2009 Research Accomplishments

Rocky Mountain Research Station

United States Department of Agriculture

Forest Service

Front cover photo: These 28-day-old northern goshawk nestlings have been banded as part of a "mark-recapture" study of the relationship between goshawk population demographics and its habitats on Arizona's Kaibab Plateau. Read more about this research on page 40.

Our mission is to develop and deliver scientific knowledge and technology that will help people sustain our forests, rangelands, and grasslands.

Station Director
G. Sam Foster

Greetings

Here we are again in a new year and it is time to reflect on our accomplishments and progress in 2009. Last year was marked with exciting advances in our science discovery, applications, and integration. Those advances were attained almost entirely with the aid of our partners and stakeholders. We continue to focus on communicating our science findings to land managers and policy makers to help them make informed decisions that will lead to the long-term sustainability of our forests, ranges, and grasslands.

Increasingly, we at the Rocky Mountain Research Station (RMRS) are translating our science results into conservation education opportunities for youth and adults, thereby hoping to infuse them with an appreciation and knowledge of the latest science as well as our enthusiasm for the land and natural resources. We have a wide variety of facilities and resources with which to do our work and are constantly seeking to upgrade them to meet our needs. Following are a few details on each of these topics, and I truly encourage you to read the rest of our exciting report.

Our scientists and science professionals have been very productive this year, which has resulted in a host of research findings, several of which are highlighted later in this report. As I stated last year, RMRS recognizes that quality science is what we are chartered to produce, hence our focus on Science First. This Research and Development (R&D) work ranges broadly across climate change, wildlife and fish, water, fire, economics, human connections, forest products, soil science, entomology, pathology, range, invasive plants, forest management and silviculture, inventory & monitoring, and air quality. We work with our stakeholders to identify important areas in which to work; then we work together to conduct the research. Finally, we work with managers, other scientists, policy makers, and others to apply our research findings. You can find out more about our science programs in this report, and for additional information, visit our Station web site at www.fs.fed.us/rmrs.

Science Application and Integration

Just two years ago, the Station created the Science Application and Integration (SA&I) Staff as part of our restructuring. This staff represents a conscious outreach to our stakeholders and customers, and includes: 1) the Wildland Fire Management Research, Development & Application (RD&A) unit, 2) the Human Factors & Risk Management RD&A (initiated in Fiscal Year 2009), 3) the National LANDFIRE program, and 4) other elements, including oversight of Experimental Forests and Ranges and Research Natural Areas (see page 8 for more information).

This past year saw significant growth in the addition of the new National Wildland Fire Decision Support Center. The SA&I staff is poised for making great strides in 2010 as we have a new Assistant Station Director, Jan Engert, who joined us in September 2009. Our plans include growth in the area of technology transfer in general for the Station, and we will be doing that in strong collaboration with our many partners.

Partnerships

Modern science is generally conducted with others, and in our case, it is with a ***lot of others*** who are our partners. One of my key focus areas for both this year and last was to significantly increase our work with external partners. With this goal in mind, the Station has really opened the door to collaboration with an even wider range of organizations, including universities (in the U.S. and abroad), conservation organizations, National Forest Systems, many other federal agencies, state forestry organizations, tribal governments, state fish and game organizations, and other state organizations. We want to work with organizations that have similar interests and resources, and that are willing to commit to solve R&D problems and help apply those results.

Conservation Education

The Forest Service sees a clear role for educating people of all ages and backgrounds, as well as our stakeholders. Given our broad mission, it is to our Agency's advantage, as well as the world in general, to help educate people about natural resource sustainability. To this end, the Forest Service has a national Conservation Education program for all citizens, as well as the More Kids in the Woods program, to support conservation education specifically with children. The Station hosts a program that dovetails into the national Conservation Education program. We also successfully compete for funds from the national More Kids in the Woods program. Finally, we provide Station funds for an internal competitive Conservation Education grant program.

New and Improved Facilities

The Rocky Mountain Station is growing, literally! One hallmark of a vibrant R&D organization is the availability of modern and efficient facilities. This, of course, is a challenge for a 101-year-old organization like the Rocky Mountain Research Station. So, we constantly strive to maintain and modernize our existing facilities, many of which are on the Historic Register, while we strategically build new ones.

Some of the exciting progress in 2009 includes: 1) completing the new lab addition at our Fire Sciences Lab in Missoula, Montana, 2) breaking ground on a new lab building near Station headquarters in Fort Collins, Colorado, and 3) initiating significant upgrades to facilities at our Fraser Experimental Forest in Colorado. In addition to these major activities, there were numerous smaller, yet significant, upgrades at many of our 12 labs and 14 Experimental Forests and Ranges. A vibrant, effective R&D organization must constantly improve!

New Faces

With the constant movement of time comes transitions in employees, and the RMRS is no different. Dr. Durant McArthur, Program Manager for the Grasslands, Shrublands, and Desert Ecosystems Program; Steve Ambrose, Assistant Station Director for Communications and Marketing; Dolores Rottach, Assistant Station Director for Operations; and Dr. Janine Powell, Assistant Station Director for Strategic Management and Accountability, have either retired or taken different jobs. On the other hand, our new faces include: Dr. Tom Crow, Program Manager for the Forest and Woodland Ecosystems Program; Dr. Frank McCormick, Program Manager for the Air, Water, and Aquatic Environments Program; Dr. Steve Warren, Program Manager for the Grasslands, Shrublands, and Desert Ecosystems Program; and Jan Engert, Assistant Station Director for Science Application & Integration. In addition to these transitions, we have seen numerous other changes in our scientific and operations employees. We have been blessed historically with excellent people, and that trend continues.

Conclusion

In conclusion, the Rocky Mountain Research Station remains a vibrant research and development organization. We have excellent employees who are working with a wide variety of partners on cutting edge science, and we are delivering our science information and tools to stakeholders and customers in ways that are valuable and useful. It is all about working hard to understand the needs of our stakeholders and customers at the local, regional, national, and international level, and then striving to meet those needs. Come join us!

Station Director

Contents

The Forest Service Research and Development mission, "develop and deliver knowledge and innovative technology to improve the health and use of the nation's forests and rangelands," guides the work we do. Our priorities are to:

- *Create credible, innovative, science-based solutions for resource management problems.*
- *Identify relevant needs and quickly and efficiently convert science gaps into findings and products for managers and citizens.*
- *Anticipate and respond to emerging issues.*
- *Enhance the ability of our customers and partners to more easily find, participate in, and use products of the RMRS research program.*

A Look at RMRS

The Rocky Mountain Research Station is one of five regional units that make up the USDA Forest Service Research and Development organization – the most extensive natural resources research organization in the world. We maintain 12 field laboratories throughout a 12-state territory encompassing the Great Basin, Southwest, Rocky Mountains, and parts of the Great Plains. The Station employs a diverse workforce of approximately 500 permanent full-time employees, of which about one-fifth are research scientists.

We administer and conduct research on 14 experimental forests, ranges, and watersheds, while maintaining long-term databases for these areas. We also oversee activities on more than 275 research natural areas (http://rna.nris.state.mt.us) and lead four ecosystem management and research partnership projects in Arizona, Colorado, Montana, New Mexico, and Nevada.

Our research program serves the Forest Service as well as other Federal agencies, State agencies, international organizations, private groups, and individuals. Research results and products are made available through a variety of technical reports, journals, and other publications, web sites, seminars, symposia, demonstrations, exhibits, and personal consultations. These help resource managers and planners balance economic and environmental demands for forest and rangeland resources worldwide.

Communicating With Stakeholders

Credible, useable, and effective scientific information is our product. We recognize that the scientific information we produce must be packaged, promoted, and delivered so that our stakeholders can use it effectively. As we disseminate information, we solicit feedback on its relevance and usefulness, monitor the success of our communication efforts, and adapt strategies as needed.

Administration and Support Services Staffs

The success of our research programs would not be possible without the critical team support provided by our nearly 400 administrative and technical employees. Most are located at Station headquarters in Fort Collins, Colorado, and at the Ogden, Utah, Service Center; others work at laboratory locations. These staffs include: Civil Rights; Budget; Public Affairs; Science Application and Integration; Acquisition Management; Facilities Management; Financial Management; Library Services; Publishing Services; Web Services; Safety, Health and Environment; and Statistics. The Station also receives Human Resources Management and budget and finance support from the Albuquerque Service Center.

Partnerships

To help advance solutions to pressing natural resource problems, the Rocky Mountain Research Station maintains key partnerships with:

National Forest Systems—Forest and grassland managers comprise the Station's largest customer segment or stakeholder group. The Station supports several national missions, including the Fire Sciences Laboratory and the Aldo Leopold Wilderness Research Institute, both in Missoula, Montana. National Forest Systems rely heavily on Station staffs to provide scientific information and assistance in implementing the Endangered Species Act, Clean Water Act, Clean Air Act, and other environmental legislation. For instance, scientists worked with the Boise National Forest, Idaho, to support management of a fire using debris flow mapping procedures developed by Station researchers. This information is helping to highlight areas of concern for high severity fire near bull trout habitat.

In addition, the National Forest Service Library, based at Station headquarters in Fort Collins, CO, regularly serves Forest Service resource specialists; the Station has played a major role in developing the national Wildland Fire Decision Support System that assists fire managers and analysts in making strategic and tactical decisions for fire incidents; and the Station is helping the Forest Service develop safe systems for high-risk environments, such as fighting wildfires.

Other Federal Land Management Agencies—The Station serves managers of the largest public land holdings in the lower 48 states, including the Bureau of Land Management, National Park Service, Bureau of Reclamation, U.S. Fish and Wildlife Service, and Department of Defense. The Station recently developed partnerships with the National Park Service, Bureau of Land Management, the non-profit Mountain Studies Institute, and local governments to conserve and protect high elevation pine forests.

Field trips and one-on-one consultations are important venues for getting research results to users.

Other Federal Non-land Management Agencies—We provide regular consultation to the Environmental Protection Agency, National Marine Fisheries Service, Natural Resources Conservation Service, and Bureau of Indian Affairs.

State, Local and Other Public Agencies—Our Inventory and Monitoring science program is the Station's largest program and provides eight Western States with resource inventory and monitoring data for use by state, county and urban planners, State resource agencies, industry, and others.

Industry—The forest products industry is an important customer for tree improvement, forest productivity, insect and disease, and engineering technology research. We collaborate with the Forest Products Laboratory in Madison, Wisconsin, to link utilization researchers with forest products research opportunities. Summer recreation and winter ski area development and expansion make these industries major customers for Station research programs.

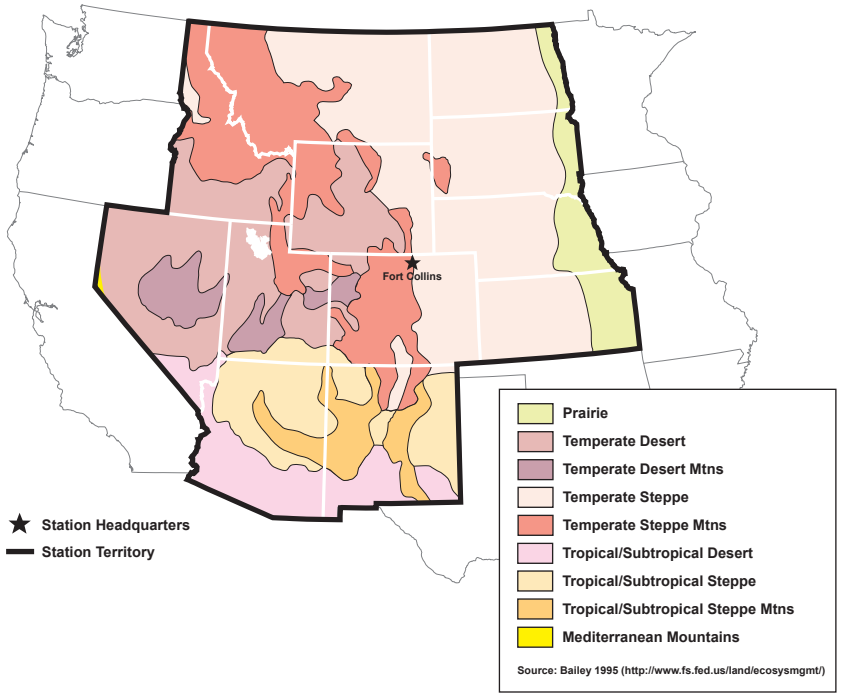
Non-government Organizations (NGOs)—Citizens representing themselves and special interest groups in land management planning efforts are a significant group requesting research information, and special interest groups are becoming increasingly aware of, and are valuing, research information for their uses. Some of these groups include: The Wilderness Society, Northern Colorado Bark Beetle Cooperative, American Forest and Paper Association, Society of American Foresters, Malpai Borderlands Group, American Fisheries Society, the Front Range Fuels Treatment Partnership, and the Soil and Water Conservation Society of America.

Tribal Governments—The Station supports a number of working relationships with several Tribal governments in many parts of our territory. For example, in cooperation with the Columbia River Inter-tribal Fish Commission, Station scientists initiated the first systematic, range-wide genetic monitoring effort for westslope cutthroat trout to better understand their habitat needs and sensitivity to climate change.

International Cooperation—Station scientists often travel to other countries to cooperate with scientists, universities, institutions, and government agencies on a variety of natural resources projects and issues. For instance, Station researchers were requested by the Australian government to assist, supplement and support Victoria State agencies in bushfire recovery efforts following

Within the Rocky Mountain Research Station Territory...

