Research Summary and Expertise Directory

USDA Forest Service
Rocky Mountain Research Station
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RMRS Invasive Species Research Program

Rocky Mountain Research Station (RMRS) personnel have scientific expertise in widely ranging disciplines and conduct multidisciplinary research on invasive species issues with emphasis in terrestrial and aquatic habitats throughout the Interior West, Great Plains, and related areas (fig. 1; Expertise Directory; appendix). RMRS invasive species research covers an array of diverse ecological and environmental gradients, from southwestern deserts to northern temperate rain forests and from low-elevation plains and basins to alpine summits (fig. 1).

The areas covered by RMRS host a number of invasive species. In general, exotic plants and aquatic organisms present great threats due to the sheer number of invaders. However, certain pathogens and terrestrial insects have high impacts on trees and forests. Invasive species of particular concern include: cheatgrass; leafy spurge; tansy ragwort; spotted knapweed; bufflegrass; saltcedar; white pine blister rust; Armillaria root disease pathogens; rainbow; brook and brown trout; golden algae; spruce aphid; and banded elm bark beetle.

RMRS houses multidisciplinary invasive species programs as old as 75 years as well as the accompanying expertise, records, specimen collections, and long-term research plots. The Station provides the basic ecological and biological information to help managers eradicate new invaders. For well-established, widespread invasive species, RMRS makes contributions to the development and testing of landscape-scale mitigation strategies to prevent further spread of invasives into new areas and to suppress invasive populations below ecological and economic impact thresholds. This is accomplished using environmentally compatible tools and integrated control programs. Station staff members work closely with land managers and other partners from domestic and international agencies and universities to incorporate scientific findings into management plans.

Figure 1—*The area served by RMRS supports about half of the National Forest lands and nearly all of the National Grasslands.*

Common themes of RMRS invasive species research include:

- Assessing biological, economic, and social impacts of invasive species in natural ecosystems.
- Developing biological control methods for invasive plants.
- Assessing the role of natural disturbances and forest management practices on the establishment and spread of invasive species.
- Determining basic biology, ecology, and genetics of invasive species and other affected species to predict future impact, management, and restoration.
- Testing treatments and methods for restoring or rehabilitating invaded ecosystems and evaluating treatment consequences to native species and ecosystem processes.
- Developing technologies for molecular identification and risk assessment models for predicting and detecting current and potential invasive species.
- Developing user-friendly technology transfer tools (e.g., Web-based tools for predicting fire's effects on invasive species) that synthesize science-based information for managing invasive species.

RMRS Invasive Species Research Priorities and Future Direction

All RMRS programs (Air, Water and Aquatics Science; Fire, Fuel and Smoke Science; Forest and Woodland Ecosystems Research; Grassland, Shrubland and Desert Ecosystems; Human Dimensions; Wildlife and Terrestrial Ecosystems; and Inventory and Monitoring Analysis Science) are conducting invasive species research on four activity areas, as defined by the National Strategy and Implementation Plan for Invasive Species Management and the newly identified Forest Service Research and Development (FS R&D) Invasive Species Overarching Research Priorities (appendix). The Overarching Research Priorities were identified in response to an external review of the FS R&D invasive species research strategy in 2006. It was recommended that FS expand its proactive research role (Prediction and Prevention, and Detection and Rapid Response), while clearly maintaining its reactive research role (Management and Mitigation, and Restoration and Rehabilitation). The proposed FS R&D research strategy will emphasize the following four priorities: (1) quantifying invasive species biology, ecology, interactions, and impacts; (2) predicting and prioritizing invasive species; (3) identifying and detecting invasive species; and (4) managing invasive species and altered ecosystems.

RMRS has dedicated approximately 13.4 scientists per year (SY) to research on invasive species issues throughout the Interior West

and other related areas (appendix). The Station has recognized research strengths in priorities (1) and (4) through its invasion biology and ecology and management and mitigation research, and its restoration and rehabilitation activities. It has recently produced significant advances in developing proactive roles for priorities (2) and (3). Proactive research is critical because it is more economically efficient and logistically feasible. For this reason, this research area warrants further expansion and increased efforts for education, training, and outreach.

