in L.H. Pardo, M.J. Robin-Abbott, and C.T. Driscoll (eds.). Assessment of N deposition effects and empirical critical loads of N for ecoregions of the United States. General Technical Report NRS-80. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.
Journal	Carr, N.B. 2011. Birds of Wyoming [Book Review]. Prairie Naturalist 43(1/2): 66-67.
Data Series	Carr, N.B., J.E. Diffendorfer, T.S. Fancher, N.E. Latysh, K.J. Leib, A.-M. Matherne, and C. Turner. 2011. Locations and attributes of wind turbines in New Mexico, 2009. U.S. Geological Survey Data Series 596.
Data Series	Carr, N.B., J.E. Diffendorfer, T.S. Fancher, N.E. Latysh, K.J. Leib, A.-M. Matherne, and C. Turner. 2011. Locations and attributes of wind turbines in Colorado, 2009: U.S. Geological Survey Data Series 597.
Fact Sheet	Carr, N.B., J.E. Diffendorfer, N.E. Latysh, K.J. Leib, A.-M. Matherne, and C. Turner. 2011. Assessing effects of energy development in Colorado and New Mexico. U.S. Geological Survey Fact Sheet 2011–3053. 2 p.
Journal	Castro, J., C.D. Allen, M. Molina-Morales, S. Maranon, A. Sanchez-Miranda, and R. Zamora. 2011. Salvage logging versus the use of burnt wood as a nurse object to promote post-fire tree seedling establishment. Restoration Ecology 19(4): 537-544.
Journal	Dean, D.J., M.L. Scott, P.B. Shafroth, and J.C. Schmidt. 2011. Stratigraphic, sedimentologic, and dendrogeomorphic analyses of rapid floodplain formation along the Rio Grande in Big Bend National Park, TX. Geological Society of America Bulletin 123(9-10): 1908-1925.
Journal	Fawcett, P.J., J.P. Werne, R.S. Anderson, J.M. Heikoop, E.T. Brown, M.A. Berke, S.J. Smith, F. Goff, L. Donohoo-Hurley, L.M. Cisneros-Dozal, S. Schouten, J.S.S. Damsté, [...] and C.D. Allen. 2011. Extended megadroughts in the southwestern United States during Pleistocene interglacials. Nature 470: 518-521.

Journal	Fedy, B.C. and C.L. Aldridge. 2011. The importance of within-year repeated counts and the influence of scale on long-term monitoring of sage-grouse. Journal of Wildlife Management 75(5): 1022-1033.
Journal	Keefe, S.H., J.S. (Thullen) Daniels, R.L. Runkel, R.D. Wass, E.A. Stiles, and L.B. Barber. 2010. Influence of hummocks and emergent vegetation on hydraulic performance in a surface flow wastewater treatment wetland. Water Resources Research 46: W11518.
Web Site	Oyler-McCance, S.J and P.D. Stevens. 2011. FORT Molecular Ecology Laboratory. *http://www.fort.usgs.gov/MEL/*.
Fact Sheet	Oyler-McCance, S.J. and P.D. Stevens. 2011. Molecular genetics at the Fort Collins Science Center. U.S. Geological Survey Fact Sheet 2011–3091. 2 p.
Journal	Reed, R.N. 2011. Alien reptiles and amphibians: A scientific compendium and analysis, by Fred Kraus [Book Review]. Herpetological Review 42(2): 306-309.
Abstract	Reed, R.N., B. Lardner, G.H. Rodda, J.A. Savidge, and A.A. Yackel Adams. 2011. Individual and demographic responses to simulated elevated prey densities in brown treesnakes (*Boiga irregularis*) on Guam. Abs. in Joint Meeting of Ichthyologists and Herpetologists, Minneapolis, MN, 6-11 July 2011. Minneapolis, MN: University of Minnesota.
Journal	Savidge, J.A., J.S. Stanford, R.N. Reed, G.R. Haddock, and A.A. Yackel Adams. 2011. Canine detection of free-ranging brown treesnakes on Guam. New Zealand Journal of Ecology 35(2): 174-181.