Rivers and Lakes

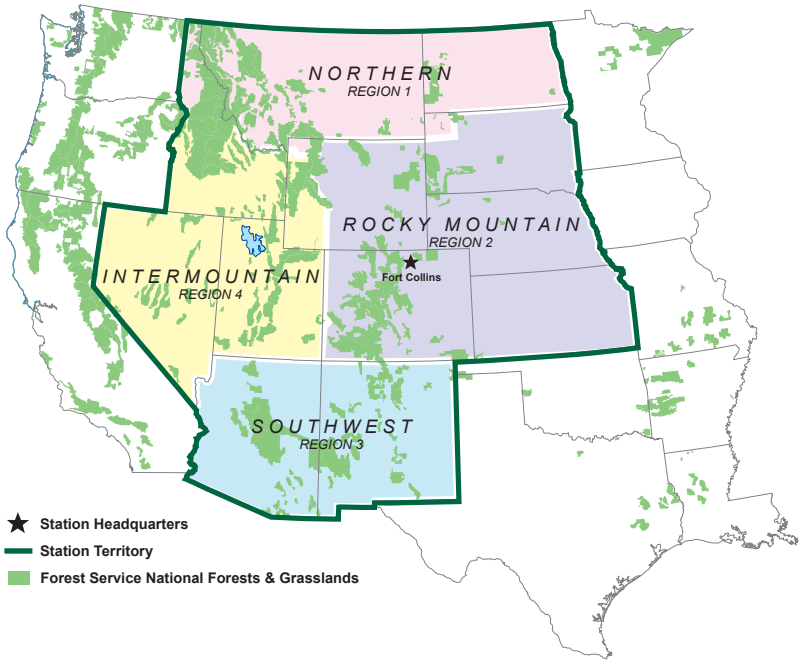


Ecoregions

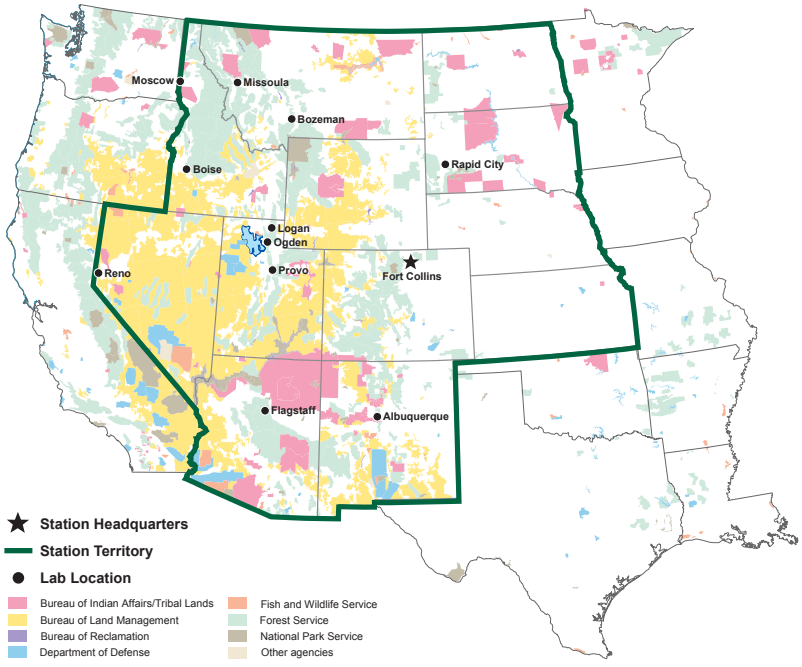
devastating wildfires that burned more than one million acres. As part of a Burned Area Emergency Response team, researchers helped analyze post-fire effects that may threaten assets from potential floods, erosion, and mudslides.

University and Non-university Cooperators—We maintain an active cooperative research program with universities and other partners in order to share expertise and facilities to assist Forest Service research and development projects. In 2009, the Station and the University of Colorado co-sponsored the school's Natural Resources Law Center's 30th Annual Conference, focusing on water quantity and quality issues.

Forest Service Regions and National Forests

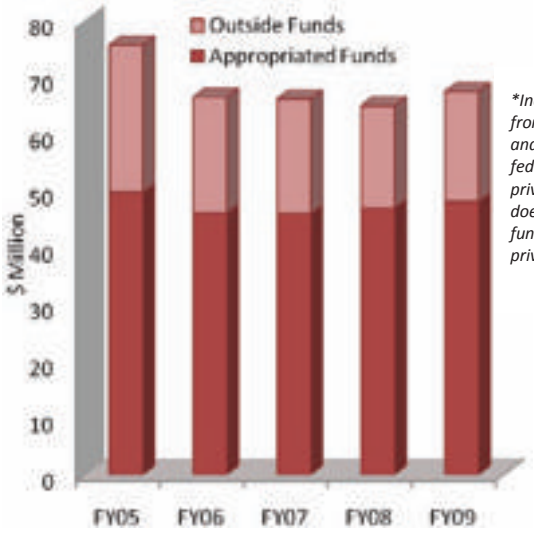


Federal Lands

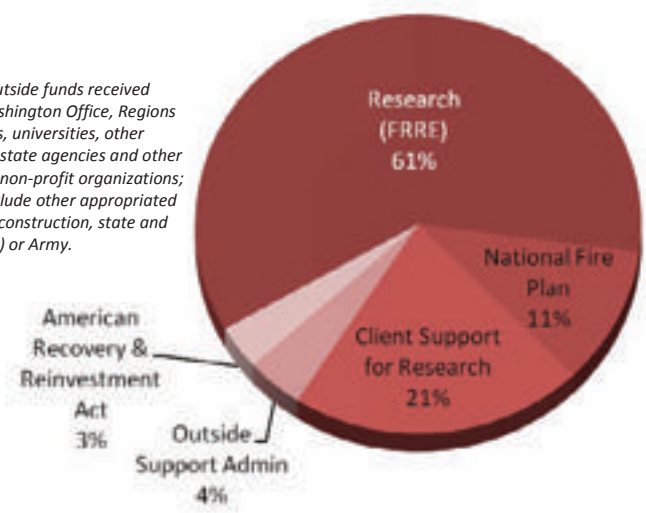


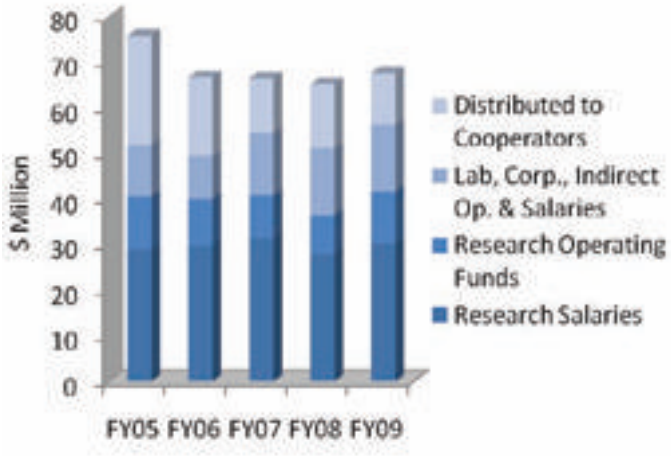
Review of Fiscal Year 2009

Incoming* and Distributed Budget

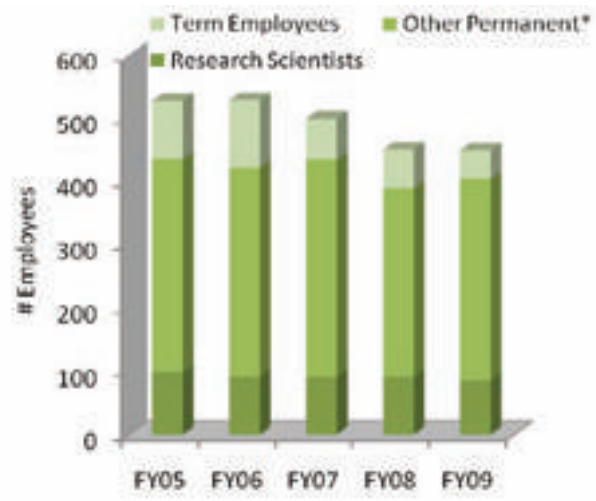


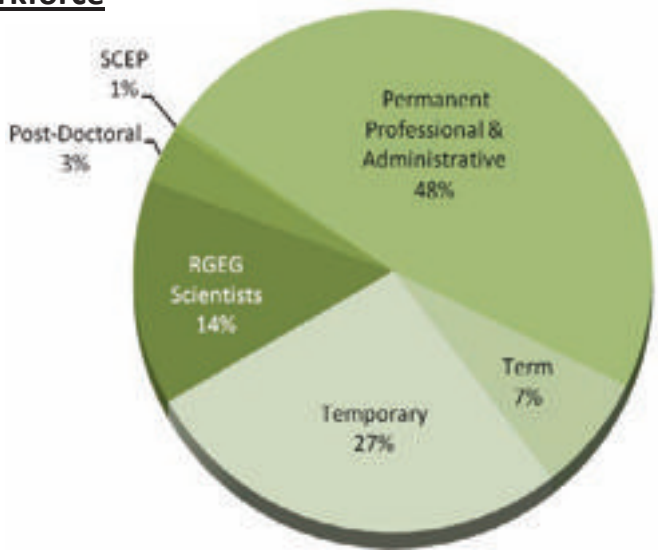
**Includes outside funds received from FS Washington Office, Regions and Stations, universities, other federal and state agencies and other private and non-profit organizations; does not include other appropriated funds (e.g., construction, state and private, etc.) or Army.*





Workforce





2009 Highlights

1. Research Ecologist Dean Pearson received the Presidential Early Career Award for Scientists and Engineers, the highest honor bestowed by the U.S. government on young professionals in the early stages of their independent research careers. He was also honored with the Forest Service 2008 Deputy Chief's Early Career Scientist Award for significant contributions to the fields of biological control, invasive species ecology, and wildlife biology.

2. Research Landscape Ecologist Sam Cushman was recognized by Elsevier, the world's leading publisher of science and health information, as the Most Cited Author 2005-2008, based on his paper, "Effects of Habitat Loss and Fragmentation on Amphibians: A Review and Prospectus," published in *Biological Conservation*, Volume 128, Issue 2 (2006).

3. Station employees Mark Finney, David Calkin, Chuck McHugh, Robert Seli, and Jeff Kaiden were recipients of the Forest Service's 2008 Chief's Honor Award. They were recognized for providing science-based applications and tools for sustainable natural resources management through the Wildland Fire Decision Support System.

4. Research Wildlife Geneticist Michael Schwartz was honored with the Forest Service 2009 Chief's National Wilderness Stewardship Research Award for his leadership in developing and applying non-invasive genetic sampling techniques that avoid physically handling and otherwise disturbing animals of interest.

5. Research Botanist Nancy Shaw received the 2008 National Award for Outstanding Achievement in Rangeland Research and Development from the Society of Range Management.

6. Research Fisheries Biologist Michael Young and retiree Bruce Rieman received the national Rise to the Future Award for their work in advancing the understanding of salmonid issues and developing tools to help guide management actions and prioritize projects.

7. The Station's Rocky Mountain Riparian Digest newsletter received the New Mexico Riparian Council Award for its achievements in improving the conditions and understanding of riparian environments in the southwestern U.S.

8. Ecologist Peter Landres was awarded by the Bureau of Land Management, National Park Service, Forest Service, and Fish and Wildlife Service for his leadership in conceptualizing and developing an interagency protocol for monitoring wilderness character.

9. The Station's annual Publications and Administration Awards went to: Best Scientific Publication – Wildlife Biologist Yvette Ortega and Research Ecologist Dean Pearson; Eminent Science Publication—Supervisory Research Wildlife Biologist Richard Reynolds and Research Forester Russell Graham; Best Technology Transfer Publication – Technical Information Specialist Kristin Zouhar, Supervisory Ecologist Jane Kapler Smith, and Research Ecologist Steve Sutherland; Visionary Science Publication – Research Forester Michael Bevers; Early Career Scientist Publication – Ecologist Sean Healey; Outstanding Customer Service – Publishing Services Group Leader Lane Eskew; Outstanding Lab Support – Program Assistant Suzette Dailey; Outstanding Program Support – Marian Lathrop; Outstanding Support (Open Category) – Program Assistant Tracie Groenier; and Customer Appreciation – retired Program Manager Durant McArthur.

10. The Station's Fort Valley Experimental Forest in Arizona received the National Weather Service's Honored Institution Award for 100 years of meteorological observations.

11. The Station received approximately 19,000 requests for publications and distributed close to 100,000 hardcopy research papers, general technical reports, proceedings, research notes, resource bulletins and other research publications. Nearly 900 publications were posted on the Station's website or on the Forest Service searchable database TreeSearch.

12. USDA Secretary Tom Vilsack and Colorado Congresswoman Betsy Markey visited Station headquarters on May 11, 2009 to learn about the Station's science programs and observe progress on the new lab facility that was under construction.

13. The Station was asked to help lead a new National Fire Decision Support Center (NFDSC), which will be located in Boise, Idaho and will provide a key link between wildland fire science development and the appropriate application of that science.

14. The Station hosted 70 scientists from the U.S., Canada, Asia, and Europe at the 41st Annual Air Pollution Workshop and Symposium, held in April 2009 in Fort Collins, Colorado.

15. Station headquarters relocated from the Natural Resources Research Center to 240 West Prospect Road in Fort Collins, Colorado.

16. Construction began on a new laboratory at Station headquarters in Fort Collins, Colorado. The new building, adjacent to the current headquarters facility, was funded in part by the American Recovery and Reinvestment Act and will house both offices and laboratories. It is scheduled to be completed by Spring 2010.

Long-term Research at Experimental Forests, Ranges and Watersheds

A unique and valuable part of the infrastructure within which we conduct research is a network of experimental forests, ranges, and watersheds. They are living laboratories where Forest Service scientists conduct studies and demonstrate research results for our stakeholders. Experimental sites are some of the few places left where ecological research can be maintained over the long term – often longer than an individual scientist's career. Experimental areas are extremely varied and are located throughout the United States and Puerto Rico.

The Rocky Mountain Research Station administers and conducts research on 14 experimental forests, ranges, and watersheds (http://www.fs.fed.us/rm/main/expfor.html). The Fort Valley Experimental Forest, located near Flagstaff, Arizona, was established in 1908, and is the site of the first Forest Service research investigations in the Nation. Following is a sampling of current work at our experimental forests and ranges.

Great Basin Experimental Range

Dr. Richard Gill (Brigham Young University) secured a Mentored Educational Grant in 2008 to "examine the interaction between grazing, drought, and temperature on plant community dynamics, plant productivity, nutrient availability, and ecosystem carbon cycles" on the Great Basin Experimental Range (GBER) in Utah. In the summer of 2009, 64 rainout shelters were installed across a full elevational gradient (mountain shrub grass to subalpine herbland communities - 6,800 to 10,000 ft. elevation) in grazed and ungrazed exclosures. Using these shelters, quantity and timing of precipitation will be modified to simulate alternate climate change senarios. Undergraduate students will be allowed to experience all phases of this mentored research program. Staff and students stayed at the Great Basin Environmental Education Center, previously the historic headquarters of the GBER, but now managed by Snow College for environmental education purposes.

Rainout shelter on the Great Basin Experimental Range.

Manitou Experimental Forest

Activities at the Manitou Experimental Forest in Colorado include:

A continuing cooperative study with the National Center for Atmospheric Research (Boulder, Colorado) on forest-atmospheric interactions involved erecting a secondary above-canopy tower to measure aerosol and trace gas exchange (The Beachon Project - http://www.tiimes.ucar.edu/beachon/).

Cooperator Dr. Brian Linkhart, using his 30-year study of flammulated owls, linked nesting date with temperature and showed that warming temperatures over the past 30 years have led to an increase of 10 days in the time of nesting (http://www.coloradocollege.edu/dept/BY/Faculty&Staff/BrianLinkhart/BrianLinkhart.htm).