Historically, RMRS invasive species research has been ad-hoc; individual scientists struggled for funding to conduct research with little coordination or communication. Recently, a multidisciplinary team was formed from across RMRS programs to develop synthesis papers that summarize current Station research activities related to invasive species. A Web site is now available (http://www.fs.fed.us/rm/invasive-species/) that disseminates research information and fosters technology transfer. Also, the quarterly newsletter *Invasive Species Science Update* was created in June 2008 to familiarize RMRS stakeholders and customers with Station activities related to invasive species. This collaborative project will develop proactive tools to better predict and prevent invasive species introduction and spread, with emphasis on climate change.

To implement and further strengthen both pro- and re-active research and management roles and interactions, we have formed an Invasive Species Working Group. The primary goal of the newly formed Invasive Species Working Group is to cross-reference science program areas and invasive species taxa, scientists, and managers from the National Forest System and State and Private Forestry Interior West regions in order to generate scientific information, develop innovative tools and technologies, and promote education and outreach activities. The Working Group will facilitate an integrated and coordinated approach to address critical invasive species issues confronting resource managers. However, success is dependent upon a long-term financial commitment. We propose that RMRS provide the necessary funding to maintain and enhance the infrastructure of the Working Group and foster extramural funding opportunities to enhance invasive species research and communication activities in response to ever-changing conditions, including climate change, fire, and other disturbances.

Summary of Taxa-Specific Research

1. Plants

By Dean Pearson, Jack Butler, Steve Sutherland, and Jane Smith

Exotic plants are the most numerous invasive organisms in the Interior West. They dramatically impact native plants and animals and reduce ecosystem services. Although relatively few invaders cause the bulk of these impacts, new exotic plants continue to arrive. Managers have increased their use of tools in response to the threat of invasive plant species in wildlands. However, many of the tools being applied, such as herbicides and classical biocontrol, originated in much simpler agricultural systems. Effective use of such tools is more challenging within complex wildland ecosystems. Moreover, land management activities such as timber harvest, road building, burning, and grazing commonly exacerbate plant invasions. Thus, extensive research is needed in all aspects of invasive plant management in the Interior West. RMRS research programs have developed critical information for the following four key research areas related to invasive plants.

Spotted knapweed invading the forest from a road corridor

Prediction and Prevention

- Develop methods to predict potential invasive plants before they arrive
- Evaluate risk by determining the attributes of native communities that render them sensitive to plant invasion
- Examine how management actions facilitate invasion
- Predict potential impacts of climate change on invasive plants and assess whether some plant species can become invasive under climate change scenarios

Early Detection and Rapid Response

- Evaluate dispersal mechanisms and invasion pathways
- Develop bioclimatic models to evaluate risk of spread to new locations

- Develop tools for eradicating new invader populations
- Assess community-based action programs for managing invasive plants

Control and Management

- Quantify impacts of invasive plants on native plants, animals, and ecosystem services
- Evaluate efficacy of management actions to reduce side effects on non-target species
- Develop and refine tools and applications such as grazing, herbicides, mechanical removal, prescribed fire, and biological control to increase success of invasive plant management
- Develop Web sites and communication approaches to increase outreach and technology transfer

