



What Are Invasive Species? ...And Do We Really Need to Worry About Them?

An invasive species is any species – non-native or native to a region – that could cause economic or ecological harm to an area. Invasives can be weeds, shrubs and trees, insects, mollusks, vertebrates and even microorganisms and pathogens such as exotic bacteria, fungi and viruses. Invasive plant species have already infested more than 125 million acres of land in the U.S., according to the National Invasive Species Council, and are moving into another three million acres every year. The cheatgrass weed alone has invaded more than 100 million acres and continues to spread rapidly.

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Are invasive species really that big of a problem? Yes. Invasive species can be found almost anywhere (rivers, oceans, grasslands, forests) and they can have wide-ranging effects on the environment and on humans. For example, invasives can change water flows, deplete nutrients and increase the risk of wildfires. Invasives can force out other species by competing for food and space, or by introducing pathogens that kill or harm other species. According to the National Invasive Species Council, 42 percent of the species on the endangered species list are at risk primarily because of invasive species. Invasive species can introduce new types of pollen or pathogens that cause respiratory ailments and other human health problems. The West Nile virus, an invasive species, has killed more than 1,000

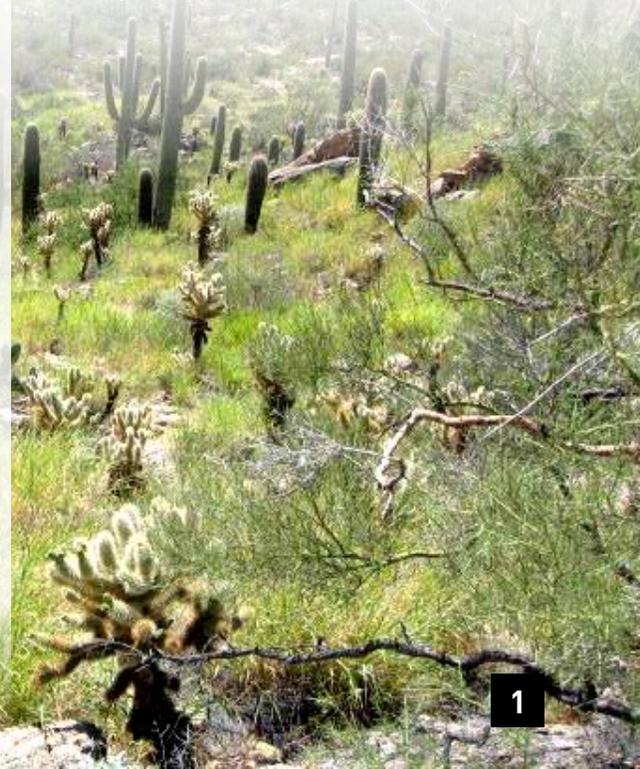
*Right: Buffelgrass (*Pennisetum ciliare*) now infests parks created to protect Sonoran Desert ecosystems. It forms a blanket of cover that can carry fire and threatens iconic native species such as saguaro cactus (*Cereus gigantea*).*

Photo: Saguaro National Park, Arizona

*Left: Saguaro provides nest cavities for the cactus ferruginous pygmy owl (*Claustridium brasilianum cactorum*)*

Photo: Norm Smith

people. Invasives can also affect the recreational value of public land, decrease the economic capacity of land to support livestock and crops, impact wildlife habitats and biological diversity, and much more. By one estimate, the damage caused by just six invasive species is about \$74 billion a year.





Rush skeletonweed (Chondrilla juncea L.) invades dry rangelands in the western United States, displaces native species, and reduces forage for livestock and wildlife.

Photo: Steve Dewey, Utah State University

“Our scientists investigate how ecosystems, native species and natural resources are affected by invasions, and what methods and materials can be developed and applied to repair the damage.”

Preventing, detecting, and managing invasive species are no easy tasks. Scientists do not fully understand all of the processes by which species move into an area, or what makes an area at risk of invasion. They also need to better understand how control measures that work in one area might be used elsewhere, as well as the best ways to restore and rehabilitate an area. As with most any ecosystem, understanding complex relationships and how one species can affect others is a complex puzzle that requires time to work out.