In addition, research work at Manitou has received a large National Science Foundation and NOAA Grant for the study of precipitation and ecosystem function.

Weather stations provide climate and air pollution data at the Sierra Ancha Experimental Forest.

Sierra Ancha Experimental Forest

An International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests, Level II (ICP2) measurement site was established at the Sierra Ancha Experimental Forest, located in southern Arizona. It is one of eleven U.S. Forest Service Experimental Forests to receive funding for this initiative. Measurements will provide information on ponderosa pine in the South Fork of the Workman Creek watershed. Associated weather station records will provide detailed climate and air pollution data. Collection of data on vegetation has also been initiated. The ICP2 site is an addition to two existing weather stations and five gauged watersheds collecting data on streamflow at Sierra Ancha.

Tenderfoot Creek Experimental Forest

Located in northern Idaho, the Tenderfoot Creek Experimental Forest, in cooperation with the Montana State University (Bozeman) Watershed Hydrology and Biogeosciences Laboratory, is focusing research on the study of watershed hydrology (streamwater sources, flowpaths, and age); land-atmosphere CO2, H2O, and energy fluxes; watershed biogeochemistry; and hydrological / biogeochemical implications of vegetation change and forest management. Researchers employ methods that include source water tracing, physical hydrology, atmospheric flux measurements, and landscape analysis techniques. Field-based research is focused on the spatial and temporal scaling of hydrological and biogeochemical processes in watersheds and stream networks.

Science Application

Ecological Research

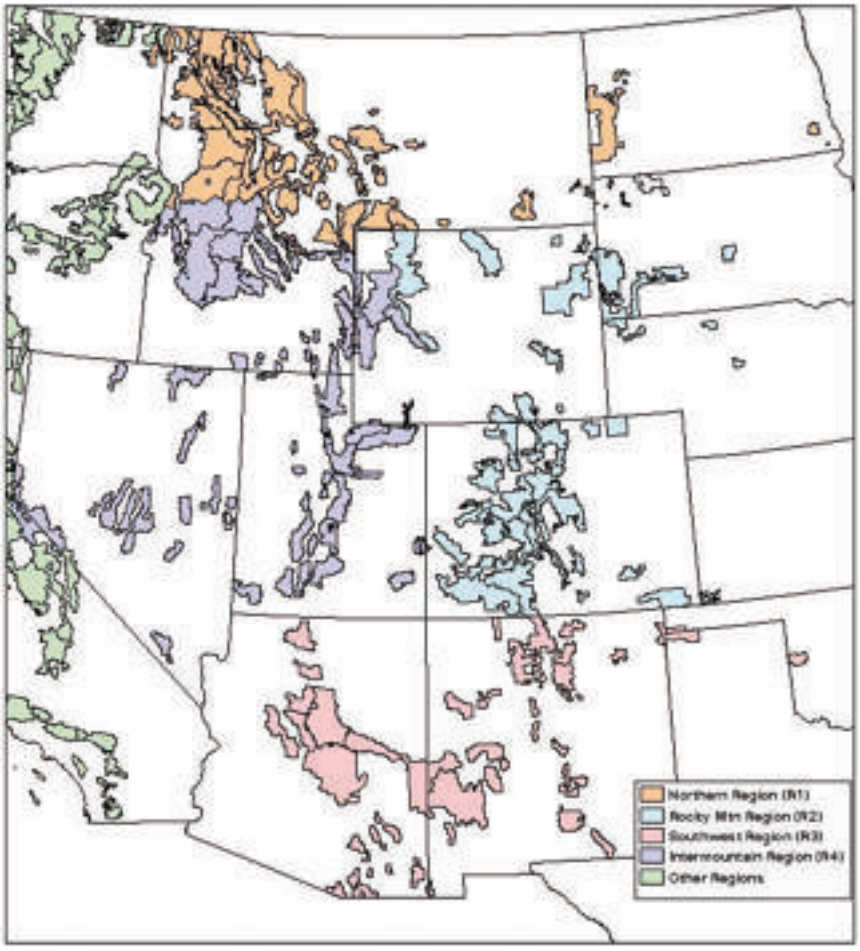
Living Laboratories

Long term

Ongoing Investigations

Research Natural Areas: Conserving Biological Diversity

The Rocky Mountain Research Station (RMRS) oversees activities on 275 Research Natural Areas (RNAs) (see map). These areas represent a variety of habitats and ecosystems from alpine ecosystems to lowlands, and from coniferous forests of the Northern Rockies to semiarid deserts of the Southwest and prairie ecosystems of the Great Plains.



The Research Natural Areas within our territory offer an unprecedented opportunity to investigate natural resources in an unspoiled and protected environment. They have been selected and managed in cooperation with the National Forest System Regions as the best possible representatives of major habitat types, or for unique ecological, botanical, geological, or hydrological features. The geographic extent ranges from the Gooding RNA 5 miles from the Mexican border to the Snowy Top RNA 100 feet from the Canadian border, and the Babbit Peak RNA on the Nevada-California state line to the Signal Hill RNA in the Sand Hills of Nebraska.

The Forest Service Research Natural Areas (RNAs) System represents a valuable ecological resource for scientists, managers and educators. The Forest Service encourages scientific and educational use of Research Natural Areas. Scientists, land managers and educators who are interested in conducting science or using RNAs for education purposes are asked to submit a request to the Rocky Mountain Research Station. Additional information is available on our website at http://rna.nris.state.mt.us/.

Recent activities within the Station's Research Natural Areas (RNA) include studies on the Boulder Creek, Lower Lost Horse Canyon, and Sawmill Creek Research Natural Areas on the Bitterroot National Forest in Montana.

At these locations, Dr. Peter T. Soule and Dr. Paul A. Knapp, professors at the Appalachian State University and the University of North Carolina, Greensboro, respectively, are studying growth responses of Douglas-fir and ponderosa pine throughout the Northern Rockies to answer several questions:

1. What is the correlation, if any, between radial growth rates, elevated atmospheric $CO_{2,}$ and increased water-use efficiency;
2. What are the radial growth rates of these species under sustained drought conditions and warmer temperatures; and
3. Are the differential responses between Douglas-fir and ponderosa pine to changing environmental conditions consistent among multiple sites that are topographically and climatologically diverse?

Because of changing atmospheric conditions, it is likely that in the forthcoming years one or more species may emerge as more competitive, thus altering the structure and composition of forests/woodlands. Given the extensive geographic range and value of Douglas-fir and ponderosa pine forests to U.S. forestry, this would have both ecological (e.g., changing composition, density, biomass and evenness) and economic implications.

Conservation Education

Station employees regularly leave their laboratories and offices to take science to people in the community. They give presentations to landowners and schools, churches, and civic groups; lead field trips for the public; help with education programs in the classroom; and contribute their expertise in museums, visitor centers, and other public forums. Employees also volunteer their time to work at a variety of Station-sponsored events that help under-served segments of society. For example:

Each year, the Station proudly participates in the **Flagstaff Festival of Science**, held in Flagstaff, Arizona. This year's 10-day Festival included star parties, open houses at observatories, tours, interactive talks, hikes, and exhibits, Science in the Park, Mountain Campus Science and Engineering Day, the Fantastic Voyage, and other popular activities to connect kids with science.

The Station is a primary sponsor and organizer of the **Annual Tu B'Shevat Festival** in Scottsdale, Arizona. Tu B'Shevat is the "Birthday of the Trees" in Israel. The event reflects cooperation between the Forest Service and the Jewish National Fund, which is responsible for forestry and land development in Israel.

The Station annually hosts, co-hosts or participates in a variety of camps, conferences and other events aimed at introducing students and minority youth to Forest Service programs. These include the **Hispanic Natural Resources Career Camp**, held annually to introduce high school students to natural resource subjects such as hydrology, forestry, wildlife, entomology, climate, and forest surveying.

In Boise, Idaho, Station scientists are involved in **Salmon Days**, an annual event that teaches kids about the Idaho Salmon and what they go through to survive the trip from the ocean to their freshwater homes. Boise scientists also participate in the "**Kids in the Creek**" program that introduces students, teachers and parents to the critters that are found in the local river.

Students learn about bird nests at the Flagstaff Festival of Science.

In 2009, through its Conservation Education Program, the Station funded ($14,000) the following projects: 1) Class in the Creek, 2) Green Kids at a Greenhouse, 3) Outdoor Laboratory at Manitou Experimental Forest, 4) Priest River Experimental Forest Interpretive Trail Signing, 5) Showcase the Science of Wildland Fire at the Montana Education Association, Montana Federation of Teachers Conference, 6) High Elevation White Pine website (www.fs.fed.us/rm/highelevationwhitepines), 7) Conservation Genetics, 8) Kids for Carnivores webpage (www.athensguy.com/explorecarnivores), and 9) Boise River Sweep.

Scientists worked with students during an Earth Day Festival in New Mexico.

Introduction to Programs

Education

Environmental Issues

Inspire & Engage

Science and Wise Resource Management

Scientists and support personnel with the Rocky Mountain Research Station work to efficiently and effectively increase the understanding of Interior West ecosystems and management strategies, and provide the best service and tools possible to our customers. To help focus our strategy, formulate budgets, and enhance our collaboration with stakeholders, our research is organized under seven Science Program Areas and the Science Application and Integration unit.

1. Air, Water and Aquatic Environments
2. Fire, Fuel and Smoke
3. Forest and Woodland Ecosystems
4. Grassland, Shrubland and Desert Ecosystems
5. Human Dimensions
6. Inventory and Monitoring
7. Wildlife and Terrestrial Ecosystems
8. Science Application and Integration

The following pages introduce each of our Science Program Areas, highlight just a few of the many studies underway throughout our 12-state territory, and showcase how our science is making a difference throughout the world. For a more comprehensive look at what we do at the Rocky Mountain Research Station, please visit our website at www.fs.fed.us/rmrs.

(Photo by Lisa Parresol)

Research results help people understand natural processes and how human management and other interventions impact these critical resources.

Air, Water, and Aquatic Environments

Air quality, water quality and availability, and aquatic habitats are critical issues within the rapidly changing western United States. Program scientists develop knowledge and science applications related to air and water quality, as well as habitat quality, distribution, diversity, and persistence of fish and other aquatic species. Research results help people understand natural processes and how human management and other interventions impact these critical resources. Additional information can be found at http://www.fs.fed.us/rmrs/research/programs/air-water-aquatics.

(photo by Lisa Parresol)

Motorized Recreation Management Strategies for Public Lands

The primary recreational use of the nation's National Forests is "Driving for Pleasure," followed closely by car camping. Whether from automobiles or all terrain vehicles (ATVs), America's desire to experience the mountains and forests from the comfort of their vehicles appears unabated. However, in some popular locations, this love of place has resulted in resource damage.

The Forest Service has a goal of creating Travel Management Plans for all National Forests by the end of 2009 to allow motorized recreation as a managed multiple use, while limiting resource damage. One of the requirements for management is understanding how resource damage occurs. Working with the Ouachita National Forest in Arkansas, Station scientists conducted a study of ATV resource damage to assist in the preparation of their Travel Management Plan. This is the eighth state across the U.S. in which the Station has conducted an ATV resource damage study.

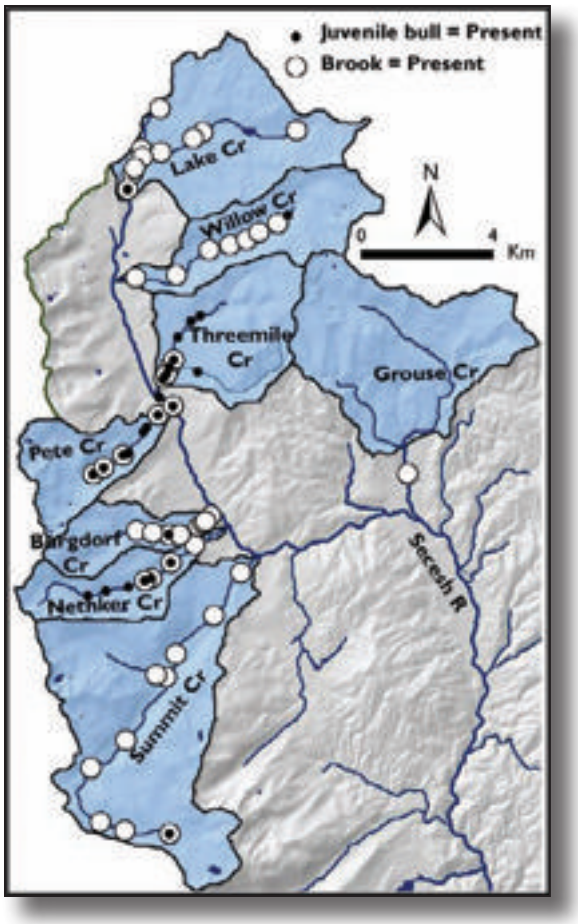
In cooperation with the Agency's San Dimas Technology and Development Center (SDTDC), the Station published the results of five years of work on techniques to estimate resource damage and management strategies to reduce damage while allowing for multiple uses of public lands. In 2009 SDTDC and the Station began working with the Environmental Protection Agency to identify effective management strategies to limit resource damage from ATV and other Off Highway Vehicles. The expected outcome of these efforts are effective, science based management strategies to allow motorized recreation on public lands while simultaneously limiting resource damage.

For more information, see: "Effects of All Terrain Vehicles on Forested Lands and Grasslands," in *Recreation Management*, 0823 1811-SDTDC, San Dimas, CA; and www.fs.fed.us/eng/pubs/pdf/hi_res/08231811hi.pdf.

Station researchers sample runoff from a rainfall simulator to determine resource damage on an ATV trail in Montana. (photo by B. Kopyscianski)

Monitoring Bull Trout Populations

Bull trout are native to much of the Pacific Northwest, but population declines associated with habitat degradation, invasive species, and overharvest have prompted listing under the Endangered Species Act. As part of the recovery process, monitoring to determine population status and trend is required, but limited budgets and potentially expansive habitats on remote Forest Service lands required a protocol that could be applied rapidly and inexpensively.



Distributions of bull trout and invasive brook trout at randomly selected locations within eight suitable habitat patches in a stream network on the Payette National Forest, Idaho.

Most monitoring protocols have traditionally focused on tracking site level abundance, but these approaches are often costly to apply and are being replaced in many instances by distributional monitoring techniques. Distributional monitoring focuses primarily on temporal patterns of occurrence within areas of suitable habitat and requires less intense sampling at individual sites, thereby making it possible to sample larger and more representative areas relevant to land managers.

Station scientists have adapted existing distributional monitoring techniques to bull trout via: 1) stream network delineation using automated GIS routines; 2) stratification of the stream network into suitable/unsuitable habitats based on ecological criteria; 3) selection of random sampling sites within suitable habitats; 4) sampling to determine bull trout occurrence within suitable habitats; and 5) resampling at regular intervals to assess potential changes in distribution within and among suitable habitats.