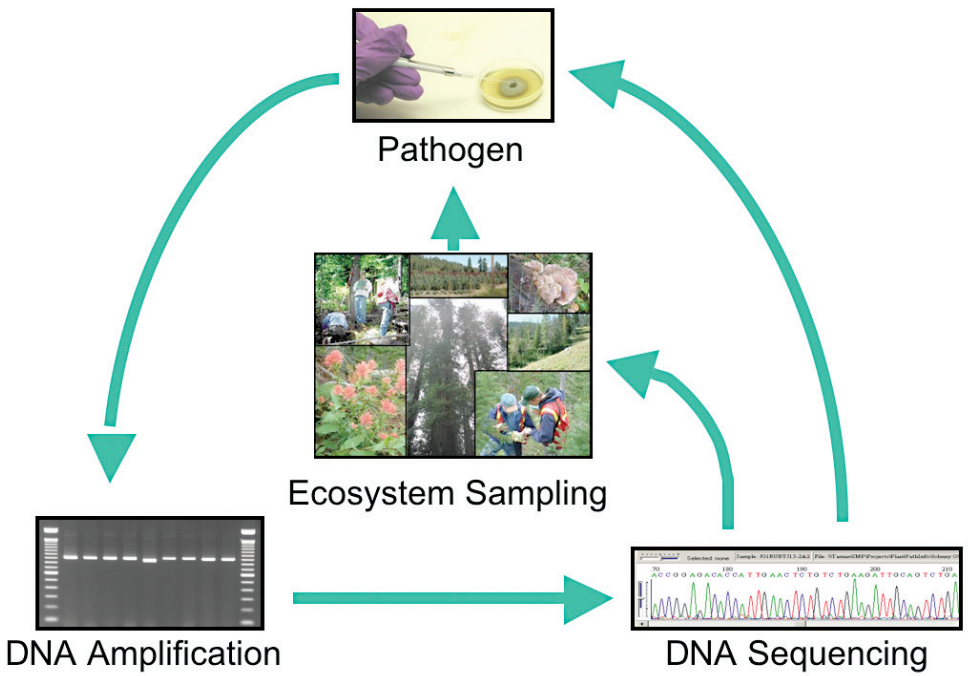
Rehabilitation and Restoration

- Evaluate the efficacy of different management tools and strategies for rehabilitating or restoring invaded ecosystems
- Develop seed mixes of native species most capable of resisting re-invasion
- Work to understand and reduce the new re-invasion and secondary invasion following successful restoration efforts and to promote ecosystem resiliency

2. Pathogens

By Ned Klopfenstein and Brian Geils

Damage caused by invasive forest pathogens is widely viewed as more severe, long-term, widespread, and difficult to restore than that caused by any other biological disturbance agent. In the last century, pathogens introduced into our native forests have threatened extinction of native tree species and critically degraded many different ecosystems across North America. Not only trees are threatened, but also the dependent forest flora and fauna. Invaders have severely diminished productivity, sustainability, and ecological functions of many forests. Diseases caused by invasive pathogens may result in altered forest succession and species composition that can dramatically impact the delivery of ecosystem services. RMRS research programs have developed critical information for the following four key research areas related to invasive pathogens like white pine blister rust, ohi'a rust, Armillaria root disease, and Fusarium root rot.



Interdisciplinary approaches, including integration of genetics, pathology, ecology and silviculture, are used by RMRS to develop science-based information/tools.

Prediction and Prevention

- Integrate genetic analysis and bioclimatic modeling to predict potentially invasive pathogens at the landscape level
- Develop proactive management strategies to mitigate impact of invasive pathogens
- Predict potential impact of climate change on invasive pathogens

Early Detection and Rapid Response

- Develop DNA-based diagnostic tools to identify potentially invasive pathogens
- Maintain culture collections, fungal herbaria, and DNA-sequence databases to help identify pathogen species and populations

Control and Management

- Identify geographic distribution of host resistance frequencies and mechanisms
- Develop systems to better evaluate risks of invasive pathogen spread
- Synthesize science information and establish Web sites and models with management information
- Provide management recommendations for impacted and threatened ecosystems

Rehabilitation and Restoration

- Use genetic analyses to identify ecologically valuable and appropriate host populations for conservation and restoration
- Maintain long-term research to monitor ecosystem function and restoration
- Synthesize science-based restoration guidelines for impacted and threatened forest ecosystems

Summary of Taxa-Specific Research

3. Insects

By Jose Negron

In North America, invasive insects have a long history of significantly altering forested ecosystems. Some examples are gypsy moth, European elm bark beetle, Asian longhorned beetle, and emerald ash borer. In the Interior West, injurious exotic insects include the banded elm bark beetle, which has killed elm trees in association with drought, and the spruce aphid, which has seriously affected spruce-fir and mixed-conifer forests. RMRS research programs are describing and quantifying the biology, ecology, and impacts of these invaders and are developing critical information for the following four key research areas.