The USDA Forest Service Rocky Mountain Research Station (RMRS) is currently engaged in a 10-year research program to explore how invasive species are affecting the grassland, shrubland and desert ecosystems of the western U.S., an area of some 900 million acres in 17 western states. “We facilitate and implement research projects that allow scientists to delve deeply into many aspects of invasive species,” says Deborah Finch, program manager. “Our sponsors and cooperators include the U.S. Department of Agriculture, other federal and state government agencies, universities and foundations, and non-government organizations. Since 2008, we have conducted studies on more than a dozen invasive species. Our scientists also investigate how ecosystems, native species and natural resources are affected by invasions, and what methods and materials can be developed and applied to repair the damage. We will initiate and cooperate on many more projects in future years to help us address these issues.”

The program focuses on four primary elements, spanning from early detection to rehabilitation. The *early detection and rapid response* element of the program explores the pathways of invasion, such as the factors that leave an area at risk of invasion. *Impact assessment and prioritization*

studies explore how damage can be minimized, assess the risks and benefits of various control strategies, and help to develop models that can predict the severity of future outbreaks. *Control and management* studies look at the details of various control methods, such as classical biological controls, and how they might work better and the risks they can pose when used in a new area. Studies in this area are also looking at non-classical biological controls such as fungal agents (see A New Form of Biocontrol: Fungal Pathogens on page 3). Finally, *restoration and rehabilitation* studies are looking at the impacts of invasive species on the overall structures of plant communities and how well restoration efforts succeed in returning an area to a desirable plant community.

“We expect that these studies will give us a much better understanding of invasive species and how they affect ecosystems,” says Finch. “A greater understanding of the science will enhance the ability of natural resource managers to develop and use management options, balancing social values with management goals, while also taking into account other issues, such as climate change.”

The invasive species research is part of a larger long-term research program that is developing scientific knowledge in five broad focal areas related to western grassland, shrubland, and desert ecosystems: disturbance (fire, drought, etc.); restoration of ecosystems; sustainability and management of ecosystems; the impacts and management implications of climate change; and invasive plant species. Those topics are addressed in other issues of *GSDUpdate*. More about the program’s efforts on invasive species can be found on the GSD website www.fs.fed.us/rm/grassland-shrubland-desert/.



Cheatgrass is a priority concern for land managers in the West because not only is it an early-season grower, replacing native plant species like sagebrush, it also alters fire frequency and reduces wildlife habitat quality and land values for farming and ranching.

Photo: Bureau of Land Management



Cheatgrass is an annual grass that forms tufts up to two feet tall.

Photo: USDA Forest Service

The pathogen *Pyrenophora semeniperda* gets its name, "black fingers of death," from the black projections protruding from killed cheatgrass seeds.

Photo: Susan Meyer

"Currently, black fingers of death is the most promising control agent we have."

A New Form of Biocontrol: Fungal Pathogens

One of the most pervasive invasive species in the West is cheatgrass, an annual grass that found its way here from Eurasia in the late 1800s, most likely in shipments of wheat. Cheatgrass gets

its name from farmers who felt cheated when they learned that their wheat fields had turned into weeds. Its greatest impact has been in the intermountain region of the interior West.



Cheatgrass (*Bromus tectorum*) has infested more than 100 million acres of land already, but a solution may soon be in sight.

Twenty years of research at the Rocky Mountain Research Station's Shrub Sciences Laboratory has led to a potential control strategy using a fungal pathogen nicknamed the "black fingers of death." Says Dr. Susan E. Meyer, the research ecologist leading the studies, "The goal of a practical, safe and cost-effective commercial product for cheatgrass biocontrol is now within reach." Sponsors for this research have included the Joint Fire Sciences Program, the Departments of Agriculture and Interior, and Idaho Army National Guard.