A pilot project successfully tested field application of the protocol in 2006 on the Payette National Forest, and similar monitoring protocols are being applied by the Boise and Sawtooth National Forests, where bull trout is a Management Indicator Species. Although the protocol was developed specifically for bull trout, it could easily be adapted to other headwater fish species by applying different ecological criteria for habitat designations.

More information is available in *A Watershed-Scale Monitoring Protocol for Bull Trout*, General Technical Report RMRS-GTR-224, available from the Rocky Mountain Research Station.

Evaluations of Large Wood in Streams Following Wildfire

Large wood is a key component of stream channel structure and aquatic habitat, influencing flow, bank stability, sediment storage, and channel form in small streams. The presence and movement of large wood can both enhance and destabilize channels. Wildfire can be an important source of wood in streams, but limited information exists on the introduction and movement of wood following burning in riparian environments.

Changes in large wood are being monitored through tagging and repeat surveys following a wildfire that burned in 2000 at a site in Northwestern Wyoming. Results show little change in the number of pieces or movement of wood during the first 3 years post-fire, and the channel maintained a largely stable form. Over time, as burned wood began to decay and fall, inputs from riparian areas increased, essentially doubling and tripling the number of pieces of wood in the channel. Observed channel changes associated with the introduction of new wood include: 1) increase in the size and number of wood jams; 2) deposition of sediment behind jams; 3) forced channel movement within the floodplain; 4) erosion of channel banks and terraces where wood re-directed flow toward the bank; and 5) new sources of sediment due to bank and channel bed erosion. Studies such as this not only document the fate of input of large wood into streams, but also provide insight into the longer-term geomorphic impacts of wildland fire.

Learn more in: "Large Instream Wood Studies: A Call for Common Metrics," in *Earth Surface Processes and Landforms* (in press); and "Large Wood Dynamics in Streams Following Wildfire and its Subsequent Impact on Channel Morphology at Little Granite Creek, Wyoming," in *Geomorphology and Vegetation: Interactions, Dependencies, and Feedback Loops*, 40th Annual Binghamton Geomorphology Symposium, October 2-4, Blacksburg, Virginia.

Large wood is a key component of stream channel structure and aquatic habitat.

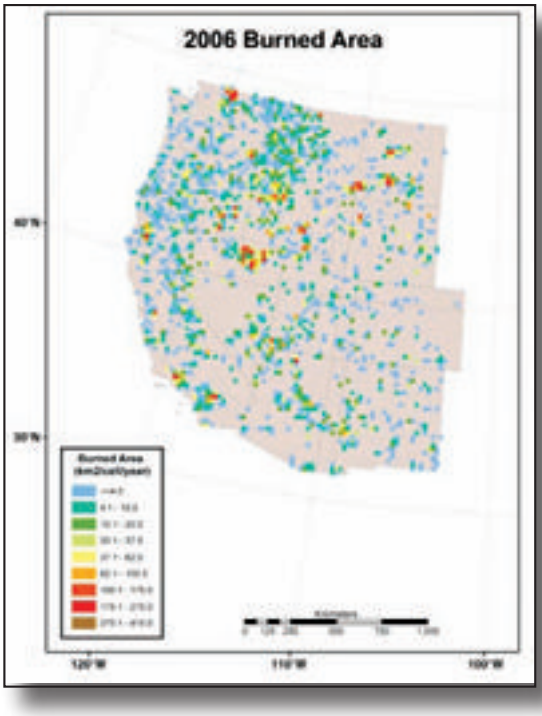
Fire, Fuel, and Smoke

Scientists with this program conduct both fundamental and applied research relating to wildland fire processes, fire behavior, the effects of fire on ecosystems and the atmosphere, and how ecosystems adapt to fire. Their mission is to improve the safety and effectiveness of fire management by creating and disseminating basic fire science knowledge, tools, and applications for scientists and managers. Find out more about this program at http://www.fs.fed.us/rmrs/research/programs/fire-fuels-smoke and www.firelab.org.

Burned Area Mapping Algorithm Supports Air Quality Forecasting

Heightened concern over the human health impacts of poor air quality and an emerging focus on global climate change are increasing the regulatory attention to smoke emissions from wildland fire. Recent revisions of federal air quality standards and impending efforts to regulate the emissions of greenhouse gases and black carbon have intensified the pressure on both land management and air regulatory agencies to address wildland fire emissions. Improved fire emission inventory methods are essential for assessing the contribution of wildland fire to air pollution and national greenhouse gas emissions. The development of emission inventories depends on burned area as a critical input. Station scientists have developed and evaluated a satellite burned area mapping algorithm to support air quality forecasting and emission inventory development.

The algorithm's fire detection rate and burned area mapping were evaluated using fire perimeter data and burn scar information derived from high resolution satellite imagery. The algorithm detected 87% of all reference fires > 4 km^2. Fires in this size range account for a substantial portion of burned area in the western U.S. (77% of burned area is due to fires >50 km^2). The dominance of these large wildfires in burned area, duration, and emissions makes these events a significant concern of land managers, air regulators, and air quality forecasters.



Annual burned area measured with the Missoula Fire Sciences Laboratory satellite burned area mapping algorithm.

The burned area data is being used to develop wildland fire emission inventories. Expected outcomes facilitated by this research include: 1) improved state compliance with federal air quality standards; 2) improved forecasting of air quality; and 3) feasible strategies for improving visibility in National Forests, Wilderness Areas, and Parks. The study will soon be published in *Remote Sensing of Environment* (http://dx.doi.org/10.1016/j.rse.2009.07.007).

Restoring Whitebark Pine Forests

Whitebark pine is declining across much of its range in North America because of the combined effects of mountain pine beetle epidemics, fire exclusion policies, and most importantly, widespread exotic blister rust infections. A comprehensive study was initiated in 1993 to investigate the effects of various restoration treatments on tree mortality, regeneration, and vascular plant response on five sites in the northern Rocky Mountains. The objective was to enhance whitebark pine regeneration and cone production using treatments that emulate the historical fire regime.

A classic whitebark pine stand in the Northern Rockies.

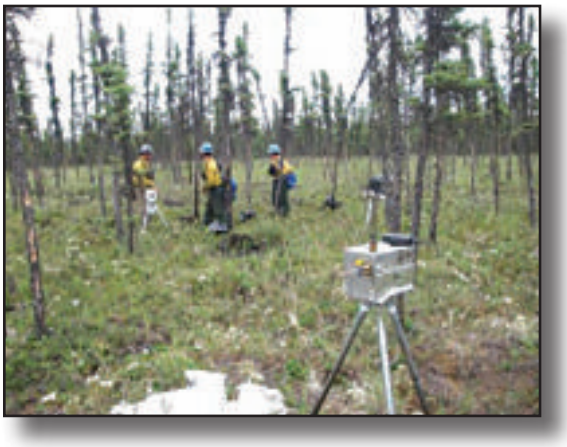
Results from this study are presented in a management guide that summarizes the extensive data collected on these research sites at the treatment unit level for three measurement periods: (1) pre-treatment, (2) 1-year post-treatment, and (3) 5-years post-treatment (one site has a 10-year post-treatment measurement). This guide is intended as a general reference to identify possible effects of whitebark pine restoration treatments at a local scale. To use this guide, managers simply match the conditions of the treatment and site to similar stratifications within the guide by first matching the proposed treatment to the fire severity regime it is supposed to mimic and, next, matching the site to the sites in the guide. Managers can then reference the effects of the treatments and use these effects to craft cutting and prescribed burning prescriptions to achieve management objectives. Each treatment unit summary has a static format that includes paired photographs, treatment effect tables, and bar charts.

In this study, scientists found that, while all treatments that included prescribed fire created suitable nutcracker caching habitat with many birds observed caching whitebark pine seed in the burned areas, there has yet to be significant regeneration in whitebark pine. All burn treatments resulted in high mortality in both whitebark pine and subalpine fir (>40%). Fine woody fuel loadings marginally decreased after fire, but coarse woody debris more than doubled because of falling snags. Vascular species decreased in cover by 20 to 80% and remained low for five years. While the treatments were successful in creating conditions that favor whitebark pine regeneration, the high level of blister rust mortality in surrounding seed sources has reduced available seed which then forced the nutcracker to reclaim most of the cached seed. Manual planting of whitebark pine seedlings is required to adequately restore these sites. Information from this study can be used to restore an important yet declining whitebark pine ecosystem.

Find out more in *Management Guide to Ecosystem Restoration Treatments: Whitebark Pine Forests of the Northern Rocky Mountains*, General Technical Report RMRS-GTR-232, available from the Rocky Mountain Research Station; and "Restoring Whitebark Pine Ecosystems in the Northern Rocky Mountains," in *Ecological Restoration* (in press).

Quantifying Fire Behavior and Intensity in Alaska's Interior

Concerns about a growing wildland-urban interface (WUI) and the potential for forest fires to burn homes and impact other resources have pushed wildland fire risk mitigation strategies to the forefront of fire management activities. Mechanical and manual fuel treatments have become the preferred strategy of many fire managers and agencies. However, few observations exist that document the actual effect of different fuel treatments on fire behavior.



Scientists install fire-proof video cameras (background next to personnel) and fire behavior flux instruments (foreground).

Station scientists, engineers, and foresters have been working closely with scientists from the Pacific Northwest Research Station, the University of Alaska in Fairbanks, and local land managers to measure the effect of different treatments on fire behavior. A research prescribed burn was conducted in June of 2009 as part of this study. The study site represents an ideal location because of its proximity to Fairbanks, existing road network, large area (550 acres) of homogenous fuels, and a current burn plan available for amendment. Three burn units were prepared, and one was burned in 2009. Each burn unit contains four fuel treatment plots (150 x 150 m) that are 8 x 8 ft thinnings pruned to 4 ft under three different fuel removal strategies: (1) haul away, (2) burn piles on site, and (3) windrow and burn on site. In addition, four shearblading treatments with and without windrowing of debris, and with and without pile burning, were prepared. Existing vegetation, including ground vegetation, understory and overstory trees and tree crowns, organic layer, and dead-down woody surface fuels, was measured before and after the burn. Researchers focused on measuring fire behavior using a combination of cameras, video, direct observations, and specially designed and built sensor packages that are capable of withstanding fire damage.

This research project builds upon and links to several other Joint Fire Science Program sponsored projects. The data and observations from this project are the first quantified tests of the effects of fuel reduction treatments on fire behavior in Alaska. Results provide the data required by fire behavior models (FARSITE, BEHAVE, and NEXUS), fuels characterization system (FCCS), and fire effects models (CONSUME). Funding for this project comes from Joint Fire Sciences, Alaska Division of Forestry, Alaska Department of Fish and Game, Bureau of Land Management, Alaska Fire Service, Bureau of Indian Affairs, and the Ruffed Grouse Society.

Forest and Woodland Ecosystems

Science helps resource managers sustain and restore the health and productivity of forest and woodland ecosystems in the West. Increasingly these areas are being impacted by human developments, uncharacteristically large and severe wildfires, insect and disease outbreaks, exotic species invasions, and severe droughts. Scientists conduct basic and applied research to help understand the function, composition, and structure of these complex ecosystems. Research results help provide sources of energy, clean water, esthetic and recreation amenities, and critical wildlife habitat. Additional information is available at http://www.fs.fed.us/rmrs/research/programs/forest-woodlands-ecosystem.

(photo by Lisa Parresol)

Gene Conservation of Threatened High-Elevation Pines

High elevation pine populations, including the ancient limber pine (*Pinus flexilis*) and Rocky Mountain bristlecone pine (*Pinus aristata*) forests, are experiencing, or are imminently threatened by, the chronic stress of the non-native disease white pine blister rust, and the acute stress of the current mountain pine beetle epidemic that is fueled by climatic warming of their mountain-top habitats. The combination of these stressors jeopardizes populations and reduces the resiliency of the forest to recover from these and other disturbances.

The mountain pine beetle is adding urgency to conservation efforts as entomologists predict that most of the reproductive limber pine will be threatened in the southern Rockies by the current epidemic, and the threat is growing in bristlecone pine forests. The Station is leading proactive efforts to collect and archive

Limber pine trees at the alpine tree line killed by mountain pine beetle.

seed and pollen from threatened populations before they are lost for: 1) ex situ genetic conservation; 2) early intervention restoration projects; 3) continued disease resistance testing studies; and 4) further research to support restoration technologies and strategies. In coordination with Forest Health Management and National Forest Systems, the Station has developed partnerships with the National Park Service, Bureau of Land Management, the non-profit Mountain Studies Institute, county governments and citizen volunteers to conserve and protect high elevation pine populations. Together, extensive seed collections for both pine species have been made across a range of habitats and land ownerships. In addition, valuable trees and populations that scientists have discovered to contain genes that provide resistance to white pine blister rust are being protected from mountain pine beetle attack.

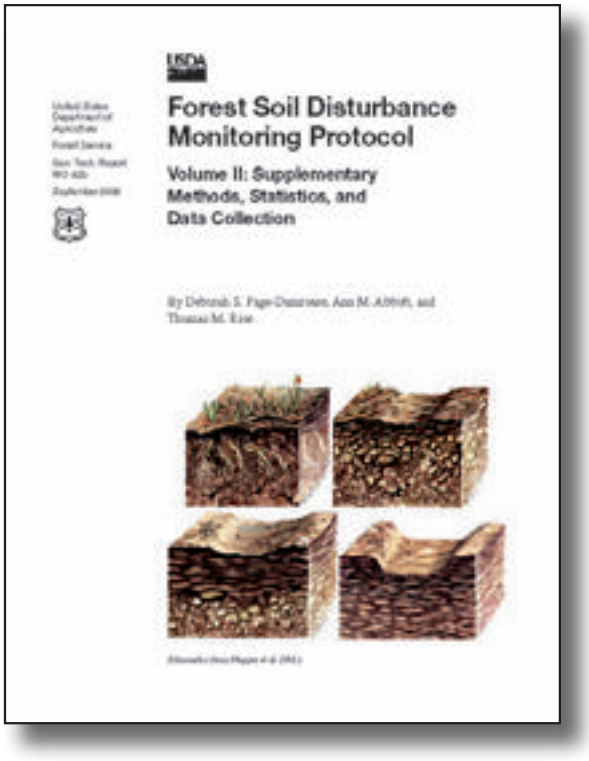
Read more about this research in "Proactive Intervention to Sustain High Elevation Pine Ecosystems Threatened by White Pine Blister Rust," in *Journal of Forest Research* 12: 327-336 (2007); "A Race Against Beetles: Conservation of Limber Pine," in *Nutcracker Notes* 14:11-12 (2008); and *Options for the Management of White Pine Blister Rust in the Rocky Mountain Region*, General Technical Report RMRS-GTR-206, available from the Rocky Mountain Research Station.