Prediction and Prevention

- Develop pathway and risk assessments to identify priority insects of concern
- Design educational programs that build public awareness of issues
- Examine how climate change may affect host response and likelihood of establishment of invasive insects
- Evaluate risk by determining the climatic and ecosystem factors that contribute to the spread of invasive insects and the damage and impact that they cause

Spruce aphid. Photo by G. Halldórsson

Banded Elm bark beetle

Early Detection and Rapid Response

- Develop tools such as the identification of pheromones or attractants in support of operational programs aimed at the early detection and monitoring of insects
- Develop taxonomic tools that can be used by agencies responsible for detection at ports of entry
- Develop specific eradication strategies for invasive insects

Control and Management

- Develop management techniques for established invasive insects to mitigate potential impacts and evaluate treatment success
- Develop decision-support systems to identify appropriate conditions for active management
- Explore biological control approaches for managing invasive insects

Rehabilitation and Restoration

- Identify native host-plant material resistant to invasive insects for use in rehabilitation and restoration of affected areas and evaluation of treatment areas
- Identify alternative plants and trees that could be used to restore affected ecosystems while minimizing ecological impacts
- Develop long-term cultural control approaches for restoring affected areas

Summary of Taxa-Specific Research

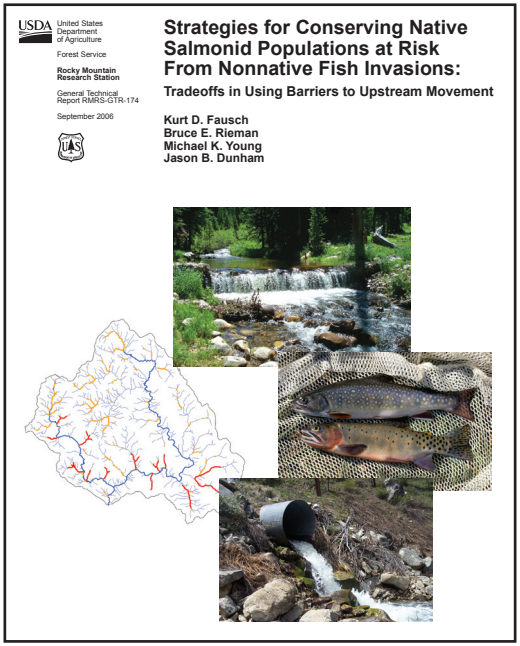
4. Aquatic Species

By Mike Young

RMRS scientists have long focused their research on nonnative aquatic species, namely salmonid fish—brook trout, brown trout, and rainbow trout —that were introduced to promote recreation but that also have substantially altered aquatic communities throughout the West. Effects on aquatic systems produced by climate change suggest that large numbers of cool-water fishes and other kinds of invasive aquatic organisms—crayfish, mussels, amphibians, macroinvertebrates, aquatic plants, and nonindigenous pathogens—will become issues. RMRS research programs have developed critical information for the following four key research areas related to invasive aquatic species.

Nonnative brook trout, top, and threatened native bull trout, bottom. Brook trout may displace bull trout through competition and hybridization. Photo by K. Morita

Native Colorado River cutthroat trout, often at risk from invasions by nonnative fish



Prediction and Prevention

- Review issues facing those attempting to manage nonnative fish invasions
- Evaluate how environmental characteristics affect the success of invasions by nonnative fish and other aquatic species
- Assess the response of nonnative and native aquatic species communities to natural disturbance and land management

Early Detection and Rapid Response

- Improve sampling to estimate the detectability of invasive fishes and other aquatic species during sampling
- Design innovative methods to determine the influence of habitat characteristics, population size, and nonnative species presence on the genetic status of native fish populations

Control and Management

- Develop pheromone-based control methods for nonnative fishes
- Assess methods for managing populations of invasive fish and other significant aquatic invaders

