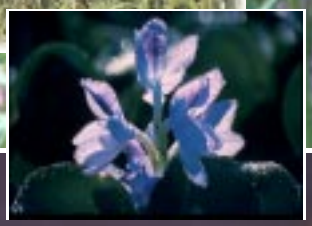
Invasive Species Science Strategy for Department of the Interior Lands in the USGS Central Region

April 2000



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

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Cover: From coastal wetlands to grasslands to mountains, invasive species threaten natural habitats and ecosystems. Examples of invasives include water hyacinth (insert) and purple loosestrife (background, courtesy Robert E. Stewart, Sr. Collection). U.S. Geological Survey photos.

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April 1, 2000

Compiled by
U.S. Geological Survey's Invasive Species Working Group

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Introduction

The spread of invasive species across the Nation is one of the most daunting ecological problems facing 21st century natural resource managers. Impacts on native habitats range from insidious to catastrophic, and cost Americans about $138 billion annually according to a 1999 Cornell University study. An estimated 5,000-6,000 invasive species have become established in the United States, and recently published studies suggest that invaders now present a threat to ecosystems and endangered species that is second only to habitat destruction.

The threats posed by the uncontrolled spread of invasive species range from loss of native species diversity to alteration of ecological structure and function, with nearly all aspects of ecological systems potentially affected. Eradication of invasive species that have already established themselves is the most difficult challenge, one that will require traditional approaches as well as molecular, biological, and chemical defenses that have yet to be discovered. Also of great importance is the development of strategies for the early detection of invasive species, for predicting their spread, and for reducing pathways of introduction.

Monitoring, prevention, and control of invasive species all depend on a thorough understanding of their ecology, dispersal mechanisms, and interactions — information sorely missing for all but a handful of species that threaten America's grassland, mountain, forest, and aquatic ecosystems in the Nation's interior and coastal regions. Increased public awareness is also needed to foster cultural and behavioral changes that are essential in combating invasive species problems through early detection and prevention.

The U.S. Geological Survey (USGS) is uniquely capable of conducting invasive species work in the USGS Central Region (Figure 1) with its cooperative research units, district offices in each State, and biological Research Centers in Montana, North Dakota, Colorado, Missouri, and Louisiana, and their field stations in additional States. The merging of water, geologic, mapping, and biologic research programs within the USGS has enhanced the potential for conducting invasive species research and monitoring. Meeting the science needs of Department of the Interior (DOI) managers is an important goal stated in the USGS strategic plan. The USGS provides a neutral framework for conducting assessment and research, and is the lead Federal agency for linking quality science to management needs in natural and seminatural ecosystems.