New Forest Soil Disturbance Monitoring Protocol

Since 1977, the Forest Service has used a core set of soil quality standards that establishes thresholds beyond which soil quality is considered adversely affected. However, there has been no clear science to establish blanket thresholds for disparate soil types, no clear direction on what should be monitored and how, and there has been little validation of the thresholds.

In 1988, a joint Forest Service project was undertaken to validate soil quality standards. This effort, called the North American Long-Term Soil Productivity Study, is now in its' 15th year in many locations. From this study, scientists learned that a site's productive capacity is governed strongly by site specific soil physical, chemical, and biological properties. However, the North American Long-Term Soil Productivity Study did not establish a method for consistent day-to-day soil

monitoring. Therefore, in 2004 researchers began testing various monitoring methods and establishing a statistical method that would allow soil information to be collected in an efficient, effective, and consistent way. The overall goal of a soil-based monitoring system is to assess forest sustainability and ensure that forest soils, when exposed to various forest management practices, retain or improve their capacity to maintain healthy, vigorous, and productive plant and animal communities, maintain balanced physical, biological, and chemical cycles, and maintain ecological functions of the forests. To do these things, scientists needed a monitoring protocol that could convey the change in soil properties from pre-harvest to post-harvest in a way that soil scientists could easily communicate to co-workers, district rangers, forest supervisors, or the public.



Station scientists developed a common method that describes and reports soil visual classes based on disturbance characteristics. This new protocol also gives soil scientists a more active role in planning and implementing management activities, and affords opportunities to recommend site specific treatments or meaningful thresholds that consider the proper soil function. The worksheets for this protocol can be uploaded into a portable data recorder so that sample size needed for each unit is calculated and the worksheets will automatically produce a results page with the distribution of points within each visual class. The protocol is easy to learn and can be used by summer technicians, volunteers, or part-time workers. When fully implemented across the U.S., the new Forest Soil Disturbance Monitoring Protocol will help give soil scientists the information they need to design site-appropriate mitigation, develop prescriptions to meet multiple resource objectives, and help achieve sustainable forest management by working to identify areas at risk from certain types of management.

In addition to the monitoring protocol (2 volumes), Station scientists have worked with the San Dimas Technology and Development Center to produce a picture guide (published October 2009) to the visual classes and have developed a training curriculum.

They also hosted a workshop on the Scientific Basis for Monitoring Soil on Forest and Rangelands (published in winter 2009/2010). This work has produced a soil risk-rating system. Because this protocol can be used nation-wide, there will also be a national soil monitoring database developed by the Agency's Washington, D.C. office. The last piece of the puzzle is validation of the soil disturbance classes. This monitoring protocol has been evaluated and tested by numerous researchers, international collaborators, and National Forest soil scientists before the final protocol was printed. The authors of Volume I and Volume II were recognized in 2007 as National Field Soil Scientists of the Year for their work on this protocol.

Copies of the 2-volume set: *Forest Soil Disturbance Monitoring Protocol – Volume I: Rapid Assessment*, and *Forest Soil Disturbance Monitoring Protocol – Volume II: Supplementary Methods, Statistics, and Data Collection*, General Technical Reports WO-82a and 82b, respectively, are available online at http://forest.moscowfsl.wsu.edu/smp/solo/documents/research_pubs.php and from the Rocky Mountain Research Station.

Fuel Treatments, Fire Suppression and Their Interactions With Wildfire

During the summer of 2007, wildfires burned over 500,000 acres within central Idaho. These fires burned around and through over 8,000 acres of fuel treatments designed to offer protection from wildfire to over 70 summer homes and other buildings located near Warm Lake. This area east of Cascade, Idaho, exemplifies the difficulty of designing and implementing fuel treatments in the many remote wildland urban interface settings that occur throughout the western United States. The Boise National Forest asked the Station to take a critical look at how $1.6 million in fuel treatments performed during one of the most intense and severe wildfire seasons of recent memory.

The Cascade Complex of wildfires burned for weeks, resisted control, and were driven by strong dry winds and burned tinder dry forests, but only burned two rustic cabins. This outcome was largely due to the existence of the fuel treatments and how they interacted with suppression activities. The areas treated with prescribed fire and mechanical thinning provided locations where firefighters could build fire lines and burn surface fuels in advance of the wildfires. They also provided firefighter safety zones and allowed firefighters to extinguish spot fires near homes. In addition, the location and presence of the treated areas influenced the overall firefighting strategies. Wildfire intensity was less in areas that were treated, and more green vegetation and unburned forest floor occurred within the areas where the fuels had been treated, compared to neighboring areas that were not treated. The strategically placed fuel treatments disrupted the progress of the fires but did not slow the spread of the fires or appreciably decrease their size. This work is additive and complementary to other studies scientists have completed showing how forest structure and composition influences both wildfire intensity and burn severity.

The North Fork fire burned intensely as it moved through an area where the fuels had been mechanically treated.

This body of work has impacted site-specific fuel treatment prescriptions to the Healthy Forest Restoration Act. Even though just published, the Warm Lake work has been used in discussions on how forests should be treated in the roadless areas of Colorado. Because forest structure and fuel treatments are integral to the discussions about forest and wildfire management, especially in the wildland urban interface, several of these publications are frequently cited (40 to over 200 times) in other scholarly literature and in land use planning documents.

For additional information, see *Fuel Treatments, Suppression, and their Interaction with Wildfire and its Impacts: The Warm Lake Experience During the Cascade Complex of Wildfires in Central Idaho, 2007*, General Technical Report RMRS-GTR-229; *Hayman Fire Case Study*, General Technical Report RMRS-GTR-114; and *Science Basis for Changing Forest Structure to Modify Wildfire Behavior and Severity*, General Technical Report RMRS-GTR-120, all available from the Rocky Mountain Research Station.

Grassland, Shrubland, and Desert Ecosystems

This program develops and delivers scientific knowledge, technology, and tools that help to understand, restore, and sustain grasslands, shrublands, and deserts under increasing threats from expanding human-related uses, invasive species, changing disturbance patterns, and climate changes. Studies focus on understanding the effects of natural and human-caused disturbances on grasslands, shrublands, deserts, and associated riparian ecosystems; developing tools, techniques, and plant materials to evaluate and manage the spread of invasive plants, and to restore disturbed uplands and riparian areas; developing knowledge and tools to manage and sustain ecosystems to provide ecosystem services and wildlife habitat; and creating a better understanding of how climate change affects grassland, shrubland, and desert flora and fauna. Learn more at www.fs.fed.us/rmrs/research/programs/grassland-shrubland-desert.

Lupines Influence Nitrogen Availability and Plant Invasion in Sagebrush Ecosystems

In semi-arid sagebrush ecosystems, availability of resources like nitrogen is a primary factor determining plant invasion success. Nitrogen fixing plant species, primarily native legumes, are often relatively abundant in sagebrush ecosystems and can contribute nitrogen that that helps maintain native species diversity and productivity. However, if a non-native species is present, nitrogen from legumes can create conditions favorable for invasion. Silver lupine (*Lupinus argenteus*) is abundant in mid-high elevation areas of western North America, and is one of the most common native legumes in sagebrush ecosystems.

Station scientists recently examined the influence of silver lupine on resource availability in sagebrush ecosystems and the implications for invasion with a field survey, a greenhouse study, and a manipulative field experiment.

In the field survey, researchers examined the effects of prescribed fire in the central Great Basin, Nevada, on silver lupine and the effects of silver lupine presence and prescribed fire on soil nitrogen and on neighboring plants. The survey included three conditions – 1 year post-burn, 3 years post-burn, and unburned control. Results show higher soil nitrogen and cover of perennial grasses and forbs in silver lupine presence, indicating that silver lupine can influence post-fire succession through environment modification.

Native legumes such as silver lupine are some of the first species to return after fire.

In a greenhouse experiment, nitrogen contribution by silver lupine under three levels of water and four levels of nitrogen were evaluated. Findings show that silver lupine contributes substantial amounts of nitrogen through root exudation while actively growing and through decomposition of nitrogen-rich tissue after aging. The ability of silver lupine to affect nitrogen availability and cycling indicates that it has the potential to significantly influence nitrogen budgets and community composition within the sagebrush steppe.

In a field experiment on the east face of the Sierra Nevada foothills, researchers investigated whether silver lupine is able to facilitate seedling establishment in unburned and burned sagebrush steppe communities. Treatments evaluated specific mechanisms by which silver lupine likely influences establishment. They examined treatment effects on environmental variables (soil nitrogen, soil moisture, soil temperature, and light) and seedling establishment of the native perennial grass squirrel tail, native perennial forb sulfur buckwheat, and non-native invasive annual cheatgrass.

Results show that silver lupine facilitates seedling establishment of native and non-native species through modification of nutrients, light, and temperature. In unburned communities, increased nitrogen availability from decomposing lupine tissue results in higher survival, plant size, and seed production for cheatgrass. In contrast, in burned communities fire masks the effect of nitrogen augmentation, and modification of the physical environment became more important.

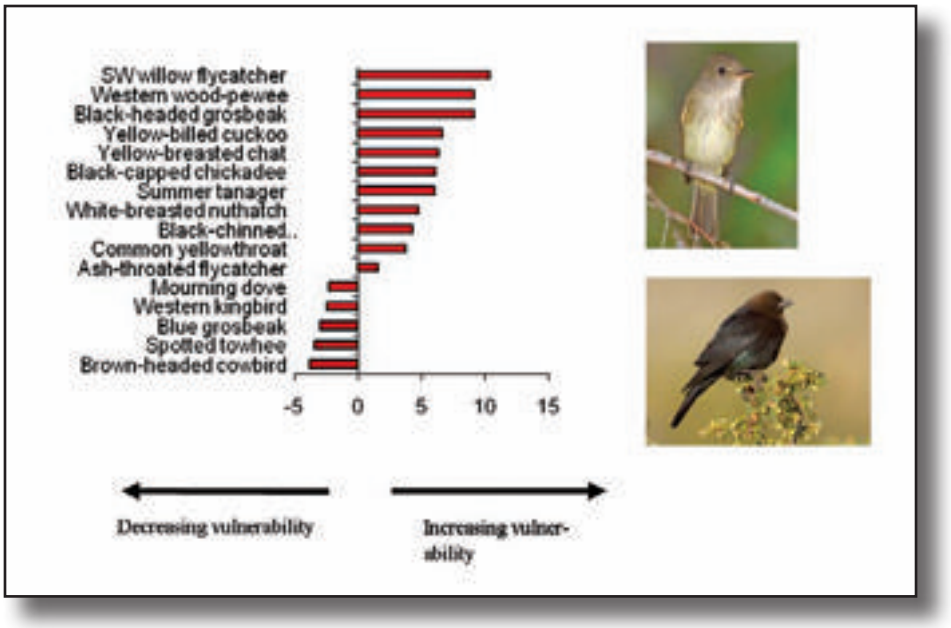
These studies indicate that silver lupine has the potential to modify sagebrush ecosystems at multiple levels – nitrogen availability and cycling and recruitment of both native and non-native species. This research also has implications for management of sagebrush ecosystems. The ability of silver lupine to increase nitrogen availability can promote resilience of native ecosystems, but it also may create an avenue for invasion. In burned communities, silver lupine appears to affect plant composition by rapid establishment following fire and facilitating particular plant species. Silver lupine can replace nitrogen that is lost to fire, and it initially may promote regrowth and establishment of native perennial grasses and forbs, thereby enhancing ecosystem resilience. However, silver lupine also may create localized patches of increased nitrogen that favor establishment of cheatgrass. Communities with well-established perennial grasses and forbs are not as susceptible to cheatgrass invasion because of greater competitive ability of adult perennial plants. However, in the absence of perennial herbaceous vegetation, such as occurs in heavily grazed areas, increased nitrogen availability associated with silver lupine may promote replacement of natives via the enhanced competitive ability of cheatgrass.

More information on this study can be found in "Effects of Water and Nitrogen Availability on Nitrogen Contribution by the Native Sagebrush Legume, *Lupinus argenteus Pursh*," in *Applied Soil Ecology* 42: 200-208; and "Influence of a Native Legume on Soil N and Plant Response Following Prescribed Fire in Sagebrush Steppe," in *International Journal of Wildland Fire* (in press).

Assessing Species Vulnerability to Climate Change

Global climate change is an increasingly critical issue for wildlife and wildland resource managers. The southwestern U.S. is predicted to experience higher temperatures, reduced precipitation, and an increase in the frequency and duration of droughts. These changes are expected to lead to losses in biodiversity and will add to pre-existing concerns for resource managers. Unfortunately, relatively few strategies have been proposed to guide managers in assessing what species may be most at risk, which is the critical first step in developing possible solutions to conserving biodiversity.

The Forest Service National Global Change Strategy identifies the need to develop adaptation and mitigation strategies for land managers to synthesize potential vulnerabilities and ecosystem responses to a changing climate. Station scientists developed a tool for assessing species' vulnerability to climate change. By applying the tool to species of interest or concern, this work will help guide resource management action to deal with potential loss of biodiversity due to climate change effects. Partners involved in the vulnerability assessment include the Forest Service's Southwest Region, U.S. Fish and Wildlife Service, Department of Defense,



Vulnerability scores of bird species in the Middle Rio Grande Bosque (New Mexico). Vulnerability is the result of various aspects of a species' biology. Here, the Southwestern willow flycatcher (top photo) shows the highest vulnerability, whereas the brown-headed cowbird (bottom photo) shows the least. (photos by Mark Chappell)

The Nature Conservancy, National Wildlife Federation, University of Arizona, Arizona State University, and others.

The vulnerability assessment tool is based on biological traits that fall within four broad categories: 1) habitat requirements; 2) physiological characteristics; 3) phenological responses; and 4) biotic interactions. Habitat issues include loss or shift in required vegetation or features needed for nesting and reproduction. Physiological traits consider the inherent limitations of each species to temperature extremes and extreme weather events such as prolonged droughts. Phenology regards the seasonal timing of species activities such as breeding or migration in relation to the timing of critical resource pulses. Biotic interactions include the potential changes in prey, predator, and disease species. To develop a tool for use by a broad spectrum of resource managers, biological traits were chosen that relate to increased species risk to climate change effects. These traits were then incorporated into a survey consisting of a series of questions, which, upon completion, generates a score that quantifies overall species vulnerability to climate change. These scores can then be used to rank species by vulnerability score, or to assess the relative importance of each of the categories in determining individual species vulnerability.