Rehabilitation and Restoration

- Monitor responses of nonnative and native aquatic species and communities to natural disturbance and land management

5. Terrestrial Vertebrates

By Dean Pearson and Deborah Finch

Terrestrial vertebrates do not represent a large number of invaders compared to invasive plants and aquatic species in the Interior West. However, several invasive terrestrial vertebrate species cause substantial economic and ecological damage in this region. Some invasive species displace or prey upon native species, thus reducing biological diversity that contributes to ecosystem stability. Most notable invaders are species native to North America, such as brown-headed cowbirds, barred owls, and bull frogs, that have undergone range expansion or were deliberately introduced into new environments. Other threats include European wild pigs, burros, nutrias, rock doves, eastern fox squirrels, red foxes, and European starlings.

Cowbird. Photo by J. W. Cricket.

At present, few studies within RMRS target terrestrial vertebrate invaders. However, several studies focus on effects of invasive plant and invertebrate species on native terrestrial vertebrates. For example, the structure and composition of plant communities are often altered by invasive plant species that reduce quality habitats and foods for animals. RMRS research programs have developed critical information for the following four key research areas related to invasive terrestrial vertebrates.

Prediction and Prevention

- Forecast how anthropogenic disturbance, urbanization, and climate change affects the likelihood of invasion and rate of spread of nonnative terrestrial vertebrates
- Assess how changes in availability of habitat and water alter distributions and demographics of vertebrate invaders (e.g., cowbirds and their hosts)
- Develop models to predict how changing landscapes, energy development, fire patterns, and invasive plants influence vertebrate invaders

Early Detection and Rapid Response

- Survey and monitor populations to assess presence and trends of vertebrate invaders and to determine when and where to eradicate new populations
- Identify locations where terrestrial vertebrate invaders have a high impact on native species and other natural resources

Control and Management

- Evaluate impacts of vertebrate invaders on native species' productivity and habitat use, and assess management options suitable for high-impact locations
- Develop methods for testing best practices for managing and controlling vertebrate invaders (e.g., through habitat management or removal of invasive vertebrates)
- Understand mitigation impacts on invaders and native animal species

Rehabilitation and Restoration

- Evaluate the ability of native species and systems to recover following various control and restoration measures
- Determine management costs and benefits for restoration of native species and ecosystems

USDA Forest Service — Rocky Mountain Research Station Invasive Species Expertise Directory

Name	Discipline	Location	Email	Phone Number	Taxa Especial Areas of Expertise
Air, Water and Aquatic Environments Science					
Isaak, Dan	Fish Biology	Boise, ID	disaak@fs.fed.us	208-373-4385	Brook trout Fire and invasive species; monitoring; climate change
Lewis, Sarah	Soil Erosion, Remote Sensing	Moscow, ID	sarahlewis@fs.fed.us	208-883-2348	N/A Remote sensing of invasive species; fire and invasive response
Medina, Alvin	Plant Ecology	Flagstaff, AZ	almedina@fs.fed.us	928-853-1391	Tamarisk Control; riparian plant interactions
Neary, Dan	Soil Science	Flagstaff, AZ	dneary@fs.fed.us	928-853-1861	N/A Fire and invasive species; soil erosion; desertification
Overton, Kerry	Fish Biology, Technology Transfer	Boise, ID	koverton@fs.fed.us	208-373-4357	Invasive nonnative trout Habitat inventory and monitoring; climate change; decision support
Rieman, Bruce	Fish Biology	Seeley Lake, MT	brieman@fs.fed.us	406-677-3813	Native & nonnative trout; risks and decision support Fish and fire; sampling nonnative invasive species; climate and fire
Robichaud, Peter	Soil Erosion, Vegetation Response	Moscow, ID	probichaud@fs.fed.us	208-883-2349	N/A Fire and invasive species; soil erosion
Young, Michael	Fish Biology	Missoula, MT	mkyoung@fs.fed.us	406-542-3254	Nonnative fish Ecology; pheromonal attraction; distribution
Aldo Leopold Wilderness Research Institute					
Landres, Peter	Ecology, Landscape Ecology	Missoula, MT	plandres@fs.fed.us	406-542-4189	N/A Wilderness; monitoring; early detection
Fire, Fuel and Smoke Science					
Harrington, Mick	Restoration, Fire Ecology	Missoula, MT	mharrington01@fs.fed.us	406-329-4836	Invasive weeds Fire and herbicide and weed
Smith, Jane	Fire Effects, Fire Regimes	Missoula, MT	jsmith09@fs.fed.us	406-329-4805	Nonnative plants Plant responses to fire; effects of invasive plants on fire regimes; literature review and synthesis
Zeller, Karl	Micrometeorology, Climatology	Ft. Collins, CO	kzeller@fs.fed.us	970-498-1238	Forecast insect emersion time and location 2D real-time seasonal climatology, 7 day forecasts of heating degree days
Zouhar, Kris	Fire Effects, Fire Regimes	Missoula, MT	kzouhar@fs.fed.us	406-829-6924	Nonnative plants Plant responses to fire; effects of invasive plants on fire regimes; literature review and synthesis