Presentation	Shafroth, P.B. 2010. Bill Williams River environmental flow program: Lessons learned and future challenges. In: Restoring Rivers in the Southwestern U.S. and Northern Mexico, 7–9 December 2010. Tucson, AZ: University of Arizona. 18 slides.
Fact Sheet	Skagen, S.K. and C.P. Melcher. 2011. Avian conservation in the Prairie Pothole region, northern Great Plains—Understanding the links between climate, ecosystem processes, wetland management, and bird communities. U.S. Geological Survey Fact Sheet 2011–3030. 4 p.
Journal	Sorrell, G.G., M.S. Boback, R.N. Reed, S. Green, C.E. Montgomery, L.S. DeSouza and M. Chiaraviglio. 2011. Boa constrictor (*Boa constrictor*). Foraging behavior. Herpetological Review 42(2): 281.
Web Site	Spaulding, S.A. 2010. Diatoms of the United States [website update]. *http://westerndiatoms.colorado.edu/*
Journal	Spaulding S.A., J.R. Pool, S.I. Castro, and F. Hinz. 2010. Species within the genus *Encyonema Kützing*, including two new species *Encyonema reimeri* sp. nov. and *E. nickcafei* sp. nov. and *E. stoermeri* nom. nov., stat. nov. Proceedings of the Academy of Natural Sciences of Philadelphia 160(1): 57-71.
Book Chapter	Spaulding, S.A., B. Van de Vijver, D.A. Hodgson, D.M. McKnight, E. Verleyen, and L. Stanish. 2010. Diatoms as indicators of environmental change in Antarctic and subantarctic freshwaters [Chapter 14]. Pages 267-283 in J.P. Smol and E.F. Stoermer (eds.). The diatoms: Applications for the environmental and Earth sciences. New York: Cambridge University Press.
Abstract	Stricker, C.A., S.D. Kovach, G.H. Collins, S.D. Farley, R.O. Rye, and M.T. Hinkes. 2010. Inter-annual variation in the foraging ecology of a brown bear population in southwest Alaska. Abs. in American Geophysical Union, 2010 Fall Meeting, San Francisco, CA, 13–17 December 2010. Washington, DC: American Geophysical Union.
Journal	Walters, D.M. M.A. Mills, B.S. Cade, and L.P. Burkhard. 2011. Trophic magnification of PCBs and its relationship to the octanol–water partition coefficient. Environmental Science and Technology 45(9): 3917-3924.
Journal	York, P., P. Evangelista, S. Kumar, J. Graham, C. Flather, and T. Stohlgren. 2011. A habitat overlap analysis derived from MaxEnt for tamarisk and the southwestern willow flycatcher. Frontiers of Earth Science 5(2): 120-129.
Admin. Report	Zeigenfuss, L.C. 2011. Bighorn sheep habitat suitability on the Mesa Verde cuesta. U.S. Geological Survey Administrative Report. 27 p.

Journal	Zeigenfuss, L.C., K.A. Schoenecker, and L.K. Van Amburg. 2011. Ungulate herbivory on alpine willow in the Sangre de Cristo Mountains of Colorado. Western North American Naturalist 71(1): 86-96.
Open-File Report	Zeigenfuss, L.C., T. Johnson, and Z. Wiebe. 2011. Monitoring plan for vegetation responses to elk management in Rocky Mountain National Park. U.S. Geological Survey Open-File Report 2011–1013. 85 p.
Ecosystems—Wildlife and Terrestrial Resources	
Journal	Biggins, D.E., J.L. Godbey, B.M. Horton, and T.M. Livieri. 2011. Movements and survival of black-footed ferrets associated with an experimental translocation in South Dakota. Journal of Mammalogy 92(4): 742-750.
Journal	Biggins, D.E., L.R. Hanebury, B.J. Miller, and R.A. Powell. 2011. Black-footed ferrets and Siberian polecats as ecological surrogates and ecological equivalents. Journal of Mammalogy 92(4): 710-720.