The tool has already been used to assess species for case studies for a Nature Conservancy workshop regarding climate change effects in the Jemez Mountains of New Mexico. Ongoing efforts include a comprehensive assessment of the terrestrial vertebrate species of the Middle Rio Grande Bosque of New Mexico, with plans for the development of a web-based version of the tool for use by managers. The tool is also being used to assess plant and animal species of concern on Department of Defense lands and on the Coronado National Forest in southern Arizona, in order to prioritize species for management action and identify specific management intervention points.

Initial results show distinct patterns of vulnerability among taxa. Bat species are most sensitive to climate mediated changes in food resources, whereas amphibian species are more affected by habitat related issues such as loss of ephemeral breeding ponds, pointing to specific conservation strategies for each group. Assessments of the bird species within the Middle Rio Grande Bosque shows that the threatened southwestern willow flycatcher is most vulnerable in future climate scenarios, whereas the brown-headed cowbird, a species whose range is already

expanding in the western U.S., is quite resilient to climate change affects. Thus, the vulnerability assessment tool can identify additional risks for a rare species and the potential for future conditions to favor the increased expansion of a relatively common species. Alternatively, the tool is useful to identify species which are currently common but may become rare.

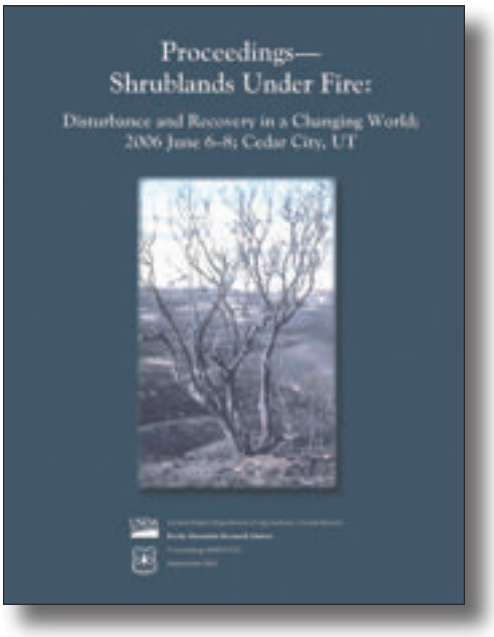
Scores obtained from the tool provide a means for managers to incorporate climate change affects into their management action plans. Guidelines produced from ongoing case studies will outline options and strategies for species management. The web-based application of the tool will allow biologists to apply the tool to species that occur in other management areas throughout the Southwest and beyond.

Vulnerability assessment presentations and climate change symposia have been given at annual and regional meetings of the Society for Ecological Restoration International, the Cooper Ornithological Society, Native American Fish and Wildlife Society, and at workshops hosted by The Nature Conservancy, Forest Guild, Region 3 Biologists, and the Bosque Improvement Group.

For more information, refer to Cooper Ornithological Society 79th Annual Meeting, April 16-18, 2009: "Climate Change: Consequences for Birds," http://www.birdmeetings.org/COS2009/sessionschedule.asp?SessionID=S04&filter=0; "Overview of Climate Change Effects on Birds," http://www.birdmeetings.org/COS2009/viewabstract2.asp?AbstractID=5228; and "Developing a Tool to Predict Species' Vulnerability to Climate Change," http://www.birdmeetings.org/COS2009/viewabstract2.asp?AbstractID=5143.

Wildland Shrub Symposium Addresses Shrubland Threats

Patterns of disturbance and recovery shape the composition and stability of all ecosystems, including shrublands, and are regulated by both natural (such as climate) and human-caused (such as livestock grazing) processes. Although these processes vary naturally, rapid or long-lasting changes in either patterns of disturbance or in pathways of recovery may result in ecosystem degradation. Humans affect shrublands by altering natural patterns of disturbance, creating new disturbances, and altering recovery. Over time, the nature and magnitude of human-caused impacts on shrublands have reflected changes in the values associated with shrub-dominated landscapes and in our capacity to enact change. Worldwide, shrub-dominated ecosystems are increasingly at risk of degradation as human-related impacts increase and natural patterns of disturbance and recovery cease to function due to the effects of climate change, changes in natural fire patterns, invasive weeds, conversion of wild shrublands to other uses such as agriculture, etc.



Shrublands are under fire, and the shrublands of western North America are no exception. Proactive measures to reduce losses to shrubland ecosystems must include the development of scientifically sound strategies and practices for restoration and rehabilitation. The development and application of these strategies and practices requires adaptive approaches as the world continues to change.

The Station helped organize the Symposium "Shrublands Under Fire: Disturbance and Recovery in a Changing World," held in Cedar City, Utah. Approximately 130 researchers, managers, and students had the opportunity to exchange research results, identify needs and explore strategies related to the subthemes: 1) Invasive Species and Shrublands, 2) Shrubland Community Dynamics and Restoration, and 3) Fire Recovery in Shrublands. The symposium was one of a series sponsored by the Shrub Research Consortium, a group of 25 universities, government agencies, and private companies with a common interest in shrubland ecology.

Proceedings from the symposium have been published and are available in *Proceedings – Shrublands Under Fire: Disturbance and Recovery in a Changing World*, Proceedings RMRS-P-52, available from the Rocky Mountain Research Station.

Human Dimensions

This program provides social and economic science-based innovation to human societies as they develop a sustainable relationship with their environment. Major issues confronting societies across the globe, such as global climate change, energy, fire, and water, all have important social and economic dimensions that are explored and addressed by this Program. Scientists also work to improve firefighter and public safety, reduce large fire costs, and expand the treatment of hazardous fuels for watershed restoration that is strategic, cost-effective, and socially acceptable. Additional information is at http://www.fs.fed.us/rmrs/research/programs/social-economics-decision.

Economics of In-Woods Fast Pyrolysis

In the Western United States there are millions of acres of accessible forest land that could benefit from mechanical fuel treatments to improve forest health and reduce hazardous fuels and the potential for severe wildfires. These treatments have the potential to produce large volumes of forest residues, including small trees, and tops and limbs of larger trees. Piling and burning of this residue is common practice. However, with increasing concerns about energy security, high oil prices, climate change, air quality and nutrient depletion, there is great interest in opportunities to utilize these forest residues as a renewable energy source and as an amendment to enhance soil productivity.

One exciting opportunity is in-woods pyrolysis. Pyrolysis is a chemical decomposition process that occurs at high temperatures. When forest biomass is heated rapidly to between about 850 and 1000 degrees Fahrenheit, the biomass decomposes into bio-char and syngas. Much of the syngas can be condensed into bio-oil, which can be burned as a direct substitute for fuel oil, or further refined into liquid transportation fuel and other high value products. Bio-char is equivalent to charcoal produced in forest fires and can enhance soil organic matter content, nutrient cycling, and nutrient and water holding capacity. The syngas that is not condensed into bio-oil can be burned to generate energy, just like natural gases such as propane. The potential to generate these

A mobile in-woods fast pyrolysis unit used for demonstration purposes.

products from forest residues with portable pyrolysis units in the woods appears to be desirable from environmental and economic perspectives. While the ecological and socio-economic costs and benefits of in-woods fast pyrolysis have not yet been fully determined, a financial assessment of in-woods pyrolysis from a private investor's perspective is complete.

Station scientists, in cooperation with Montana State University, developed a financial analysis of an in-woods portable pyrolysis plant capable of utilizing 22 bone dry tons (BDT, 0% moisture content in the biomass) of forest residues in a 12-hour work day. The plant and necessary equipment (e.g. a loader and storage tanks for the bio-oil) are estimated to cost $3.46 million. The analysis assumes 60% of this investment will be borrowed at an interest rate of 9% for 7 years, and the plant will operate 329 days per year over a 10-year operating life. Three employees are needed to operate the plant at a cost of $28.35/hour per employee, including wages and benefits. The plant will be located near on-going harvesting operations, move twice per year and purchase chipped forest residues for $33/BDT. Allowances have been made for annual maintenance, repairs, insurance and the costs of delivering bio-oil and bio-char to markets. Much of the plant's energy requirement is supplied by burning the syngas produced; however, the analysis does include an allowance for the purchase of some propane gas.

Output as a percentage of input mass is 57.5% bio-oil, 27.5% bio-char and 15% syngas. The pyrolysis plant will produce 788,560 gallons of bio-oil and 2,178 tons of bio-char for sale each year. Based on average #2 fuel oil prices over the period January 2008 to June 2009 and adjusting for the energy content of bio-oil relative to fuel oil, a price of $1.38/gallon was adopted for bio-oil. A price of $150/ton has been assumed for bio-char, which is its energy equivalent value if burned like coal. Standard federal and Oregon state company income taxes have been accommodated in the analysis.

The first row in the table highlights the financial performance of the in-woods mobile pyrolysis plant given these assumptions. The internal rate of return indicates that an investor could make 5.4% on invested funds. The average annual after tax cash flow is $66,000 and the investment of capital by the entrepreneur is paid back by the pyrolysis plant in the ninth year of operation. The second row of the table indicates that with fuel oil prices (and bio-oil energy equivalent prices) closer to where they were in August 2009, the pyrolysis plant is not a sound investment. However, if fuel oil prices return to the levels they were at in the summer of 2008 (row 3), or bio-char can be sold in horticultural markets at $250/ton (row 4), in-woods pyrolysis could represent an attractive investment opportunity.

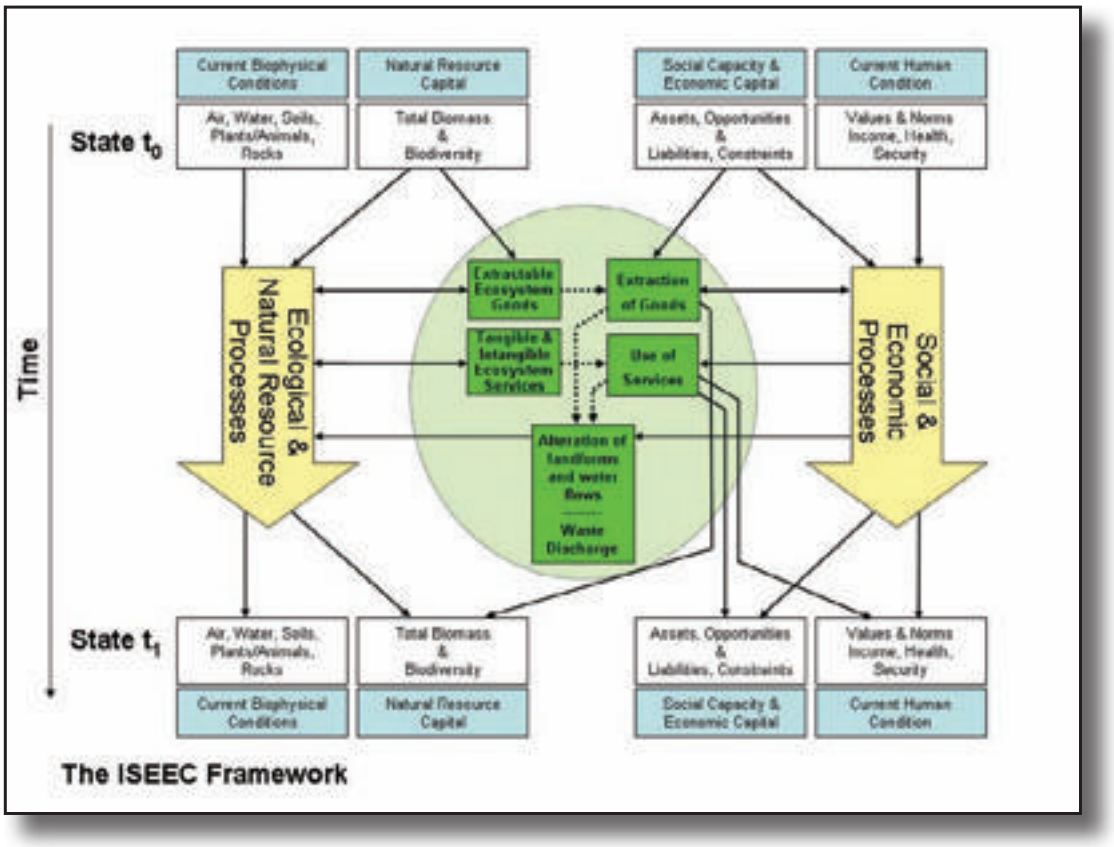
	Prices			After-tax returns		
	# 2 fuel oil ($/gal)	Bio-oil ($/gal)	Bio-char ($/ton)	Internal rate of return (%)	Average annual cash flow ($)	Pay-back period (years)
(1)	2.67	1.38	150	5.4	66,000	9
(2)	2.16	1.12	150	–6.1	–81,000	>10
(3)	3.18	1.65	150	14.2	175,000	8
(4)	2.67	1.38	250	14.6	181,000	8

These results were presented at four well-attended fast pyrolysis demonstrations held in Oregon in August 2009. Ongoing pyrolysis research is assessing the role this process can play in mitigating climate change, reducing carbon emissions in the United States and generating carbon credits, and evaluating the potential for bio-char as a soil amendment. This information is needed to inform both natural resource and energy policy-makers, as well as potential bioenergy investors.

An Integrated Framework for Considering Rangeland Sustainability

RMRS scientists, in collaboration with the Sustainable Rangelands Roundtable (http://sustainablerangelands.warnercnr.colostate.edu/), developed the "Integrated Social, Economic, and Ecologic Conceptual (ISEEC) Framework" in the context of identifying indicators of rangeland sustainability.

Ecological systems and processes provide the biological interactions underlying ecosystem health and resilience. Social and economic infrastructures and processes provide the context in which rangeland use and management occurs and in which ecosystem health and resilience improve or deteriorate. The premise of the framework is that all these systems and processes interact and affect one another. The ISEEC Framework proposes that ecosystem goods and services (EGS) act as an interface by which ecological systems and processes affect and are affected by social and economic systems and processes.



Consider the applicability of the ISEEC Framework in the context of potential energy resource development. Energy development is stimulated by economic demand. First, the energy resource must be extracted. In the case of oil and gas, wells must be drilled and an infrastructure for transport put in place. For wind or solar power, equipment must be installed and connectivity to the electricity grid must be provided. Roads, pipelines, and/or transmission lines are likely to be built, resulting in altered landforms and habitat change. The maintenance of roads and equipment results in more intense human presence, which might imply land fragmentation or further changes in habitat.

Changes in development provoke responses in ecological processes and lead to altered ecological states. Changes in ecosystem services, as perceived and experienced by people, provoke responses in social and economic processes. There might be management or regulatory responses, for example, in an attempt to alter people's behavior by changing incentive structures to encourage less pollution or more recycling, or to conserve energy or promote particular forms of energy. There might be responses in terms of investment in alternative energy technologies. These responses, on both sides of the framework, have further effects on ecosystem services and uses of ecosystem services. Changes and responses to changes iterate through the framework over time.