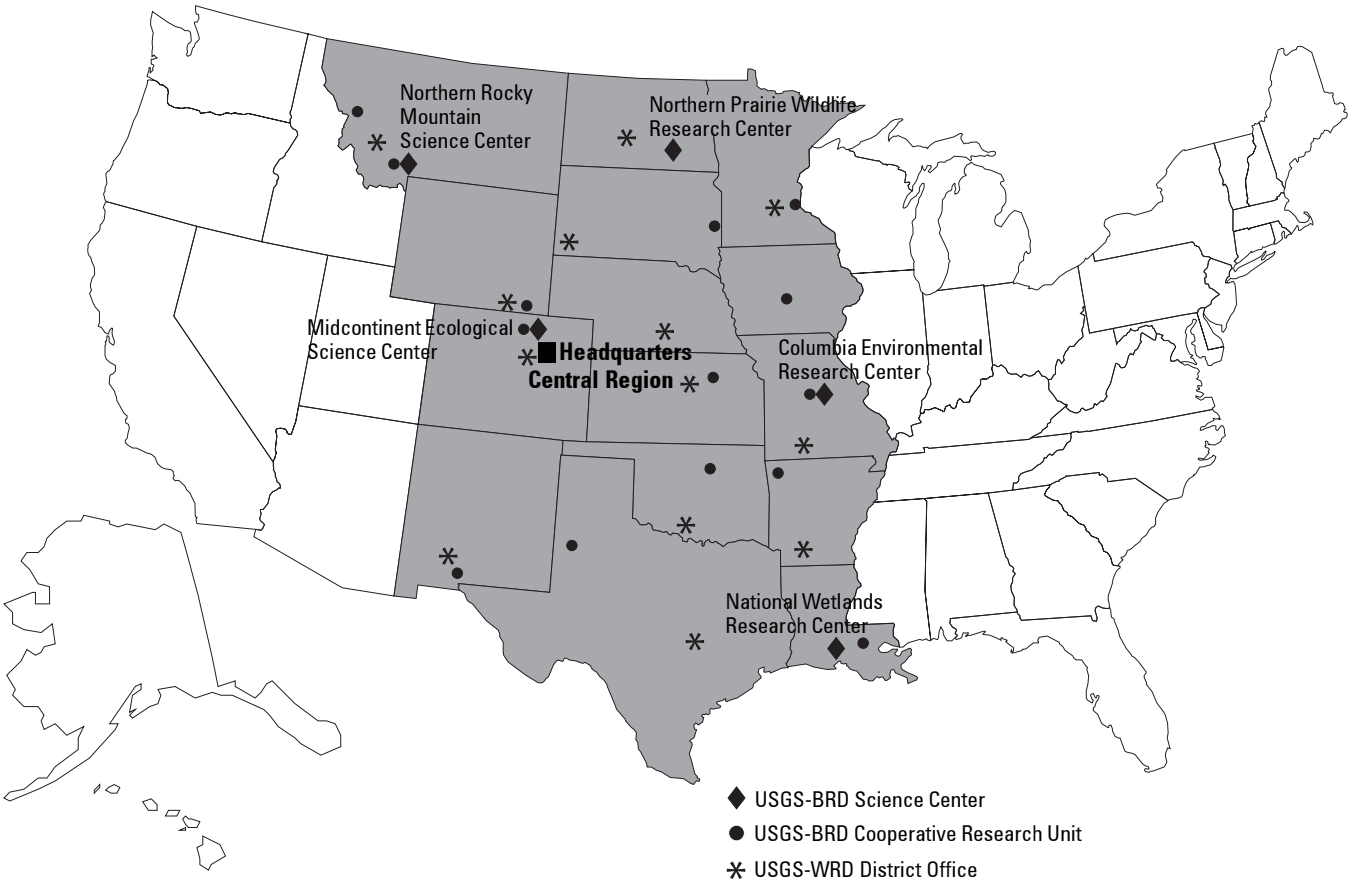

Figure 1. U.S. Geological Survey's Central Region including Biological Research Centers and Cooperative Research Units as well as Water Resources District Offices.

Rationale and Objectives

The DOI manages approximately 13.365 million ha (33 million acres) of Federal land in the Central United States, including 90 National Park Units (2.5 million ha; 6.2 million acres), 174 National Wildlife Refuges (2.7 million ha; 6.7 million acres), and 7.6 million ha (18.7 million acres) of Bureau of Land Management (BLM) lands. Invasive species topics have ranked among the top three research needs submitted annually by the region's land management bureaus since 1995. For National Parks, invasive species are ranked as a top threat to the natural and cultural resources in the USGS Central Region. The National Park Service (NPS) Natural Resource Challenge, which calls for inventory and monitoring to assess "vital signs" within and among parks, provides an unprecedented opportunity for the USGS to provide support for NPS personnel concerned with invasive species.

With limited resources among DOI bureaus and a wide range of potential research projects, it is important that a regionwide strategy be developed to provide land and natural resource managers with the information they need as quickly and effectively as possible. Research needs are not limited to detection and impact assessment. Management-oriented research could provide the information needed to control or eradicate invasive species and to promote ecological integrity that prevents their further spread.

In response to concerns expressed by DOI resource managers, the USGS-Biological Resources Division (BRD) established invasive species as a core program element in 1998. Five national goals were established, around which BRD Regions and Research Centers agreed to focus and structure their activities. These goals include (1) understanding the pathways of introduction, (2) assessing and reporting the abundance and spread of invasive species, (3) assessing the effects of invasive species on ecosystem properties, (4) considering the susceptibility of systems to invasion, and (5) developing and evaluating management and control methods.

In 1999, the USGS Central Regional Office appointed a team of BRD scientists to form working groups with advisors from DOI client agencies to identify the major invasive species problems and research needs for six major ecosystem types or "biomes" in the 15-State Central Region. The NPS Intermountain Region office assisted the working groups by surveying Central Region parks to identify specific problems and management needs. The BRD leader for each working group compiled the findings and recommendations for the respective biomes. This document represents a synthesis of the various working group (i.e., biome) reports and outlines integrated strategy based on their recommendations (BRD contributors and DOI advisors are listed in Appendix 1).

Invasive species are loosely defined to include (1) all alien, nonnative plant and animal species such as European cheatgrass, German brown trout, and white pine blister rust from Asia and (2) native species (from somewhere in the United States) that have been introduced to areas they would not have occupied naturally, such as lake trout into Yellowstone Lake. (Common names of species are used in this report; other common names and scientific names are given in Appendix 2.) In some areas, human activities have caused atypically high rates of spread of species that are indigenous to the Central Region (e.g., invasive shrubs in arid grasslands, native trout in previously fishless lakes). This strategy focuses primarily on nonnative invasive species.