Journal	Biggins, D.E., T.M. Livieri, and S.W. Breck. 2011. Interface between black-footed ferret research and operational conservation. Journal of Mammalogy 92(4): 699-704.
Journal	Biggins, D.E., B.J. Miller, L.R. Hanebury, and R.A. Powell. 2011. Mortality of Siberian polecats and black-footed ferrets released onto prairie dog colonies. Journal of Mammalogy 92(4): 721-731.
Journal	Blehert, D.S., J.M. Lorch, A.E. Ballmann, P.M. Cryan, and C.U. Meteyer. 2011. Bat white-nose syndrome in North America. Microbe 6(6): 267-273.
Journal	Boyles, J.G., P.M. Cryan, G.F. McCracken, and T.H. Kunz. 2011. Economic importance of bats in agriculture. Science 332(6025): 41-42.
Journal	Boyles, J.G., P.M. Cryan, G.F. McCracken, and T.H. Kunz. 2011. Response to: "Concerns about extrapolating right off the bat" [Letter]. Science 333(6042): 287-288.
Admin. Report	Castle, K.T., M. Biel, L.E. Ellison, A. Chanlongbutra, M. Chase, D. Licht, M. May, and D.E. Biggins (Compilers). 2011. A National Park Service manager's reference notebook on plague (*Yersinia pestis*). U.S. Geological Survey Administrative Report. 95 p.
Book Chapter	Connelly, J.W., S.T. Knick, C.E. Braun, W.L. Baker, E.A. Beever, T. Christiansen, K.E. Doherty, E.O. Garton, S.E. Hanser, D.H. Johnson, M. Leu, R.F. Miller, D.E. Naugle, S.J. Oyler-McCance, et al. 2011. Conservation of greater sage-grouse: A synthesis of current trends and future management. Pages 549-563 in S.T. Knick and J.W. Connelly (eds.). Greater sage-grouse: Ecology and conservation of a landscape species and habitats. Berkeley, CA: University of California Press.
Journal	Cryan, P.M. 2011. Wind turbines as landscape impediments to the migratory connectivity of bats. Environmental Law 41: 355-370.
Abstract	Cryan, P.M., J.W. Jameson, E.F. Baerwald, C.K.R. Willis, R.M.R. Barclay, E.A. Snider, and E.G. Crichton. 2010. Evidence of mating readiness in certain bats killed by wind turbines. Abs. in 40th Annual Symposium on Bat Research Denver, CO, 27–30 October 2010. Kenosha, WI: North American Society for Bat Research.
Journal	Cryan, P.M., C. Uphoff Meteyer, J.G. Boyles, and D.S. Blehert. 2010. Wing pathology of white-nose syndrome in bats suggests life-threatening disruption of physiology. BMC Biology 8(135): 1-8.
Abstract	Doll, A., M. Wunder, R. Lanctot, and C. Stricker. 2011. Estimating arrival times of Arctic-breeding dunlin using stable isotopes. Abs. in 4th Western Hemisphere Shorebird Group Meeting, Vancouver, BC, Canada, 11-15 August 2011. Arlington, VA: U.S. Fish and Wildlife Service, Western Hemisphere Shorebird Group.
Journal	Eads, D.A., D.E. Biggins, D.S. Jachowski, T.M. Livieri, J.J. Millspaugh, and M. Forsberg. 2010. Morning ambush attacks by black-footed ferrets on emerging prairie dogs. Ethology, Ecology, and Evolution 22(4): 345-352.

Journal	Eads, D.A., J.J. Millspaugh, D.E. Biggins, T.M. Livieri, and D.S. Jachowski. 2011. Postbreeding resource selection by adult black-footed ferrets in the Conata Basin, South Dakota. Journal of Mammalogy 92(4): 760-770.
Abstract	Ellison, L.E., T.J. O'Shea, and P.M. Cryan. 2010. A map of the big brown bat wing: "Typical" damage and scarring in an urban maternity population prior to white-nose syndrome. Abs. in 40th Annual Symposium on Bat Research Denver, CO, 27–30 October 2010. Kenosha, WI: North American Society for Bat Research.