Insights gained from monitoring changes and responses allow managers to anticipate some effects of energy development and proactively mitigate such effects. They can also be used to systematically evaluate and compare alternative forms of energy development. Rangelands can be used to produce plant materials for use as feedstock for biofuel production. Biofuels may contribute to human well-being to the extent that they replace other fuel sources and more efficiently use byproducts of other resource uses. States are mandating that certain percentages of their energy come from renewable sources. Demand for products like ethanol and syngas is increasing, and technologies are being developed to produce them more efficiently and from different feedstocks. Demand for such energy sources, and others yet to be developed, could be expected to increase as biofuels become part of a portfolio of renewable energy options. Once a plant material for biofuel production is selected and cultivated on rangelands, it becomes responsive to management. Trade-offs occurring when one land use, or mix of uses, is chosen over others imply there could be a net loss of other EGS, such as reduced forage and changes in wildlife habitat, erosion potential, or altered viewscapes. Depending on the feedstock selected, there might be effects in other sectors of the economy. Using corn as a biofuel feedstock, for example, has impacts as other potential uses of corn are displaced or made more costly. Some land uses are compatible, while others are not. Oil and gas development or wind power might be compatible with grazing; raising biofuel feedstocks might not. Wind turbines have been associated with killing bats and birds. Reductions in the numbers of bats and birds might lead to changes in insect populations, resulting in other ecosystem changes. Changes in ecosystem services or compatibilities resulting from development of particular forms of energy could be used to evaluate the relative desirability of one energy form or another.

The framework is described in more detail in "An Integrated Social, Economic, and Ecologic Conceptual (ISEEC) Framework for Considering Rangeland Sustainability," in *Society and Natural Resources*, 22(7):593-606.

Reducing Wildfire Hazards in the Wildland Urban Interface

The 2003 Healthy Forests Restoration Act called for local communities to collaborate on developing Community Wildfire Protection Plans (CWPPs) to reduce their wildfire hazard. CWPPs are tailored for communities in the wildland-urban interface, which are at high risk of damage or loss of life from wildfire. A CWPP is intended to be a community-driven process to prioritize fuel treatments on both federal and non-federal lands and to devise and carry out measures to reduce the ignitability of structures. Communities are expected to take the lead in collaboratively developing a plan tailored to their own fire-risk situations.

Research identified common elements that facilitate the development of a community Wildfire Protection Plan.

Station scientists are part of a nationwide research team that studied 13 communities in eight different states as they developed CWPPs. Cases were selected to represent a range of variation in geography,

ecological and social contexts, and planning scales. To aid in the application, a research application advisory team was organized as part of the project. Documents and stakeholder interviews from each CWPP were collected and analyzed using a model that considered: 1) the social and ecological context in which each plan was developed; 2) the planning process used in the CWPP; and 3) plan implementation and outcomes. The research team looked for common elements in the strategies and social make-up of communities that successfully developed a CWPP. The goal was to pinpoint the critical factors in human interaction that can make or break a CWPP process.

The research identified 10 common elements that facilitate the development of a CWPP. These include: 1) selection of an appropriate scale for planning; 2) availability of community resources and skills; 3) prior experience with collaborative problem solving; 4) networks of relationships among people and organizations; 5) emergent leadership; 6) framing of the issues; 7) collaborative process that meets the needs of stakeholders; 8) information sharing and social learning; 9) outcomes that build relationships, knowledge and ownership; and 10) building sustainable capacities to address wildfire risk into the future.

Research found that social networks, learning communities, and enhanced community capacity are important outcomes of a successful process and can strengthen a community for taking on other collective tasks. Though the eventual impact of these planning efforts to reduce property damage due to wildfires remains to be seen, the one immediate impact of a CWPP is a greater shared sense of responsibility for the risks of wildfires and greater preparedness to deal with a wildfire (such as evacuation planning). The project also has served as a model for incorporating science application and knowledge transfer into the design of Joint Fire Science Program (JFSP) research projects, and it was recently featured in the JFSP *Fire Science Digest,* July 2009 publication.

In addition to getting feedback from the manager advisory team, the research team held three knowledge transfer workshops around the country to share findings with managers who play critical roles in facilitating CWPP development. These workshops also put the research findings into practice as they helped local land managers build relationships and networks and share information on CWPP activities in their particular jurisdictions.

A summary of the project can be found in: "Critical Elements in the Development and Implementation of Community Wildfire Protection Plans (CWPPs)," in *The Fire Environment—Innovations, Management, and Policy, Conference Proceedings. 26-30 March 2007; Destin, Florida*, Proceedings RMRS-P-46CD, available from the Rocky Mountain Research Station.

More information on this study and a complete set of articles, documents, and reports can be found at: www.firescience.gov (search for "CWPP" or project "04-S-01").

Inventory and Monitoring

Scientists provide the data, analyses, and tools needed to identify and evaluate the current status and trends in the condition of forests and rangelands throughout the Interior West. Results help identify changes in use, management options and impacts, and threats and impacts of climate change, fire, insects, disease, and other natural processes. The Forest Inventory and Analysis Program is a central component of this Science Program. Details are available at http://www.fs.fed.us/rmrs/research/programs/inventory-monitoring-analysis.

Assessing Trends in Conifer Mortality in the Interior West

There is significant widespread mortality of several conifer species occurring in the Interior West. Much of this tree mortality is the result of insect infestations caused by mountain pine beetles and defoliators. Some forest researchers believe that these recent forest insect epidemics are unprecedented in extent and severity and are the result of climate change. The Station's Interior West Forest Inventory and Analysis (FIA) program has been conducting broad-scale annual inventories on the extent and conditions of forests in the Interior West region since 2000. These annual inventories show promise in detecting trend and magnitude of conifer mortality in several Interior West states.

An analysis of conifer mortality was recently conducted for Colorado using six years of data collected with FIA's annual inventory, beginning in 2002. Colorado is experiencing unprecedented levels of conifer mortality, largely as the result of a mountain pine beetle epidemic. This study provided an opportunity to test the usefulness of the FIA annual inventory system for quantifying rapid change in mortality of the State's major conifer species over six consecutive years, 2002-2007.

FIA field crew installs a plot in a lodgepole pine stand. FIA provides data on trends in tree mortality over time.

Results indicate significantly higher levels of conifer mortality occurred in 2006 and 2007 compared to the four earlier years. The average annual number of conifer trees that died in Colorado has more than doubled over the six-year period. Tests were conducted to look for statistically significant differences in conifer mortality for individual conifer species between years. These analyses confirmed that significant increases in tree mortality did occur for some conifer species, but not for others. For example, there has been a significant increase in lodgepole pines killed by mountain pine beetles. The average number of lodgepole pine trees killed each year by mountain pine beetle increased from 1 million trees in 2002 to 10.5 million trees in 2007.

Results of this research can help resource managers: 1) understand how to interpret tree mortality data collected in annual inventories; 2) quantify tree mortality by species and cause of death; 3) assess trends in tree mortality over time; and 4) correlate tree mortality data with other time-series data such as rainfall and temperature data. If these broad-scale mortality events are a result of a changing climate, monitoring efforts such as FIA's

annual inventory are needed to provide accurate, consistent, long-term data for managers and researchers to study relationships between tree mortality and changing climate patterns.

More information can be found in: "Analysis of Conifer Mortality in Colorado Using Forest Inventory and Analysis's Annual Forest Inventory," in *Western Journal of Applied Forestry* (in press); and "Opportunities to Improve Monitoring of Temporal Trends with FIA Panel Data," in *Forest Inventory and Analysis (FIA) Symposium 2008; October 21–23, 2008; Park City, UT*, Proceedings RMRS-P-56CD, available from the Rocky Mountain Research Station.

Determining Changes in Timber Transport Carbon Emissions

There is growing interest in determining the impact of forestry activities on the global carbon budget. While both standing trees and forest products may sequester atmospheric carbon for some period of time, it is recognized that many forest management activities result in the release of carbon from fossil fuels. Timber transport is a major source of such emissions. Current estimates of the carbon "cost" of getting logs to mills are derived from surveys of mill owners or truck drivers. However, even in cases where comprehensive surveys exist, the duration of their validity is uncertain. As harvest patterns change and the processing industry evolves, the distances that logs are transported, together with corresponding fuel emissions, are likely to fluctuate.

Some of the carbon sequestered in forest products is offset by fossil carbon released in the timber haul process. Recent advances help determine the current and past timber transport carbon "costs."

Members of the Station's Inventory and Monitoring and Human Dimensions Programs, the Bureau of Business and Economic Research at University of Montana, and the NASA-funded North American Forest Dynamics Project have devised a way to use historical inventory and satellite data to comprehensively track changes in likely timber haul emissions. Forest Inventory and Analysis (FIA) Timber Processing Output (TPO) records, collected for decades across the country, give snapshots of how timber flows from particular counties to particular mills. Time series of Landsat satellite imagery can be used to give exact locations of harvest sites, and when TPO and Landsat data are combined in a geographic information system (GIS), likely haul routes, distances, and emissions may be calculated.

This system was piloted in Ravalli County, Montana. Transport-related emissions, evaluated as a fraction of transported wood carbon at 4 points in time, rose from 0.5% in 1988 to 1.7% in 2004 as local mills closed and spatial patterns of harvest shifted due to decreased logging on federal lands. The apparent sensitivity of transport emissions to harvest and infrastructure patterns suggests that timber haul is a dynamic component of forest carbon management that bears further study both across regions and over time. The developed monitoring approach, dependent on nationally collected TPO data and globally available satellite imagery, could readily be adapted to provide current and historical estimates of transport emissions in a consistent way across the country.

More information about this project may be found in: "Changes in Timber Haul Emissions in the Context of Shifting Forest Management and Infrastructure," in *Carbon Balance and Management*, (in press); and "Determining Landscape-level Carbon Emissions from Historically Harvested Forest Products," *Forest Inventory and Analysis (FIA) Symposium; October 21–23, 2008: Park City, UT*, Proceedings RMRS-P-56CD, available from the Rocky Mountain Research Station.

FIA Data as Used for Simulation and Validation in the Forest Vegetation Simulator

The Forest Vegetation Simulator (FVS) is a national system of forest growth models maintained by the USDA Forest Service, Forest Management Service Center (FMSC). It is the official tool for stand growth projection on National Forest lands, but it is also used widely on other ownerships. Model extensions and post-processors permit FVS users to perform a broad range of functions, including silvicultural manipulations, wildlife habitat analyses, and fuel treatment evaluations. The Station's Forest Inventory and Analysis (FIA) program maintains a network of permanent plots on all forested lands of the U.S. Because of the geographic ranges covered by FIA data and FVS growth models, there are many opportunities to develop linkages of mutual benefit to the programs. For end users of FIA data and FVS, there are two important opportunities: 1) to use FIA data as source data in FVS simulations that are run at large landscape scales; and 2) to use FIA data as a geographically unbiased validation source.

The FIA program has made FIA plot data available in FVS-ready for several years, but improvements in the FIA data delivery system and FVS data management options have provided an opportunity to make the process more convenient for users and to take greater advantage of FIA variables. The Interior West (IW-FIA) program is leading an effort to update the FIA to FVS data delivery process, in cooperation with FMSC and the Northern Research Station. When the new data delivery process is completed, it will give FVS users unprecedented access to FIA data for use in a wide variety of applications. Although FVS growth models were developed using the best data available at the time, a large quantity of data have been acquired by the FIA program since many of the regional FVS variants were first created. Under the annual inventory system now used by the FIA program, there is a constant stream of new data that can be used to validate or calibrate many of the submodels that make up the regional variants. This presents an opportunity to develop a process of continuous quality control, where current FIA data can be used to improve existing models, and future FIA data can be used to validate previously updated models. IW-FIA is working with FMSC and Utah State University to develop standardized procedures for this validation cycle.

Collecting field data for the Forest Vegetation Simulator (FVS).

This research will create stronger links between two important Forest Service programs, provide greater user access to data, and increase user confidence in simulation results. End users of FIA data and FVS will be able to use FIA data as source data in FVS simulations that are run at large landscape scales, and use FIA data as a geographically unbiased validation source.

More information on can be found in: "Improving Longleaf Pine Mortality Predictions in the Southern Variant of the Forest Vegetation Simulator," in *Third Forest Vegetation Simulator Conference; 2007 February 13-15; Fort Collins, CO*, Proceedings RMRS-P-54; "Using FIA Data in the Forest Vegetation Simulator," in *Forest Inventory and Analysis (FIA) Symposium 2008; October 21-23, 2008; Park City, UT*, Proceedings RMRS-P-56CD; and "Inventory-based Sensitivity Analysis of the Large Tree Diameter Growth Submodel of the Southern Variant of the FVS," in *Third Forest Vegetation Simulator Conference; 2007 February 13-15; Fort Collins, CO*, Proceedings RMRS-P-54, all available from the Rocky Mountain Research Station.

Wildlife and Terrestrial Ecosystems

This program focuses on six components: 1) understanding the ecological tradeoffs of vegetation management on wildlife populations, communities and habitats; 2) understanding the underlying causes and consequences of species invasions over time and space and emergence of zoonotic (animals to people) diseases to better manage and mitigate these threats to native biodiversity, ecosystem services, and human populations; 3) applying genetic tools for monitoring populations, assessing threats to populations, defining populations or species, understanding the degree of connectivity/isolation of a population, and measuring how populations respond to environmental changes over time and space; 4) providing high-quality information on species and habitats at risk that helps to develop effective management strategies; 5) assessing human/wildlife interactions; and 6) developing monitoring methods that can be applied in a cost-effective manner for many species and across landscapes ranging from National Forest to regional. Learn more at http://www.rmrs.nau.edu/wildlife/.

Genetic Monitoring of Westslope Cutthroat Trout

It is well known that you can't run a store if you don't know what's on the shelves. Before the days of laser scanning, stores spent considerable time and expense periodically counting their inventory. For a land management agency like the Forest Service, all of the resources on the land they manage—trees, animals, water, and grass—are the inventory, and effective land management requires knowledge of the status and trends of these resources. Monitoring is the tracking of resources over time, and it provides vital information not only concerning status and trend, but also providing data to evaluate the efficacy of restoration efforts. However, tracking these natural resources is far more difficult than counting items on a shelf. In particular, mammals and fish tend to be difficult to monitor because they move and hide. Additionally, the population size for many species changes rapidly from year to year. Tracking these erratic or cyclic changes in population size is frequently difficult and extremely expensive, and it may not be very informative concerning the longer-range status and health of populations.