Major Biomes of the Central Region

Centered roughly on the 100th meridian, the USGS Central Region stretches from the Canadian border to the Gulf Coast and from the Mississippi River to the Intermountain West. The region encompasses a wide variety of terrestrial and aquatic habitats (Figure 2, Fenneman physiographic map). In the southern ***Coastal Plain***, low-lying Gulf Coast wetlands slope upland into Coastal Prairie and bottomland hardwood wetland forests, with a deep extension up the Mississippi Valley. To the north, the ***Ozark Plateau*** and ***Ouachita Mountains*** cover a smaller area, though with high native biodiversity. On the plateau, the rolling landscape of oak-hickory forest is interrupted by low mountains and narrow valleys. The Ouachita Mountains trend east to west and include communities dominated by pine in addition to the oak and hickory.

Grasslands and prairies characterize the flat to gently rolling plains and tablelands of the ***Great Plains*** and western ***Central Lowlands***. Shortgrass and mixed-grass prairie is scattered with trees, shrubs, and occasional valleys, canyons, or mountains break the extensive view from the Great Plains. In the easternmost portion of the Central Lowlands, tallgrass prairie is interspersed with deciduous forests. To the west, the ***Rocky Mountains*** rise as high as 4,300 m (14,000 ft) and have pronounced vegetation zonation. The various zones, including alpine tundra, subalpine forest, and dry, rocky foothills, support a variety of plants and animals. In the midst of the Rocky Mountains, the semidesert environment of the ***Wyoming Basin*** consists of high plains broken by isolated hills and low mountains. These ***arid lands*** support a variety of species adapted to a drier environment. In the southwestern corner of the region, the Chihuahuan Desert features the region's most arid land, with undulating plains from which somewhat isolated mountains rise.

Aquatic ecosystems of the Central United States are as diverse as the region's topography and climate. Much of the Nation's surface water resources occur here in the form of natural lakes and human-constructed reservoirs; large rivers, many of which have been harnessed for hydropower production and flood control; high mountain streams and lakes; small spring-fed streams; ephemeral pools and streams in the southwest area; hydrothermal springs and geysers; the western end of Lake Superior; and numerous natural lakes and wetlands created by glacial activity. These aquatic habitats and their accompanying riparian zones support an equally diverse group of biotic communities. They occur within each of the other major biomes and also serve as corridors for invasion between them.

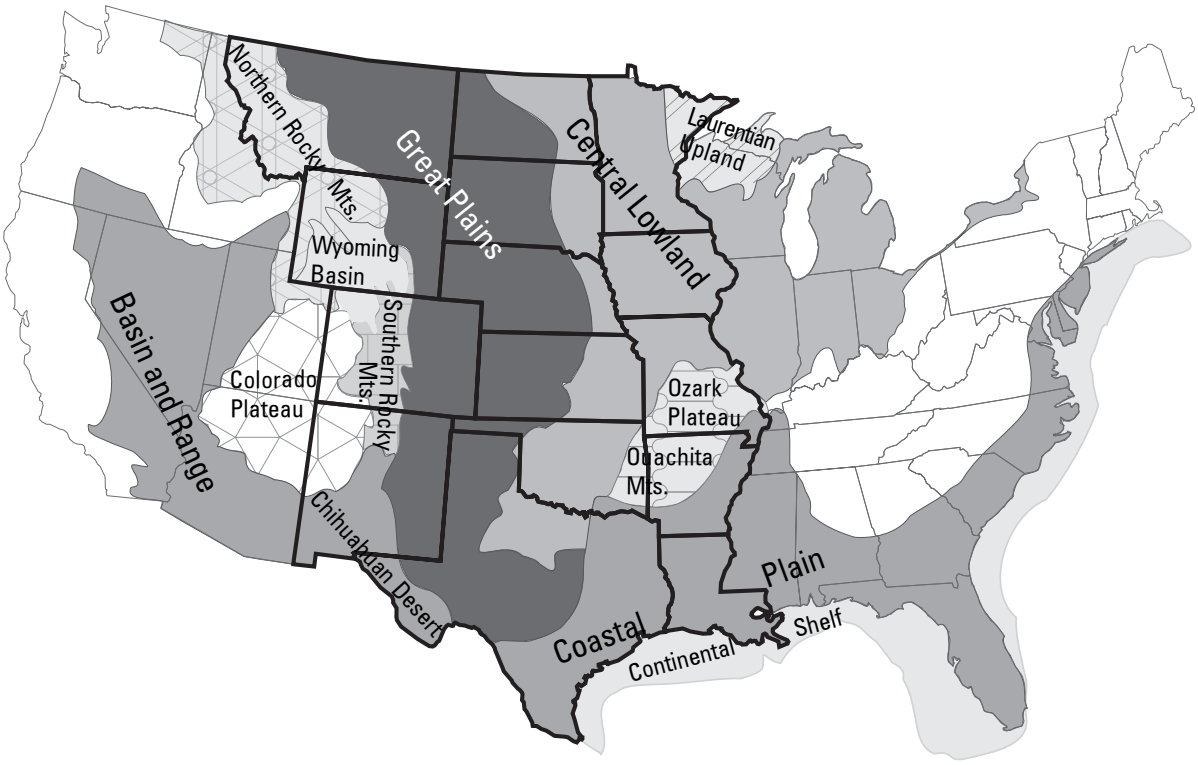

Figure 2. Central Region biomes, based on Nevin M. Fenneman's 1928 "Physical Divisions" map that appears in *The National Atlas of the United States of America*, published by the USGS in 1970.