Cheatgrass typically invades desert shrublands, ecosystems that would normally be home to a variety of native plants. It is able to take over such areas in part because of how it reacts to fire. After a fire occurs, many native species are slow to recover. Cheatgrass, on the other hand, responds very quickly to the newly opened space and changed soil conditions, rapidly spreading throughout the area. Once an area has a lot of cheatgrass, it is at high risk of even more fires; a cheatgrass-dominated landscape – a continuous carpet of plants that dries out in early summer – is a richer fuel source than the native plants. With more frequent fires, native plants can be wiped out entirely.

The cheatgrass's reproductive cycle also makes it more likely to spread. Its seeds germinate

in the fall, and when spring arrives, it is ready to grow to maturity and produce seeds. Native species don't follow the same pattern, so the cheatgrass has little competition from other plants. During times of drought, cheatgrass can claim all the moisture for itself, before other plants have even started growing.

The end result is a cheatgrass monoculture – nothing but cheatgrass. And a landscape that is at high risk of wildfire.



Team BFOD. Photo: USFS

In addition to Meyer, the research group includes scientists from Gonzaga University in Spokane, Washington, and Brigham Young University in Provo, Utah. They have spent years working to understand why cheatgrass is such a successful invader and how it might be controlled. As part of their research, they looked at using natural enemies of cheatgrass to control it – an approach known as biocontrol. The most promising agent they have found is a naturally occurring fungus called *Pyrenophora semeniperda*, which can kill dormant cheatgrass seeds. Killing the dormant, ungerminated seeds is key, because they can lay quiet for two to three years, giving rise to renewed cheatgrass infestations long after other eradication methods, such as mowing or herbicides, have seemingly controlled the problem. The scientists began calling the fungus the black fingers of death, or BFOD, when they noted the dark finger-like growths that emerge from the dead seeds.

"This pathogen is not completely effective if used alone, but it could be a valuable tool for use along with other control methods," says Meyer. "Currently, black fingers of death is the most promising control agent we have."

The group's studies have looked at details such as: What percentage of dormant seeds is typically killed by BFOD, and how does that change with habitat and weather changes? How long can the pathogen persist if there are no



Top and bottom:
Houndstongue (*Cynoglossum officinale*
L.) is a poisonous weed that can
cause liver damage in livestock,
resulting in death.

Photos: Mary Ellen Harte



host seeds? Are some strains of the pathogen more deadly than others? Will the pathogen infect other grass species?

“Our next steps are to select the more effective strains of the pathogen and develop a delivery system that is lightweight, economical and effective, and work toward commercially viable biocontrol products,” says Meyer. “To this end, we have applied for a patent for our product, and we also plan to explore whether BFOD is effective against other invasive species.”

In related work, another research group recently funded by the Station’s Competitive Research Initiative has started a new study investigating some 700 other fungal endophytes that have been isolated from cheatgrass populations across the West. They are studying whether those endophytes increased or decreased the growth of cheatgrass. They have found that some do enhance cheatgrass growth, while others decrease it. “Understanding these relationships, says research plant ecologist Dr. Rosemary Pendleton, may lead to a better understanding of why cheatgrass is so invasive and how it can be more effectively managed.”

Classical Biocontrol with Insects: New Questions Emerging

Classical biocontrol – the use of imported natural enemies such as insects to control a non-native invasive pest species – can be a very effective tool for controlling weed infestations. However, despite some spectacular successes, outcomes are often inconsistent or unpredictable. Much of the research done in the past focused on finding insect species that act on particular invasive species, rather than on predicting the effectiveness of such programs or understanding the broader ecosystem effects that might occur once the insects were released. Much more research is needed to explore and better understand potential biocontrol agents and how they will interact with their target species and the community as a whole.

Among the questions that need to be addressed: Which agents are best suited for use with which invasive species, based on their biology, ecology and the potential interactions between the species? How can we better predict how

two species will interact, given changing environments, including those altered by climate change? And how are the native plants that remain behind after successful biocontrol responding to a different environment? Are they rebounding once there is no competition from invasive species? Several studies funded by RMRS are exploring those questions.