Journal	Fagerstone, K.A. and D.E. Biggins. 2011. Black-footed ferret areas of activity during late summer and fall at Meeteetse, Wyoming. Journal of Mammalogy 92(4): 705-709.
Journal	Foley, J., D. Clifford, K. Castle, P. Cryan, and R.S. Ostfeld. 2011. Investigating and managing the rapid emergence of white-nose syndrome, a novel, fatal, infectious disease of hibernating bats. Conservation Biology 25(2): 223-231.
Journal	George, D.B., C.T. Webb, M.L. Farnsworth, T.J. O'Shea, R.A. Bowen, D.L. Smith, T.R. Stanley, L.E. Ellison, and C.E. Rupprecht. 2011. Host and viral ecology determine bat rabies seasonality and maintenance. Proceedings of the National Academy of Sciences, USA (PNAS) 108(25): 10208-10213.
Journal	Gutzwiller, K.J., W.C. Barrow Jr., J.D. White, L. Johnson-Randall, B.S. Cade, and L.M. Zygo. 2010. Assessing conservation relevance of organism–environment relations using predicted changes in response variables. Methods in Ecology and Evolution 1(4): 351-358.
Journal	Haig, S.M., W.M. Bronaugh, R. Crowhurst, J. D'Elia, C.A. Eagles-Smith, C. Epps, B. Knaus, M.P. Miller, M.L. Moses, S. Oyler-McCance, W.D. Robinson, and B. Sidlauskas. 2011. Genetic applications in avian conservation. The Auk 128(2): 205-229.
Journal	Koizumi, N., T.W. Quinn, M. Park, J. Fike, K. Nishida, T. Takemura, K. Watabe, and A. Mori. 2011. Isolation and characterization of 21 polymorphic microsatellite loci in the Japanese dace (*Tribolodon hakonensis*). Conservation Genetics Resources 3(3): 565-567.
Journal	Muths, E. and J.M. Hero. 2010. Amphibian declines: Promising directions in understanding the role of disease. Animal Conservation 13 (Supp.): 33-35.
Journal	Muths, E., R.D. Scherer, and D.S. Pilliod. 2011. Compensatory effects of recruitment and survival when amphibian populations are perturbed by disease. Journal of Applied Ecology 48(4): 873-879.
Journal	Newmark, W.D. and T.R. Stanley. 2011. Habitat fragmentation reduces nest survival in an Afrotropical bird community in a biodiversity hotspot. Proceedings of the National Academy of Sciences, USA (PNAS) 108(28): 11488-11493.
Journal	Osborne, C., P. Cryan, T.J. O'Shea, L.M. Oko, C. Ndaluka, C.H. Calisher, A. Berglund, M.L. Klavetter, R.A. Bowen, K.V. Holmes, and S.R. Dominguez. 2011. Alphacoronaviruses in New World bats: Prevalence, persistence, phylogeny, and potential for interaction with humans. PLoS ONE 6(5): 1-11.
Journal	O'Shea, T.J., P.M. Cryan, E.A. Snider, E.W. Valdez, L.E. Ellison, and D.J. Neubaum. 2011. Bats of Mesa Verde National Park, Colorado: Composition, reproduction, and roosting habits. Monographs of the Western North American Naturalist 5(2011): 1-19.
Journal	O'Shea, T. J., L.E. Ellison, and T.R. Stanley. 2011. Adult survival and population growth rate in Colorado big brown bats (*Eptesicus fuscus*). Journal of Mammalogy 92(2): 433-443.
Journal	Oyler-McCance, S.J. and J.A. Fike. 2011. Characterization of small microsatellite loci isolated in endangered Indiana bat (*Myotis sodalis*) for use in non-invasive sampling. Conservation Genetics Resources 3(2): 243-245.
Journal	Oyler-McCance, S.J., J.A. Fike, T. Talley-Farnham, T. Engelman, and F. Engleman. 2011. Characterization of ten microsatellite loci in the broad-tailed hummingbird (*Selasphorus platycercus*). Conservation Genetics Resources 3(2): 351-353.