Overview of Invasive Species Problems on DOI Lands

All Central Region biomes are affected by invasive species. Some have been present for 100 years or more, but the observed numbers and impacts of invasive species have increased dramatically during the past three decades. Short-term effects on native flora and fauna can be serious, even disastrous, but their cumulative impacts on ecosystems may not be understood until decades after the invader has become established. Recent widespread invasions of new species in the central region portend dramatic changes in ecosystems during the 21st century. An overview of current invasive species problems identified in Central Region biomes is presented below.

Coastal Plain

Department of the Interior trust resources in the Gulf Coastal Plain are potentially affected in a number of ways by invasive species. Loss of native biological diversity constitutes one of the biggest long-term potential impacts affecting the 10 National Parks and 44 National Wildlife Refuges in the Central Region Coastal Plain. In addition, changes in ecosystem characteristics due to invasive species raise important concerns about many issues including alteration of wildlife habitat, changes in fire regimes, impacts on restoration efforts, changes in soil erosion rates, and the need for adjustments in management plans.

A wide variety of species constitute invasive threats to the Coastal Plain. At present, an overall assessment and ranking of these threats are lacking and constitute a basic information need. It is also important to keep in mind that invasive species that are currently absent from the Central Region Coastal Plain may pose major future threats of unknown severity. Different ecosystem types vary in the species that pose problems and the degree to which they are currently affected or threatened by invasive species.

The most widely recognized invasive species of the Coastal Plain occur in aquatic habitats. They include such famous invaders as water hyacinth, hydrilla, small-leaved salvinia, giant salvinia, water lettuce, and Eurasian water-milfoil. In coastal marshes, a smaller number of invaders cause problems, though these can be locally severe. The introduced giant sugarcane plumegrass produces enormous, dense stands that are generally believed to be of little wildlife value, while alligatorweed causes local reductions in native diversity.

In coastal Texas and Louisiana, escaped populations of Chinese tallowtree have established extensive, self-replacing monocultures that have radically altered marsh, forest, and prairie ecosystems. Tallow's ability to grow and escape into the wild, however, appears to be strongly limited by winter

minimum temperatures at present. For this reason, it is only likely to pose a problem below about 32°N latitude. Unlike native woody plants of the region, tallow is capable of its greatest growth in wetland habitats; it is more tolerant of flooding and salt stress than many native species. But its threat to native coastal habitats has received little analysis.

Animals also cause problems for coastal marsh and baldcypress swamps, most conspicuously the introduced nutria, a large exotic rodent. Nutria populations are currently at high levels because of a general collapse of the fur trade and a near cessation of harvesting pressure. The feeding activities of nutria lead to the denudation of local areas of concentrated use. In 1999, over 40,500 ha (100,000 acres) of Louisiana coastal marshes were denuded by nutria; the more degraded areas will likely naturally convert to open water, with little chance for recovery.

The Coastal Prairie ecosystem along the Texas and Louisiana coast, as with most other prairie and grassland ecosystems, is badly degraded, severely infested with invasive species, and at severe and immediate risk from further degradation. Since only about 1% of the original Coastal Prairie remains in even seminatural condition, this system is particularly vulnerable. Perhaps the most severe threat comes from the Chinese tallowtree, which suppresses fire, thereby converting Coastal Prairie from a fire-controlled system to a tallow-controlled one. A number of other invaders are also believed to contribute to the degradation of the Coastal Prairie, including Macartney rose, Brazilian vervain, Japanese climbing fern, Johnsongrass, and several escaped pasture grasses. Nonnative animals also cause problems for management of Coastal Prairie habitat. Of greatest impact are red fire ants, believed to cause dramatic reductions in native ants and other insects as well as adverse effects for amphibians and small mammals. Feral hogs contribute substantially to soil disturbance in Coastal Prairie systems and have been observed to facilitate successful invasion by Chinese tallow at the Aransas National Wildlife Refuge.

Introduced pasture grasses also pose major problems for native vegetation in the mesquite savannas of southern Texas. Guineagrass is widely planted for cattle pastures and escapes readily and rapidly. Productivity of escaped populations appears to be very high compared to native assemblages, and near monocultures develop in the understory of infested savannas. A similar pattern occurs for other invasive grasses, including King Ranch bluestem, buffelgrass, Kleberg bluestem, and Lehman's lovegrass. The interactive effect of historical as well as current grazing practices on invasive species problems is an additional concern in this region.