One researcher, for example, is studying the chemical interactions between biocontrol agents and their invasive host species, to identify the factors that can affect successful biocontrol. “We are finding that biocontrol insects affect weed chemistry in very different ways,” says Dr. Justin B. Runyon, a research entomologist at the RMRS Biocontrol Research Laboratory in Bozeman, Montana. “We are finding that leaf- and root-chewing biocontrol insects cause the weeds to make huge amounts of defensive chemicals in leaves, whereas galling insects (those that build structures on the plants) have little impact on weed chemistry.” When weeds produce the defensive compounds, he explains, they may have fewer resources available for growth or producing seeds, helping lead to their demise. Runyon notes that in one study, he “tricked” houndstongue plants into producing defensive chemicals even without insects; instead, he applied a plant hormone. “Our goal is to isolate and determine what role



The toadflax stem-mining weevil known as *Mecinus janthinus* has often been used to control Dalmatian and yellow toadflax species.

these defense mechanisms play in successful biocontrol, and to see if the success of biocontrol agents can be related to the defenses they induce.”

Another research entomologist, Dr. Sharlene E. Sing, also at the RMRS Bozeman Biocontrol Research Laboratory, is looking at what happens when species evolve or otherwise adapt to new environments, in the context of weed biocontrol. “Classical weed biological control



Leafy spurge invades prairies, pastures and other open areas and is major pest in national parks and preserves.

Photo: Jack Butler

pairs biocontrol agents (non-native insects) with exotic plant species that have become invasive,” she says. Typically, these pairs co-evolved and are well suited to each other; the insects have evolved to consume the plants in one way or another. But what happens if the invasive plants have undergone some form of adaptation? Will the insects still be able to find and control them? Sing’s research is looking at improving biological control of two invasive species, yellow or common toadflax (*Linaria vulgaris*) and Dalmatian toadflax (*L. dalmatica*). The toadflax stem-mining weevil known as *Mecinus janthinus*, a biocontrol agent, has often been used to control both species. But now a hybrid invasive species, hybrid toadflax, has developed as a result of cross-pollination between the two invasive plants. In addition, genetically distinct biotypes of the weevil have been found in association with the two original invasive toadflax species. What do all of these new variations mean for biocontrol? Are the new weevil biotypes effective only against certain toadflax species? Will any of them be effective against the hybrid toadflax? Is there some other biotype of the weevil that might be more effective? Sing’s research hopes to tease out these complex relationships, resulting in a biocontrol project that addresses these genetic complexities.

And what happens after a successful biocontrol program? Few long-term studies have looked at how resident native plants respond when competing invasive weeds are suppressed. Research ecologist Dr. Jack L. Butler is studying how native vegetation has responded to suppression of leafy spurge (*Euphorbia esula* L.), an aggressive weed. He has found, for example, that while the total abundance of the native vegetation did increase after leafy spurge control, other factors did not improve. The relative abundance of the native species remained lower than that of the non-native species, and in fact, other non-native species essentially replaced leafy spurge as the dominant species. “This study highlights the need to treat new infestations as soon as possible, to avoid the long-term residual effects of large contributions to the seed bank, native species loss and ecosystem modification,” says Butler.

Musk thistle, an invader of the Black Hills, is an aggressive weed in pastures, rangelands and roadsides. Because it reproduces solely from seed, the key for successful management is to prevent seed production.

Other Projects: Fire, Birds, Seeds and More

Many other research projects funded by RMRS are also helping to fill in the missing pieces of the invasive species puzzle. Each one, in its own way, will contribute to a fuller understanding of the science of various species and their relationships. Ultimately, this body of information will help natural resource managers to develop better management options, leading to better control of invasives and the restoration of western ecosystems to a more natural state.