Journal	Oyler-McCance, S.J. and J.M. Parker. 2010. Characterization of ten microsatellite loci in midget faded rattlesnake (*Crotalus oreganus concolor*). Conservation Genetics Resources 2(1): 123-125.
Book Chapter	Oyler-McCance, S.J. and T.W. Quinn. 2011. Molecular insights into the biology of greater sage-grouse. Pages 85-94 in S.T. Knick and J.W. Connelly (eds.). Greater sage-grouse: Ecology and conservation of a landscape species and its habitats (Studies in Avian Biology vol. 38). Berkeley, CA: University of California Press.
Journal	Oyler-McCance, S.J. and J. St. John. 2010. Characterization of small microsatellite loci for use in non-invasive sampling studies of Gunnison sage-grouse (*Centrocercus minimus*). Conservation Genetics Resources 2(1): 17-20.
Journal	Pilliod, D.S., E. Muths, R.D. Scherer, P.E. Bartelt, P.S. Corn, B.R. Hossack, B.A. Lambert, R. McCaffery, and C. Gaughan. 2010. Effects of amphibian chytrid fungus on individual survival probability in wild boreal toads. Conservation Biology 24(5): 1259-1267.
Journal	Poessel, S.A., D.E. Biggins, R.M. Santymire, T.M. Livieri, K.R. Crooks, and L. Angeloni. 2011. Environmental enrichment affects adrenocortical stress responses in the endangered black-footed ferret. General and Comparative Endocrinology 172(3): 526-533.
Journal	Poessel, S.A., S.W. Breck, D.E. Biggins, T.M. Livieri, K.R. Crooks, and L. Angeloni. 2011. Landscape features influence postrelease predation on endangered black-footed ferrets. Journal of Mammalogy 92(4): 732-741.
Journal	Ransler, F.A., T.W. Quinn, and S.J. Oyler-McCance. 2011. Genetic consequences of trumpeter swan (*Cygnus buccinator*) reintroductions. Conservation Genetics 12(1): 257-268.
Journal	Ransom, J.I. 2011. Customizing a rangefinder for community-based large animal surveys. Biodiversity and Conservation 20(7): 1603-1609.
Admin. Report	Ransom, J.I., J.E. Roelle, L.C. Zeigenfuss, and S. Germaine. 2011. Annual Report for 2010 Wild Horse Research and Field Activities. U.S. Geological Survey Administrative Report. 20 p.
Journal	Stanley, T.R. 2010. Land use and small mammal predation effects on shortgrass prairie birds. Journal of Wildlife Management 74(8): 1825-1833.

Table 2-2. Other FORT Products Delivered in FY 2011. Abbreviations: BIMD=Biology Information Management and Delivery; DSS=Decision Support System/Web Application ENV=Terrestrial, Freshwater and Marine Environments; FAER=Fisheries: Aquatic and Endangered Resources; INV=Invasive Species; NGP=National Geospatial Program; NAWQA=National Water-Quality Assessment; NSIP: National Streamflow Information Program; R&D=Research and Development; ST=Status and Trends; WTER=Wildlife: Terrestrial and Endangered Resources.