In the inland floodplain forests of the Lower Mississippi Alluvial Valley, as well as oak-hickory forests in Louisiana and Arkansas, Chinese tallow is again a major concern. This species achieves its highest growth rates in mesic sites and, given sufficient light, can invade and achieve canopy status. Nutria damage to seedlings and saplings is another major invasive problem for floodplain forests. In restoration efforts in particular, nutria have been found to decimate regeneration, destroying 80%-100% of the planted seedlings and saplings. Effects on natural regeneration are also believed to be high. A number of plants are known to cause locally important problems in the hardwood and pine forests of the Coastal Plain region, including Japanese honeysuckle, Chinese privet, multiflora rose, and kudzu. The fruittree leafroller, best known as an insect pest on fruit trees, was first observed in a small tract of southern baldcypress in the Atchafalaya Basin in 1983; by 1993, approximately 60,000 ha (148,260 acres) were infested. Repeated defoliation by this new pest causes partial dieback of mature baldcypress trees and mortality of saplings. The Formosan termite is another new insect pest in Gulf Coast baldcypress and live oak stands and in historic buildings in some National Parks.

Rocky Mountains

The Rocky Mountains extend 5,000 km (3,100 mi) from New Mexico to Canada, creating the western border of the Central Region. The elevations range from about 1,500 m (4,922 ft) along the plains to 4,399 m (14,433 ft), and the widths range from 120 km (75 mi) to 650 km (404 mi). There are many examples of invasive fishes, mammals, plants, insects, and diseases in the Rocky Mountains.

Hundreds of highly invasive exotic plant species have had profound effects on the ecology and economy of the Rocky Mountain region. For example, European cheatgrass has invaded significant portions of the western pinyon-juniper woodlands, ponderosa pine, Douglas-fir, and prairie areas throughout the region. Many native shrubs and perennial grasses cannot survive the increased competition from cheatgrass (as many as 3,000-10,000 plants/m^2; 280-930 plants/ft^2), which alters fire frequency and intensity. Instead of fires occurring every 60 years, they now occur every 3-4 years in areas where cheatgrass has displaced native sagebrush and grass cover. Several rare plant species are being displaced by cheatgrass and other introduced plants. Purple loosestrife (another European weed), Russian olive, and tamarisk are rapidly invading wetlands and streamsides. Purple loosestrife spreads quickly and crowds out native plants that animals use for food and shelter.

Sagebrush and mountain shrub habitats are seriously impacted by leafy spurge and Russian knapweed, and are beginning to experience widespread invasion of many species like spotted knapweed, diffuse knapweed, yellow toadflax, and dalmatian toadflax, ox-eye daisy, and other ornamental plants. In addition, some of the nonnative plants used in rehabilitation efforts are thought to be invasive species that can displace natives. These include grasses like smooth brome, orchardgrass, yellow sweetclover, and forage kochia.

Many forest-dwelling Neotropical migrant songbirds breed in the Rocky Mountains and winter in Central and South America. Wildlife biologists suspect that declining population size in the songbirds may be due, in part, to increased predation and brood parasitism by invasive bird species, such as the house sparrow. Invasive plants can also alter the structure of native habitats, making them less fit for songbirds and other fauna.

Two species of hoofed mammals were deliberately introduced into Colorado, the Rocky Mountain goat and the moose. Although these species occasionally wandered into Colorado in pre-settlement times, breeding populations did not occur until after deliberate introduction. Accidentally introduced mammals in Colorado and Wyoming include the house mouse and the Norway rat. The potential effects of these introduced mammals on Rocky Mountain ecosystems are poorly understood.

A host of introduced pathogens are having profound effects on native species. White pine blister rust is decimating whitebark and timber pines in the northern Rocky Mountains. The disease has eliminated most whitebark pine west of the Continental Divide and now occurs in Yellowstone National Park. Whitebark pine nuts are the most important fall fattening food for grizzly bears in the Yellowstone ecosystem. In years of pine nut failure, mortality of grizzly bears due to conflicts with humans increases threefold. Loss of whitebark pine could significantly reduce the carrying capacity and affect population dynamics of the threatened grizzly bear.

Lungworm-pneumonia complex is a bacterial disease that causes spontaneous mortality in the lambs of bighorn sheep in summer. Although some strains of the disease complex are native to bighorn sheep and others are related to domestic sheep, disease exchange can be fatal to both groups. Proximity to domestic sheep is highly correlated with mortality in newly reestablished bighorn sheep populations. Whirling disease, introduced from Europe, is a parasitic infection that attacks recently hatched trout. It is now affecting native and nonnative trout populations in Colorado. At first, the disease was thought to affect only hatchery fishes; however, the native greenback cutthroat trout may also be susceptible. Amphibian decline throughout the region may be due, in part, to predation by nonnative sport fishes and introduced pathogens.