- Several studies are looking at the intersection of invasive species, fire and restoration. Over the last century, riparian communities along the Middle Rio Grande in New Mexico have become increasingly dominated by the invasive species salt cedar (*Tamarix ramosissima*) and Russian olive (*Elaeagnus angustifolia*). These woody plants have greatly altered the structure of these vegetative communities, and have increased the frequency and severity of wildfires. Native tree species, such as the Rio Grande cottonwood (*Populus deltoides* ssp. *wislizeni*) and Goodding’s willow (*Salix gooddingii*), unfortunately, do not resist fire damage well and do not regenerate very successfully after fire. This increased fire danger has led to a number of fuel reduction (exotic tree and debris removal) projects as well as studies on the potential effects on wildlife, vegetation and groundwater. For example, a long-term RMRS project is looking at the effects of fuel reduction treatments along several reaches of the Rio Grande, and how they might affect bird populations. The goal is to identify the fuel reduction practices that will preserve native species, reduce catastrophic fire risk, and have the least impact on native wildlife species. Related studies are seeking to assess the immediate and long-term responses of plants, animals and water to wildfire, to better understand how ecosystems respond to fire,



Photo: John M. Randall, The Nature Conservancy



Seeds of invasive plants catch on hiking boots, which transport them to new areas to invade.

Photo: Alan Cleaver

to compare invaded fire-prone ecosystems on the Middle Rio Grande to those relatively free of invasives, and to aid in the development of ecosystem management practices.

- Ponderosa pine forests of the Black Hills are also at high risk for high-severity fires, due to changes in the historic fire regime. After the 2000 Jasper fire, the largest fire in the history of the Black Hills National Forest of South Dakota, RMRS researchers began studying how the severity of different burns may influence where non-native plants show up. A manager armed with this knowledge will be better equipped to detect and control weeds following a fire. Similarly, RMRS ecologist Stefanie Wacker is examining responses of native and invasive plants to disturbances from timber harvest; she plans to use her results in a Ph.D. dissertation at South Dakota State University.
- The Great Basin Native Plant Selection & Increase Project, with funding from Bureau of Land Management's Great Basin Restoration Initiative, is working on several fronts to increase the availability of native plant seeds and foster successes in restoring native plant communities across the Great Basin. Some 20 different groups in ten states are working on various projects. Among their goals are an increased understanding of genetic variability in native species; identifying pollinators, seed predators and plant diseases; developing management strategies to enhance agricultural seed production; and transferring their research results to seed growers and land managers.

What Can You Do About Invasive Species?

Learn more about invasive species in your area. Check out the National Invasive Species Council website, at www.invasivespecies.gov. The site holds an extensive list of background information, including fact sheets and photographs, resources for land managers and teachers, and more. Your local Cooperative Extension office may also have information on invasive species that are a problem in your area. You can find your local office at www.nifa.usda.gov/Extension/USA-text.html. Also consider how your activities might be contributing the

problem. Have you accidentally introduced a hitchhiking exotic plant seed, pathogen or virus from your travels abroad? Could you be spreading invasive species as a boater, hiker, horseback rider, biker or angler? Have your off-road vehicle explorations disturbed soils and plants, opening the area for invasions? Learn what local programs are in place to combat the problem.

The National Invasive Species Council offers some practical tips:

- Clean hiking books, waders, boats and trailers, and off-road vehicles and other pathways of spread to stop hitchhiking invasive species
- Use certified "weed-free" forage, firewood, hay, mulch and soil
- Don't dump live bait into waterways
- Remove invasive plants from your land
- Plant non-invasive plants in your garden
- Care for aquarium fish and other pets properly so they don't become invasive

Bozeman Biocontrol Lab Renovation – Almost Done!

An extensive renovation of the RMRS Bozeman Biocontrol Research Laboratory, which is administered by GSD, is nearly complete.

The main building is being modernized with a new heating system, restrooms, lighting and finishes. There is also new state-of-the-art research equipment, including two growth chambers, a fume hood and other lab and greenhouse apparatus. Outside, the building has been restored to its original 1962 style. An RMRS Sustainable Operations microgrant, awarded to Dr. Justin Runyon, will be used to install pollinator-friendly, drought-tolerant landscaping, further enhancing the exterior.

The nearby warehouse building has also been upgraded, with a new roof, siding, insulation and lighting. Both buildings will also have updated safety and handicap features, as well as energy-saving measures.



Illustration of the renovated RMRS Bozeman Biocontrol Research Laboratory at the Montana State University campus in Bozeman, Montana.