Product Type	Mission Area/Programs	Citation
Core Science Systems		
DSS	BIMD, NGP	Science Base Repository, version 1.0.0 (Web based data repository and management) (T. Kern)
DSS	BIMD, NGP	Science Base Catalog, version 1.9.0 (Web-based metadata catalog and search) (T. Kern)
DSS	BIMD, NGP	Science Base Event Manager, version 1.2.0 (Web-based workshop/event planning and user registration) (T. Kern)
DSS	BIMD	Professional Pages, version 2.0.0 (Web-based scientist user profile and accomplishment capture and display) (T. Kern)
DSS	BIMD	Radio Asset Inventory System, version 2.5.0 (Web-based data collection and reporting) (T. Kern)
Ecosystems		
Training	ENV, WTER	Geomorphic Analysis of Fluvial Systems, Chicago, IL, October 4-8, 2010 (J. Friedman, F. Fitzpatrick, A. Gellis, J. O'Connor, A. Simon)
Training	ENV, FAER, INV, ST, WTER	myUSGS 4.0 Training, Community for Data Integration Annual Meeting, Denver, CO, 16 Aug. 2011 (T. Kern, G. Montgomery, J. Dawson)
Training	ENV, FAER, INV, ST, WTER	ScienceBase Training, Community for Data Integration Annual Meeting, Denver, CO, 16 Aug. 2011 (T. Kern, L. Smyrl, S. Tekell, D. Mack)
Training	ENV, FAER, INV, ST, WTER	Mobile Applications Training, Community for Data Integration Annual Meeting, Denver, CO, 16 Aug. 2011 (T. Lawall)
DSS	ENV, FAER, INV, ST, WTER	myUSGS 3.0, Final Release, Core Science Systems/ Infrastructure, July 2011
DSS	ENV, FAER, INV, ST, WTER	myUSGS 4.0, Preview Release, Core Science Systems/ Infrastructure, Aug. 2011
DSS	ENV, FAER, INV, ST, WTER	ScienceBase, version 1.30, Core Science Systems/ Infrastructure, Aug. 2011
DSS	ENV, FAER, INV, ST, WTER	Pinedale Anticline Data Management System, Final Release, Bureau of Land Management, Aug. 2011
DSS	ENV, WTER	Dose Response Calculator for ArcGIS. USGS Data Series 631, online at *http://pubs.usgs.gov/ds/631/*, Sept. 2011 (S.E. Hanser, C.L Aldridge, M. Leu, and S.E. Nielsen)
Training	ENV, WTER	Wild Horse Aerial Survey Training for BLM Managers, Reno, NV, 2–4 Aug. 2011 (J. Ransom)
Workshop	ENV	Results of Monitoring Analyses and Willow Restoration Trials in Relation to Comprehensive Conservation Plan for Arapaho NWR, Arapaho NWR, Walden, CO, 28 June 2011 (G. Auble, B. Cade, K. Schoenecker)
Training	FAER	Field Techniques for 2D-based Aquatic Habitat Modeling, Grant Creek, AK, 16–24 Sept. 2011 (L. Hanson, C. Holmquist-Johnson, T. Waddle)

Product Type	Mission Area/Programs	Citation
DSS	FAER	SmartRiver GIS desktop application (C. Talbert)
DSS	INV	National Invasive Species Council Performance Tracking System, version 2.0.0 (Web-based Performance Element Status Capture) (T. Kern)
Workshop	INV	Powell Center Cheatgrass Modeling Working Group, "Integrating ecological forecasting methods to improve prioritization of natural resource management: an invasive species example." 11–13 January 2011, Fort Collins, CO (J. Morisette)
Workshop	INV	Our Changing Oceans Workshop, "Marine Invasions and Climate Change," 19–21 Jan. 2011, Washington, D.C. (T. Stohlgren)
Workshop	INV	Webinar, GLEDN-SISIN Training, (Great Lakes Early Detection Network, Global Invasive Species Information Network) 11 Feb. 2011, USGS Fort Collins Science Center, Fort Collins, CO (C. Jarnevich)
Workshop	INV	Impacts of Invasive Pythons on Native Vertebrates in Florida 8–9 March 2011, University of Florida, Fort Lauderdale Research and Education Center (R. Reed)
Training	INV	Rapid Response Team Training for Hawaii Invasive Species Councils, Hawaii, 14 Feb.–5 March 2011, Guam National Wildlife Refuge, Guam (J. Stanford)
Training	INV	National Invasive Species Council Training/Field Trip, Rocky Mountain National Park, CO, 15 June 2011 (T. Stohlgren)