Arid Lands

Arid portions of the Central Region include the "cold" desert of the elevated Colorado Plateau (western Colorado and northwestern New Mexico) south into the "warm" Chihuahuan Desert (southwest New Mexico and west Texas). These arid regions have been heavily invaded by tamarisk in riparian habitats. Invasive plants including leafy spurge, Russian knapweed, and yellowstar thistle are spreading in these arid areas. Throughout much of the arid lands in the Central Region, native grass cover has declined as much as 35% since 1900, while mesquite, other shrubs, and invasive plant species have increased exponentially. These plants are expanding their ranges into grasslands and shrublands, especially where the grasslands and shrublands have been overgrazed, but they are often controlled to some extent as part of grazing management.

In the arid Southwest, National Park Service staff cited concerns related to an extensive list of invasive grasses and forbs (e.g., yellow sweetclover, musk thistle, two species of whitetop, several species of knapweed, common mullein, field bindweed, buffelgrass, and fountain grass). Collective ecological changes associated with these species are extensive: alteration of wildfire frequency and intensity, loss of native plants and animals, soil erosion, changes in nutrient cycling and other aspects of soil biogeochemistry (including microbial ecology), loss of plants of traditional cultural importance, and decline of soil moisture and water table depth.

Several invasive woody species, particularly tamarisk and Russian olive, have become serious problems over the past 50 years. Their invasion is partly attributed to attempts at soil stabilization and livestock grazing. They have resulted in changes in topsoil erosion rates, fire regime, and riparian habitat disturbance. Once these invasive shrubs become established, there is only limited potential for conversion to native grasses and woody species. When tamarisk invades a site, changes in ecosystem function result in a redistribution of nutrient and water beneath and within these invaders. There has been some success in the use of fire to reduce honey mesquite and increase grass cover in the neighboring Sonoran Desert of Arizona.

The xeric landscapes of the Central Region have been affected by many introduced animal species including horses, burros, pigs, goats, Barbary sheep (and even gemsbok and ibex in New Mexico and many exotic game animals in Texas), red deer, dogs, cats, mice, and rats. Nonnative bullfrogs are known to affect native amphibian populations. Little is known about the cumulative or long-term affects of most of these introduced species.

Widespread grazing by cattle, however, has caused major cumulative effects on the ecology of the arid Southwest. Many native grasses preferred by cattle, such as ryegrass, have entirely disappeared in some arid rangelands. Cattle have also altered vegetation composition by serving as an agent for the spread of invasive grasses such as Lehman's lovegrass. Grazing by large cattle herds has also reduced fire frequency by the reduction of fuel in some areas, which is leading to limited expansion of woodlands into semidesert grassland. Conversely, cattle have reduced the regeneration of palatable woody species such as willow and cottonwood in riparian areas.

Cryptobiotic crusts (dominated by blue-green and green algae, lichens, mosses and microfungi) of the arid Southwest region are also affected by invasive plants and animals. These crusts, which stabilize soils and intercept rainfall, contribute nitrogen and organic matter to ecosystems, which are especially important in desert ecosystems where nitrogen levels are low and often limit productivity. The algal fibers that generally confer tensile strength to the living soil crusts are easily destroyed by cattle, especially when the crusts are dry and brittle. Changes in fire and moisture regime associated with invasive plants can also affect these unique crustal ecosystems.

Central Grasslands

There are four main types of Central grasslands: grading wettest to driest, they are the prairie pothole wetlands and the tall-grass, mixed-grass, and short-grass prairies. Fewer than

10% of the Central grasslands that existed when Europeans arrived remain today; these grasslands are among the Nation's most imperiled ecosystems. Remaining central grasslands are vulnerable to invasive alien plants, and some are in danger of losing the very characteristics that distinguish them as native grasslands. Land managers in the DOI have long recognized this threat. Weed management is part of the management plan for virtually all federally controlled grasslands in the Central Region. Some DOI grassland managers reported particularly serious problems with invasive weeds. In a recent survey at Theodore Roosevelt National Park, a cool season grassland, only 13% of the 847 transects were free from alien plants, and the invasive yellow sweetclover was the sixth most common species encountered.

Although some portions of the grassland ecosystem are not yet significantly infested with invasive plants, BLM and other land management agencies are concerned about the loss, possibly irrecoverable, of native grasslands that may occur if action is not taken to prevent the spread and establishment of invasive weeds. Species of concern in the northern portion of the Central Region include leafy spurge, Kentucky bluegrass, Canada thistle, smooth brome, European cheatgrass, knapweeds, musk thistle, star thistle, and sweetclovers. Farther south in the Great Plains and south Texas, invasive species include Bermudagrass, Kentucky bluegrass, Johnsongrass, Guineagrass, buffelgrass, sericea lespedeza, Scotch thistle, kochia, and red-horned poppy. Buffelgrass invasion has destroyed habitat required by the reticulate collared lizard and spot-tailed earless lizard, reptiles with a very restricted range in south Texas that are thought to be declining.