A message from the Program Manager

Invasive Species is one of five focal areas of the Grassland, Shrubland and Desert Ecosystems Science Program (GSD). Our program mission is to develop and deliver knowledge and tools that will help to sustain and restore grasslands, shrublands and deserts threatened by invasive species, disturbances, urban pressures and climate change. Scientists in our program study the physiological, behavioral and demographic responses of plants and animals to invasions by non-native species, especially in interaction with other stressors such as fire and climate change. Our research also evaluates the capacity for species to adapt to environmental changes. We provide decision support by developing new plant materials for use in restoring ecosystems under stress, guidance for identifying ecosystems at risk from invasive species, and assessments and tools for determining species and ecosystem vulnerability.

—Dr. Deborah Finch,
Science Program Manager

Meet Some of the GSD Scientists



Dr. Jack Butler is a research ecologist at the RMRS Forest and Grassland Research Laboratory in Rapid City, South Dakota. His research addresses invasive species impacts, biological control of invasive species and range ecology. He works with managers in the northern Great Plains to help identify effective methods and practices for sustaining rangelands, including populations of native plant and animal species. He has hosted several workshops on black-tailed prairie dogs and livestock management, and he seeks solutions for eradicating exotic plants such as leafy spurge and sickleweed and restoring native plant communities.



Dr. Susan Meyer is a research ecologist stationed at the RMRS Shrub Sciences Laboratory, Provo, Utah. Her work focuses on the regeneration biology of native intermountain shrubs, forbs and grasses, in the context of the ecological restoration of shrublands, including the study of within-species genetic variation in germination regulation and seedling establishment ecology. She also works on the biology and pathogen control of the exotic annual grass cheatgrass.



Dr. Rosemary Pendleton is a research ecologist stationed at the Forestry Sciences Laboratory in Albuquerque, New Mexico. Her current research focuses on reproductive biology and establishment ecology of native plant species. She has studied the effects of fire on grassland vegetation and soil properties, including perennial grass recovery, biodiversity, floral resources for pollinators, soil microtopography and biological soil crust function. She is also investigating the biology and control of cheatgrass using endophytes, and the reproductive biology and gene flow in creosote bush (*Larrea tridentata*) at the northern ecotone.



Dr. Justin Runyon is a research entomologist stationed at the RMRS Bozeman Biocontrol lab who conducts research on biological control of invasive plants. He is involved in the search for and the evaluation, approval and monitoring of exotic natural enemies (usually insects) for the suppression of invasive weeds. A goal of his research is to understand and predict the outcomes of biocontrol introductions by applying the chemical ecology of plant-insect interactions to classical biological control of weeds – two fields that have largely progressed independently to date.



Dr. Sharlene Sing, stationed at the RMRS Weed Biocontrol Lab in Bozeman, Montana, works on many collaborative studies to improve the efficacy and safety of classical weed biological control. One study aims at determining if toadflax biocontrol agents exhibit differential responses to yellow x Dalmatian toadflax hybrids vs. either of the parental toadflax species. She has engaged in long-term pre- and post-biocontrol release monitoring projects on yellow and Dalmatian toadflax, leafy spurge, salt cedar and Russian olive. Also, she is assessing the potential for integrating herbicide treatments and biological control of Dalmatian toadflax on prescribed burn-treated rangeland.



Stefanie Wacker is a Ph.D. student at the Geographic Information Science Center of Excellence, South Dakota State University, Brookings, and is also employed as an ecologist by RMRS under the Student Career Experience Program authority. She is stationed at the Forest and Grassland Research Laboratory in Rapid City, South Dakota. Her Ph.D. research is evaluating the effects of timber harvesting on understory invasive and native plant species of ponderosa pine forests in the Black Hills of South Dakota.

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Cottonwood is often killed by fire, but invasive salt cedar resprouts and spreads, as seen here after a Rio Grande fire.

Photo: USDA Forest Service



Field crews measure tamarisk structure before control treatments.

Photo: USDA Forest Service

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Grassland, Shrubland and
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Publications are available online in TreeSearch: www.treesearch.fs.fed.us.