Name	Discipline	Location	Email	Phone Number	Taxa Especial Areas of Expertise
Forest and Woodland Ecosystems Research					
Bentz, Barbara	Entomology	Logan, UT	bbentz@fs.fed.us	435-755-3577	Bark beetles Climate change; temperature dependency; population biology
Chew, Jimmie	Landscape Modeling	Missoula, MT	jchew@fs.fed.us	406-542-4171	All vegetation Decision support; introduction and impacts of invasive species
Ferguson, Dennis	Silviculture	Moscow, ID	deferguson@fs.fed.us	208-883-2351	Invasive plants Fire effects on invasive plants
Fowler, James	Plant Ecology	Flagstaff, AZ	jffowler@fs.fed.us	928-556-2172	Invasive plants Fire and invasive species; ponderosa pine weeds
Geils, Brian	Plant Pathology	Flagstaff, AZ	bgeils@fs.fed.us	928-556-2076	*Cronartium*, *Arceuthobium* Epidemiology; ecology
Gottfried, Gerald	Forestry	Phoenix, AZ	ggottfried@fs.fed.us	602-225-5357	Red brome; cheatgrass Pinyon-juniper and oak woodlands; sonoran desert; silviculture; restoration; post-fire recovery
Hudak, Andrew	Forestry, Rangeland Ecology	Moscow, ID	ahudak@fs.fed.us	208-883-2327	N/A Woody encroachment; vegetation mapping; landscape ecology
Jain, Terrie	Silviculture, Fire	Moscow, ID	tjain@fs.fed.us	208-883-2331	White pine blister rust; root-rot fungi Management and disease interactions; fire and disease interactions
Kim, Mee-Sook	Plant Pathology, Genetics	Moscow, ID	mkim@fs.fed.us	208-883-2362	White pine blister rust; *Armillaria*; *Fusarium*; ohi'a rust Diagnostics; risk models, population genetics, phylogeography
Klopfenstein, Ned	Plant Pathology, Genetics	Moscow, ID	nklopfenstein@fs.fed.us	208-883-2310	*Armillaria*; white pine blister rust; *Fusarium*; ohi'a rust Molecular diagnostics of forest pathogens and microbes; phylogenetics; phylogeography; predicting invasive pathogens
Lynch, Ann	Entomology	Tucson, AZ	alynch@fs.fed.us	520-626-9582	Spruce aphid Impact; population biology; landscape ecology
Negron, Jose	Entomology	Ft. Collins, CO	jnegron@fs.fed.us	970-498-1252	Bark beetles Biology and ecology; management