In the southern Great Plains sericea lespedeza has become a serious invader of native prairies and is thought by many managers to be their greatest threat. The species was widely planted for roadside stabilization and is still in use as a pasture plant in the Southeastern United States. Likewise, smooth brome, crested wheatgrass, and Bermudagrass were planted for stabilization or forage but have proven themselves persistent invaders of native prairies. Leafy spurge and Canada thistle are both targets of extensive biological control programs, although success has been variable, particularly with respect to thistle.

Many riparian zones and prairie wetlands of the Central Region are already heavily invaded by Russian olive, cattail, and purple loosestrife. Though this list is far from exhaustive, it illustrates the taxonomic breadth of the issue. Moreover, the taxonomic implications of invasive plants are somewhat unclear because many invasive plants are congeners of native species, and some (e.g., *Bromus inermis*) have been found to produce hybrids.

Notably few on this list of grassland invaders are animals. Although feral dogs and cats cause severe problems in local areas, they are not broadly identified as problem species throughout the region's grasslands and prairies. Three National Parks cited feral hogs as significant problems. Undoubtedly, many less conspicuous invertebrates have gained footholds in the central grasslands with no one to observe their presence. We know that cabbage butterflies, for example, are a widespread Eurasian species, but we are ignorant of their effect on native plants and animals.

Pathogens associated with introduced species are having significant effects on some grassland fauna. The herpes virus that causes duck plague is an example of an infectious disease of domestic waterfowl that has begun to infect migratory waterfowl. This virus first appeared in the Western United States near San Francisco in 1972; in 1973 duck plague killed approximately 40,000 mallards in southeastern North Dakota. Avian cholera, a disease of domestic poultry since at least 1867, was not a widespread concern of grassland bird managers until the mid-1970's when it emerged as a major cause of death in migratory waterfowl.

Ozark Plateau and the Ouachita Mountains

Except for a small area in Illinois, all of the Ozark Plateau and Ouachita Mountains fall within the USGS Central Region. The Eastern Deciduous Forest is the largest and most extensive plant community of the Ozark Plateau and Ouachita Mountain area. In addition, the Ozark Plateau formerly supported several large areas of prairie, and a few remnants remain. Nine National Park units and 14 National Wildlife Refuges are located within the Ozark Plateau and Ouachita Mountains.

Large areas of the Ozark Plateau and Ouachita Mountains are relatively undisturbed by midcontinent standards and are floristically diverse; but these locations have few nonnative plants. For example, about 13% of the 976 vascular plants found at Ozark National Scenic Riverways in south-central Missouri are nonnative, a percentage that is below that for the National Parks in the Midwest (17%) and the remainder of the State of Missouri (28%). In a recent inventory of the flora of seven natural landmarks along the Jacks Fork River at Ozark National Scenic Riverways, botanists collected 636 plant taxa; only 43 taxa were nonnative. Of the nonnative taxa only sericea lespedeza, star thistle, and Johnsongrass are considered aggressive invaders. However, the number of invasive species collected in riparian areas suggests that these areas may act as corridors for the movement of invasive species.

That there is a lack of nonnative taxa in the large National Parks of the Ozark Plateau and Ouachita Mountains is also supported by botanical surveys at Buffalo National River Park in northwest Arkansas. In a recent study of the effects of prescribed fire on savanna and glade plant communities at Turkey Mountain, a wilderness area within the park, botanists collected 351 species; only 4 were nonnative. None of the four species is considered an aggressive invader. In the riparian forest of Buffalo National River, however, botanists have recorded 377 plant taxa; only 33 were nonnative, again suggesting that riparian areas may act as invasion corridors. Of the nonnative taxa at Buffalo National River, several are aggressive invaders: Japanese honeysuckle, sericea lespedeza, multiflora rose, annual bromes, and garlic mustard. Unfortunately, the extent of the area invaded by these species is unknown. The park has been successful in eradicating kudzu from abandoned residential sites.

In contrast to the larger National Parks of the Ozark Plateau and Ouachita Mountains, the small National Parks have a history of disturbance and host many nonnative plants. About a third of the flora of Wilson's Creek National Battlefield, a 708-ha (1,749.5-acre) Civil War battlefield park in southwestern Missouri, is nonnative. Similarly, invasive species account for about 20% (112 out of 605 species) of the flora of George Washington Carver National Monument, a historic site also in southwestern Missouri. Invasive, nonnative plants threaten many of the significant cultural and natural resources of small National Parks. At Wilson's Creek National Battlefield, species such as Osage orange and annual bromes threaten unique limestone glade plant communities and the federally endangered plant, Missouri bladderpod. Also at Wilson's Creek, restoration of historic oak savanna has been hampered by invasive, nonnative species such as sericea lespedeza, Johnsongrass, and two species of sweetclover. Wilson's Creek and other small parks are using tree removal, mowing, limited herbicide application, and prescribed fire to control nonnative plants. In 1994, Wilson's Creek National Battlefield began long-term plant community monitoring under a joint USGS-NPS inventory and monitoring program.