New advances in rapid genotyping have enabled the use of population and landscape genetic methods to monitor populations. Sampling to obtain large, representative genetic samples potentially provides information that reflects a species' status, including its distribution, connectivity, patterns of diversity, and local effective

Electrofishing for cutthroat trout in a Montana stream.

population size (related to the number of breeding individuals in a local population). As an alternative to counting, one can ask: is a species maintaining its range? Are its populations connected, or are they becoming fragmented? Are populations losing genetic diversity, and if so, where? For some species, such as trout, additional important questions arise about whether native trout are becoming increasingly hybridized with imported species, and if so, where. Also, in the near future, managers will be able to evaluate the resistance of populations to environmental changes and diseases based on specific genetic links to traits such as thermal tolerance.

Of the many resources managed by the Forest Service, the status of native fish is of particular interest. Not only are native fish highly valued by the public, but they are extremely sensitive to climate changes that alter stream flow and temperature. Additionally, their populations are under stress from exotic competitors and, for many species, ranges are rapidly shrinking. For example, westslope cutthroat trout are now absent from 95% of their historical range in the Missouri River basin.

In cooperation with the Forest Service's Northern Region, the Montana Department of Fish, Wildlife and Parks, the University of Montana, the Forest Service Washington Office, and the Columbia River Inter-tribal Fish Commission, Station scientists initiated the first systematic, range-wide genetic monitoring effort for westslope cutthroat trout. Genetic samples from over 100 streams in Montana were collected; eventually, samples will be collected on a regular basis from over 600 streams covering the entire range of westslope cutthroat trout. In addition to cutthroat trout, researchers also continue to obtain genetic samples of other species, including amphibians, such as tailed frogs, and other fish of interest, such as the federally threatened bull trout.

The Relationship Between Northern Goshawks and Their Habitats

The Forest Service's mandate to monitor how populations of plants and animals respond to management can be time consuming and expensive. Therefore, managers need to know if they can use the presence or absence of habitats needed by a species as a surrogate for monitoring the species' populations.

Researchers have been studying the northern goshawk on Arizona's Kaibab Plateau for 19 years.

On Arizona's Kaibab Plateau, a 700 m^2 forested area that includes the North Kaibab Ranger District and the Grand Canyon National Park-North Rim, Station researchers have been investigating the relationship between northern goshawks and their habitats for 19 years. Science has shown that while goshawks, a large and powerful predator of forest birds and mammals, use mature and old forests for nesting and foraging, they also hunt along forest edges and into openings. The researchers are ranking over 120 goshawk home ranges from best to worst based on the demographic performance (ranking criteria: annual home range occupancy rate, total years eggs were laid, total young produced, annual survival of breeding adults, and annual fidelity to range) of goshawks on each of the home ranges. The ranking of each home range is then being related to its specific forest composition and structure at four spatial scales: the nest area, post-fledgling family area, territory, and home range.

Researchers are learning that achieving an understanding of goshawk habitat relationships, and the hope of using habitat as a monitoring surrogate, is not straightforward. First, food appears to be the driving factor affecting goshawk reproduction (as opposed to forest composition and structure), and total prey abundance is highly variable year-to-year. High year-to-year variation in food abundance appears to be dependent on annual precipitation which varies on the study area between wet (El Niño) and dry (La Niña)

periods. The researchers' working hypothesis is that precipitation drives primary forest productivity, which in turn drives prey populations and goshawk reproduction.

In 19 years of intensive mark-recapture research on goshawks, studies show no differences in frequency of egg laying or total young produced among home ranges irrespective of the amount of habitat that has been altered by tree harvests, fire, or catastrophic blow-down of trees in each of the four home range spatial scales. Three factors appear to be interfering with the researchers' ability to detect the "expected" lowered-reproduction response to these habitat changes: 1) a relatively small amount of habitat change per home range; 2) the over-riding effects of inter-annual variation of food abundance on goshawk reproduction, irrespective of forest composition and structure; and 3) a strong effect of goshawk longevity (life span), combined with a very high annual fidelity rate to territory, on total reproduction. The longevity effects stem from the fact that for shorter-lived goshawks, the higher the turnover rate (replacement) of breeders on home ranges; and, the higher the turnover, the greater the number of missed years of breeding and the production of fewer young. About 25 percent of all breeding goshawks lay eggs in 1 year only and produce an average of less than 2 young in their lifetime, while only a few individuals live to breed more than 7 years. The maximum young produced by a single female was 23 in a 12-yr breeding life span. Thus, the effects of longevity on total reproduction is strong...long-lived goshawks on a "poor" (highly altered) home range could lay eggs more often and produce more young than short-lived hawks on "good" (unaltered) home ranges.

Another factor complicating the detection of habitat change on reproduction and survival is the diverse diet of goshawks. Goshawks feed on a wide variety of birds and mammals, each occupying different habitats. While the researchers' long-term prey abundance and goshawk reproduction data shows that prey abundance determined *over the entire suite of prey* is what counts, some open forest prey such as ground squirrels, rabbits, and hares can be quite abundant and are relatively large compared to other goshawk prey. To an extent, opening a forest by thinning trees may simply cause goshawks to partially switch to prey that are more abundant in forest openings, allowing goshawks to sustain their egg laying.

In summary, the likelihood of successfully monitoring goshawk population trends by tracking their habitat is low. Because of the importance of prey to goshawk reproduction, managing forests to sustain goshawk populations must include managing for the habitats of each species in the suite of goshawk prey.

For additional information, see: "Northern Goshawk Habitat: an Intersection of Science, Management and Conservation," in *Journal of Wildlife Management* 72:1047-1055; and "Sampling Considerations for Demographic and Habitat Studies of Northern Goshawks," in *Journal of Raptor Research* 39:274-285; or visit www.rmrs.nau.edu/lab/people/rreynolds.

Modeling Habitat Suitability for At-Risk Woodpecker Species

Station scientists are working with National Forest managers and The Nature Conservancy to develop and test habitat suitability models for at-risk woodpecker species nesting in burned and unburned dry coniferous forests of Idaho, Oregon, and Washington. Their goal is to use habitat suitability maps to guide the strategic placement and prescriptions for fuels management in unburned forests and for salvage logging activities in recently burned forests. They focus on woodpeckers and other cavity-nesting birds because the long-term persistence of many depends on fire-prone landscapes, and several are considered species at-risk (management indicator and sensitive species). A paucity of scientific information about the ecological consequences of fuels treatments and postfire salvage logging prevents managers from adequately predicting environmental effects of these management activities on wildlife and their habitats.

White-headed woodpecker habitat is being studied by Station scientists.

In recently burned ponderosa pine-dominated forests, studies show that a range of conditions from unlogged to partially logged forests provide habitat for successful nesting of black-backed and Lewis's woodpecker, respectively. High habitat suitability of black-backed woodpecker is characterized by high prefire crown closure with high densities of relatively smaller snags, whereas high suitability of Lewis's woodpecker is described by areas of moderate prefire crown closure with moderate densities of large snags. Both species nest in areas of moderate-to-high burn severity. Studies also show that in recently burned forests, the interspersion of wildfire-burned and unburned ponderosa forests is critical for nesting white-headed woodpeckers. In unburned forests, the interspersion and juxtaposition of open and closed ponderosa forests is also of high suitability for nesting white-headed woodpeckers.

Habitat suitability models were developed from remotely sensed data and then mapped over forest-wide areas that are burned and unburned. The models are being field tested by conducting woodpecker surveys to determine if the birds are nesting in forests predicted to be of moderate-to-high suitability and absent in low suitability. Once the models are validated, managers plan to treat low habitat suitability areas that could move toward moderate and high suitability. The managers' goal is to design larger landscape treatments that would help connect moderate and high habitat suitability areas in ponderosa-dominated forests, where such conditions are consistent with historical forests described within the last 150 years.

More information can be found in: "Nest-site Selection by Cavity-nesting Birds in Relation to Postfire Salvage Logging," in *Forest Ecology and Management* 257: 151-159; "Modeling the Effects of Environmental Disturbance on Wildlife Communities: Avian Responses to Prescribed Fire," in *Ecological Applications* 19:1253-1263; "Detection Probabilities of Woodpecker Nests in Mixed Conifer Forests in Oregon," in *The Wilson Journal of Ornithology* 121(1):82–88; and "Habitat Suitability Models for Cavity-nesting Birds in a Postfire Landscape," in *The Journal of Wildlife Management* 71(8):2600–2611; or visit http://www.rmrs.nau.edu/wildlife/birdsnburns/ (see fire-related publications).

Science Applications and Integration

The **Human Factors and Risk Management RD&A** (Research, Development and Application) program is helping the Agency develop ultra-safe systems in high-risk environments. The challenge is to develop a safety culture in the Forest Service that is highly reliable, resilient and takes a proactive and systematic approach to managing risk. Work being done by the RD&A, in partnership with universities, agencies and the private sector, includes:

- Human Factors Handbook for Accident Investigations
- Implementation of Safety Management Systems
- Training for Firefighters on "mindfulness" and mind fitness
- Understanding, documenting and learning from key decisions made in high-risk situations.

In 2009, the Human Factors and Risk Management RD&A was successful in strengthening the network of leadership, decision-makers and practitioners who recognize the importance of organizational culture, psychology, and human physiology on public and firefighter safety. The 10th annual Wildland Fire Safety Summit was dedicated to these topics and a national interagency workshop with one of the world's leading scholars of human factors in accident investigation (Dr. Sidney Deckker) set the foundation for changing how accident investigations are conducted and reported across multiple agencies in the federal government.

For additional information, see http://fsweb/science-applications-integration/docs/human-factor-risk.pdf.

The **Wildland Fire Management RD&A** program helps develop and apply wildland fire science, decision support tools, and science integration service to the national interagency wildland fire community. The RD&A serves as a primary point of contact for communication between scientists and participating field managers, and as an advisor to program administrators at local, regional, and national levels, focusing on:

- Coordinating fire science application, including interoperability and delivery of wildland fire decision support systems and science liaison with the Wildland Fire Program Analysis Project
- Developing and supporting the Wildland Fire Decision Support System (WFDSS) (In 2009, WFDSS was utilized in over 6,700 fire incidents nationwide)
- Projecting annual fire suppression costs
- Coordinating scientific efforts associated with wildland fire costs
- Supporting development of hazardous fuels planning applications

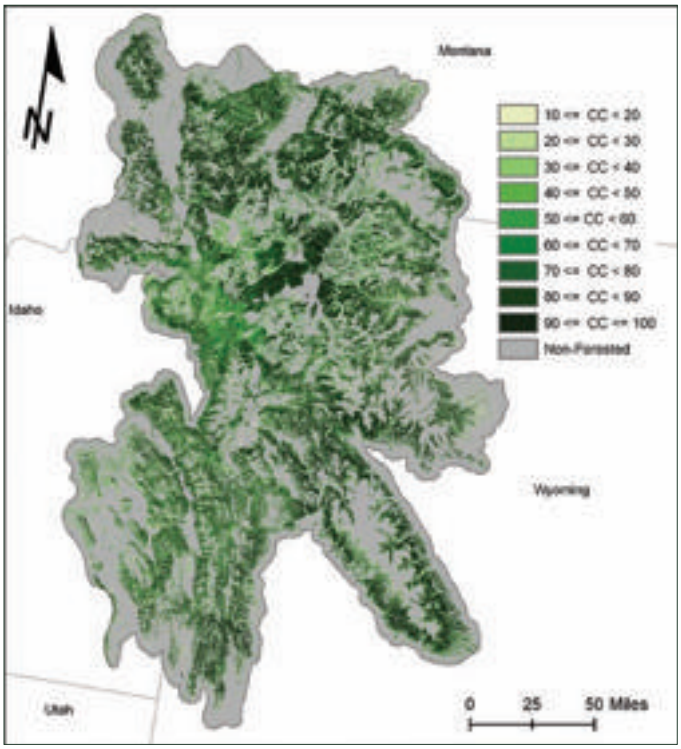
This Program also played a major role in development of the National Fire Decision Support Center. The Center will serve as a single focal point to support agency goals of improving strategic and tactical decision making for large fires. It will provide improved and consistent decision support information on large and long duration Forest Service wildland fires. The Center will also improve the capability to make strategic decisions through a directed research program, and increase agency awareness. Finally, it will expand application of decision support information in risk-informed decision making.

In 2009, the comprehensive mapping of the fuels and potential fire behavior of the United States under LANDFIRE was brought to a successful completion. The national **LANDFIRE program** (www.landfire.gov), also known as the Landscape Fire and Resource Management Planning Tools Project, was a five-year, multi-partner project producing consistent and comprehensive maps and data describing vegetation, wildland fuel, and fire regimes across the United States. It was a shared project between the wildland fire management programs of the U.S. Department of Agriculture Forest Service and U.S. Department of the Interior. The Rocky Mountain Research Station has been instrumental in the development and production of the LANDFIRE data layers.

In 2009, LANDFIRE data were used in over 500 fire incidents, enabling fire managers to be more knowledgeable of land conditions and strategic in placement of resources, which increased safety and decreased expenditures.

Specific RMRS data products for the United States completed in 2009 include:

1) Biophysical gradient data for Hawaii;
2) Fuel calibration workshops (six) for the eastern and mid-western United States;
3) Tool development: analytical models to help analyze and validate fire behavior outputs and more direct analysis of data in GIS mapping software;
4) Quality control on LANDFIRE data layers produced on contract for Alaska and Hawaii; and
5) In conjunction with the Pacific Northwest Research Station, Pacific Wildland Fire Science Lab, researchers created the Fuel Characteristic Classification System (FCCS) data layer for the eastern United States.



This map, showing percent forest canopy cover, is an example of data produced for fire managers by the LANDFIRE Program.

More information is available in: "Spatial Fuel Data Products of the LANDFIRE Project," in *International Journal of Wildland Fire* 18, 250–267; "LANDFIRE: A Nationally Consistent Vegetation, Wildland Fire, and Fuel Assessment," in *International Journal of Wildland Fire* 18, 235–249: "Equations to Convert Compacted Crown Ratio to Uncompacted Crown Ratio for Trees in the Interior West," in *Western Journal of Applied Forestry* 24(2):76-82; and "LANDFIRE Data Access Tool (LFDAT) for ArcGIS 9.2-9.3 (version 2.1)," National Interagency Fuels Technology Team and USDA Forest Service Rocky Mountain Research Station, available at www.niftt.gov.

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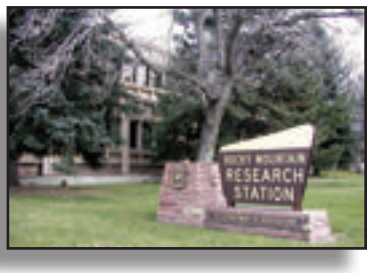

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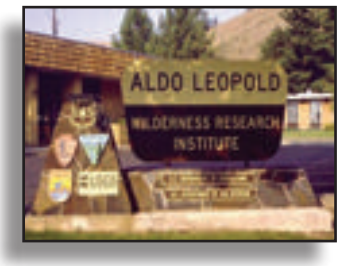

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