Name	Discipline	Location	Email	Phone Number	Taxa Especial Areas of Expertise
Schoettle, Anna	Plant Ecology, Ecophysiology, Genetics	Ft. Collins, CO	aschoettle@fs.fed.us	970-498-1333	High elevation five-needle pines; white pine blister rust Ecological genetics – host; population dynamics – host; silvicultural intervention
Sieg, Carolyn	Plant Ecology	Flagstaff, AZ	csieg@fs.fed.us	928-556-2151	Invasive plants Fire and invasive species; ponderosa pine weeds
Sutherland, Steve	Plant Ecology, Fire	Missoula, MT	ssutherland@fs.fed.us	406-329-2122	Spotted knapweed; cheatgrass; *Circium*; orange hawkweed Fire and invasives plants; fuel reduction and invasive plants; restoration
Grassland, Shrubland and Desert Ecosystems					
Butler, Jack	Plant Ecology	Rapid City, SD	jackbutler@fs.fed.us	605-716-2160	Invasive plants Invasive species impacts; control efficacy; vegetation restoration
Chambers, Jeanne	Plant Ecology, Restoration	Reno, NV	jchambers@fs.fed.us	775-784-5329	Cheatgrass Invisibility; population dynamics
Finch, Deborah	Restoration, Wildlife, Ecology	Albuquerque, NM	dfinch@fs.fed.us	505-724-3671	Riparian invasive plants; Tamarisk; Russian olive Fire and fuel reduction; animal productivity; riparian communities
Ford, Paulette	Ecology, Fire	Albuquerque, NM	plford@fs.fed.us	505-724-3670	Bark beetle-fungus relationships Grassland fire ecology and restoration; fungus-bark beetle ecology; animal ectoparasites
Kitchen, Stan	Botany	Provo, UT	skitchen@fs.fed.us	801-356-5109	Halogeton; cheatgrass Salt desert ecology
Magaña, Hugo	Fish Ecology, Aquatic Biology	Albuquerque, NM	hmagana@fs.fed.us	505-724-3682	Aquatic invasive plant and fish species Toxic aquatic algae; conservation of endangered fish; warm water systems
Meyer, Susan	Plant Ecology, Genetics	Provo, UT	smeyer@fs.fed.us	801-356-5125	Cheatgrass Biocontrol; population genetics; community ecology
Pendleton, Rosemary	Plant Ecology	Albuquerque, NM	rpendleton@fs.fed.us	505-724-3673	Yellow starthistle Plant reproductive ecology; restoration of invaded communities; pollination ecology
Richardson, Bryce	Forest Genetics, Pathology	Moscow, ID	brichardson02@fs.fed.us	208-883-2311	Five-needled pines; blister rust Population genetics; ecological genetics; biogeography
Runyon, Justin	Entomology	Bozeman, MT	jrunyon@fs.fed.us	406-994-4872	Invasive weeds Plant-insect interactions; chemical ecology; biocontrol efficacy and safety

Name	Discipline	Location	Email	Phone Number	Taxa Especial Areas of Expertise
Shaw, Nancy	Restoration Ecology	Boise, ID	nshaw@fs.fed.us	208-373-4360	Cheatgrass; rush skeletonweed Re-vegetation; plant materials; seed germination
Sing, Sharlene	Entomology	Bozeman, MT	ssing@fs.fed.us	406-994-5143	Invasive plants Weed biocontrol; community and spatial ecology; risk-benefit assessment
Wacker, Stefanie	Plant Ecology	Rapid City, SD	swacker@fs.fed.us	605-716-2210	Invasive plants Disturbance ecology; invasive species impacts; spatial modeling
Human Dimensions					
Champ, Patty	Economics	Ft. Collins, CO	pchamp@fs.fed.us	970-295-5967	White pine blister rust; high elevation pines Non-market value; economic optimization of management options
Jones, Greg	Economics, Landscape Modeling	Missoula, MT	jgjones@fs.fed.us	406-542-4167	Invasive plants Spatial decision support system
Wildlife and Terrestrial Ecosystems					
Ortega, Yvette	Wildlife Biology, Ecology	Missoula, MT	yortega@fs.fed.us	406-542-3246	Invasive plants Trophic interactions; avian ecology; efficacy of control measures
Pearson, Dean	Community Ecology	Missoula, MT	dpearson@fs.fed.us	406-542-4159	Invasive plants Community ecology; invasion biology; trophic interactions

Appendix—This cross-walk table shows problem statements associated with RMRS program areas invasive species research and overarching research priorities. These priorities were identified in response to an external review of the FS R&D invasive species research strategy.