Training	INV	MaxEnt Training for Texas Parks and Wildlife and Ethiopia Wildlife Commission, USGS Fort Collins Science Center Resource for Advanced Modeling, CO, 5 April 2011 (C. Jarnevich)
Workshop	INV	Modeling Workshop for Ethiopia Wildlife Commission, USGS Fort Collins Science Center Resource for Advanced Modeling, CO, 24 April 2011 (J. Morisette)
Workshop	INV	Tallgrass Prairie National Preserve Intensive Modeling Session, USGS Fort Collins Science Center Resource for Advanced Modeling, CO 21–23 June 2011 (J. Morisette)
Workshop	INV	Modeling Invasive Species: Online Training for Chinese Scientists, Colorado State University, Fort Collins, CO, 26–28 Sept. 2011 (T. Stohlgren)
Workshop	INV	MaxEnt Training for Western Governors Association, Lesser Prairie Chicken Technical Working Group, USGS Fort Collins Science Center RAM, Fort Collins, CO, 2 Aug. 2011 (C. Jarnevich)
Workshop	INV	MaxEnt Training and Modeling Workshop for Wisconsin DNR, Fort Collins Science Center RAM, Fort Collins, CO, 19–23 Sept. 2011 (C. Jarnevich)
Workshop	INV	MaxEnt Modeling Workshop for U.S. Fish and Wildlife Service and Kansas Dept. of Wildlife, Parks, and Tourism, Fort Collins Science Center RAM, Fort Collins, CO, 2–4 Nov. 2010 (C. Jarnevich)
Training	INV	North American Invasive Species Network–Global Invasive Species Information Network (NAISN–GISIN) training, Boise, ID, 16 Nov. 2010 (C. Jarnevich)
DSS	ST	Distributable Installation of VisTrails and Software for Advanced Habitat Modeling (SAHM) (C. Talbert)
Workshop	ST	Plains and Prairie Pothole Climate Change Project Workshop, USGS Fort Collins Science Center, Fort Collins, CO, 8–9 Nov. 2010 (S.K. Skagen)
DSS	ST	Wind Turbine GIS Data Series for Colorado and New Mexico (T. Fancher)

Product Type	Mission Area/Programs	Citation
Training	ST	Negotiation Skills for Natural Resource Professionals: Building a Foundation, USGS Fort Collins Science Center, 10–12 May 2011 (N. Burkardt)
Training	ST	Strategies and Tactics for the Experienced Natural Resource Negotiator, USGS Fort Collins Science Center, 13–15 Sept. 2011 (N. Burkardt)
Training	ST	Negotiation and Conflict Resolution (one day segment of five-day USGS Leadership 101 class), National Conservation Training Center, Feb. 2011 and May 2011 (N. Burkardt)
Training	ST	Advanced Negotiation Training for Natural Resource Professionals, Casper, WY. Co-taught with S. Smutko of University of Wyoming/Ruckelshaus Institute. 11–12 Aug. 2011 (N. Burkardt)
Workshop	ST	Kauai National Wildlife Refuge Complex Visitor Services Transportation Workshop, Hawaii: 21–25 March 2011, "Visitor and Community Experiences and Perceptions of Kilauea Point NWR and Alternative Transportation (N. Sexton)
DSS	WTER	White Nose Syndrome Tissue Tracking System, Preview Release, U.S. Fish and Wildlife Service, Aug. 2011 (L. Everette)
Climate and Land-Use Change		
Workshop	R&D	Climate Change Adaptation, Santa Fe and Carson National Forests, New Mexico; Ghost Ranch Conference Center (near Albuquerque), NM, 24–28 Jan. 2011 (C.D. Allen)
Workshop	R&D	Climate change adaptation options for the Four Corners area, Durango CO, 1–2 Dec. 2010 (J. Baron)
Workshop	R&D	Bridging Boundaries: Adaptation Planning for Grasslands and Forests in the Black Hills and Plains, Rapid City, SD, 19–21 April 2011 (J. Baron)
Natural Hazards		
DSS	Earthquakes	@USGSted Twitter tool for National Earthquake Information Center, Aug. 2011 (L. Smyrl)
Water		
Workshop	WATER: Groundwater, NSIP, NAWQA (Also ENERGY: Energy Resources, Contaminant Biology)	Powell Center: Effects of Hydraulic Fracturing on Water Resources Scoping Workshop, USGS Fort Collins Science Center, Fort Collins, CO, 24–25 Aug. 2011 (Z. Bowen)

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