			FS R&D Invasive Species Overarching Priorities			
RMRS program	**Problem statement from charter**	**SY**	**1. Quantifying invasive species biology, ecology, interactions, and impacts**	**2. Predicting and prioritizing invasive species**	**3. Identifying and detecting invasive species**	**4. Managing invasive species and altered ecosystems**
Air, Water and Aquatics Science	▪ Define key biological processes and patterns to understand the distribution, resilience, and persistence of native aquatic and terrestrial species.	2.0	Dwire, Isaak, Magaña, Young	Isaak, Young	Magaña	Magaña, Young
Fire, Fuel and Smoke Science	▪ Improve understanding of post-fire invasion by exotic species. ▪ Address needs of restoration programs by focusing on treatment effects on ecosystem characteristics, including weed invasion.	0.3				Harrington
Forest and Woodland Ecosystems Research	▪ Understand complex interactions of management treatments and other ecosystem disturbance processes, and develop tools and technologies that predict, detect, and manage the new and existing invasive species. ▪ Develop methods to foster restoration of impacted ecosystems, increase resilience to future invasions, and identify ecologically valuable populations for conservation.	4.1	Bentz, Chew, Geils, Lynch, Klopfenstein, Negron, Schoettle, Sieg	Klopfenstein	Klopfenstein, Negron	Bentz, Ferguson, Geils, Gottfried, Klopfenstein, Lynch, Negron, Schoettle, Sieg, Warwell
Grassland, Shrubland and Desert Ecosystems	▪ Understand the effects of invasions, develop tools and techniques to manage the increasingly rapid spread of invasive species, and assess success of approaches for restoring ecosystem function and conserving native species following invasive plant removal.	4.2	Butler, Chambers, Finch, Ford, Kitchen, Magaña, Meyer, Pendleton, Shaw, Wacker	Butler, Richardson	Magaña	Butler, Chambers, Finch, Kitchen, Magaña, Meyer, Pendleton, Richardson, Shaw, Sing, Runyon, Wacker

(continued)

			FS R&D Invasive Species Overarching Priorities			
RMRS program	Problem statement from charter	SY	1. Quantifying invasive species biology, ecology, interactions, and impacts	2. Predicting and prioritizing invasive species	3. Identifying and detecting invasive species	4. Managing invasive species and altered ecosystems
Human Dimensions	▪ Develop a landscape-scale decision support system for invasive species management. ▪ Understand exotic species occupancy patterns across broad geographic scales. ▪ Understand the principal factors influencing the introduction and spread of nonnative invasive plants.	1.0	Flather	Flather, Landres	Landres	Jones, Landres
Wildlife and Terrestrial Ecosystems	▪ Understand the underlying causes and consequences of species invasions and emergence of zoonotic diseases to better manage and mitigate these threats to native biodiversity, ecosystem services, and human populations.	1.8	Ortega, Pearson	Ortega, Pearson		Ortega, Pearson
Total		**13.4**				

Notes

Fire, Fuel and Smoke Science

Air, Water and Aquatics Science

Inventory, Monitoring and Analysis Science

Wildlife and Terrestrial Ecosystems

Forest and Woodland Ecosystems

Grassland, Shrubland and Desert Ecosystems

Human Dimensions

Aldo Leopold Wilderness Research Institute

The USDA Forest Service's Rocky Mountain Research Station is one of seven units nationwide that make up the most extensive natural resource research organization in the world. Headquartered at the foot of the Rockies in Fort Collins, CO, the Station maintains 12 laboratories within a 12-state territory (see map). Scientists conduct studies nationwide, with emphasis on the Rocky Mountains, Great Basin, Great Plains, and Southwest. Research serves the Forest Service, as well as other Federal and State agencies, international organizations, private groups, and individuals. For more information, visit www.fs.fed.us/rmrs.