The National Wildlife Refuges in the Ozark Plateau and Ouachita Mountains report problems with nonnative plants similar to those reported by the small National Parks. Agricultural weeds are common on refuges, because of their managed habitat and proximity to agricultural lands. Common invasive weeds include sericea lespedeza, kudzu, Johnsongrass, and barnyardgrass. Kudzu is a particular concern for refuges in Arkansas, where well-established stands and new infestations threaten native forest. For example, at Holla Bend National Wildlife Refuge (NWR) in Arkansas, a fairly new infestation of kudzu covers 41 ha (101 acres) and is spreading rapidly. This aggressive species is capable of overtopping mature forest and shading out all light to the understory. Johnsongrass and barnyardgrass infest 816 ha (2,016 acres) and 2,041 ha (5,043 acres) respectively, at Bald Knob NWR in Arkansas. Johnsongrass also infests 816 ha (2,016 acres) at Holla Bend NWR in Arkansas, 1,220 ha (3,015 acres) at Washita NWR in Oklahoma, and 200 ha (494 acres) at Mingo NWR in Missouri. These nonnative grasses crowd out and prevent the reestablishment of native grasses, which are preferred wildlife forage. Washita NWR is also battling an infestation of red-horned poppy, a common agricultural weed that is very difficult to control as it produces seed nearly year-round. This agricultural weed may be gaining a toehold in wildlands as well.

Aquatic Ecosystems

Aquatic ecosystems occur in each of the other major biomes in the Central Region. Because of human development of water resources and changes in watersheds, many aquatic systems have been altered. Large river systems like the Mississippi, Missouri, Platte, Arkansas, and Colorado are dammed or leveed for hydropower, flood control, or other purposes.

Lakes, streams, rivers, and other aquatic habitats of the Central Region, as their counterparts in the eastern and western parts of the country, are also altered or are threatened by invasions or introductions of nonindigenous, invasive aquatic species. Although the problems they cause are well recognized, invasive aquatic plants and animals continue to be distributed by activities such as boating, aquaculture, maritime commerce, fish stocking, and the horticulture industry. Introductions resulting from these ongoing activities threaten many areas managed by DOI bureaus. These agencies are primarily concerned with the threats these organisms pose to biodiversity, native species, natural habitats, and ecosystem health and function. They are also concerned with the threats or barriers nonindigenous species pose to native species restoration, particularly for species classified as threatened and endangered. The financial costs associated with nonindigenous species are also a concern because control efforts, which typically require a long-term commitment, can be cost prohibitive.

Invasive aquatic plant species that are generally of concern to the DOI agencies include purple loosestrife, hydrilla, water hyacinth, Eurasian water-milfoil, and giant salvinia. Animal species of concern include zebra mussel, several species of introduced crabs and carp, the New Zealand mud snail, nutria, rudd, ruffe, rusty crayfish, spiny water flea, and rainbow smelt. The protozoan *Myxosoma cerebralis,* the etiological agent of whirling disease, is a major concern of those agencies dealing with salmonid populations. Additionally, several fish species that were initially introduced to enhance sportfishing are no longer desired because of their negative effect on native fish and other aquatic organisms. Species of concern include several bass, carp, sunfish, perch, and walleye species in warm and cool waters and various salmonid species in colder waters. Frequently, the nonindigenous species disperse into adjoining waters or are intentionally transferred to other waters by individuals.

Introduced fish have had profound impacts on native fish and aquatic biota across all other biomes within the region. For example, the native greenback cutthroat trout inhabited the cold water streams in the mountains of Colorado. It was near extinction by the early 1900's because of broadscale stocking of nonnative brown trout and rainbow trout. Three of the other four native subspecies of cutthroat trout are extinct. The potential displacement of native species is of equal concern. Yellowstone Lake in Yellowstone National Park, Wyoming, is one site that has been recently invaded. The nonnative lake trout, a native of the Great Lakes, had been introduced into one of the Nation's premier fisheries. The native Yellowstone cutthroat trout may not compete well against lake trout. Lake trout eat cutthroat trout. If population sizes of cutthroat trout decline, grizzly bears could lose an important posthibernation food because the native cutthroat trout spawn in the streams and are easy prey for the bears, whereas the nonnative lake trout spawn in deep water.

Rainbow smelt, another invader which has colonized numerous lakes along the Minnesota-Ontario border after being introduced by humans, first appeared in Voyageurs

National Park in 1990. Because of their intermediate trophic position—as consumers of zooplankton (including icthyoplankton) and as prey for top predators—rainbow smelt have the potential to introduce a wide array of ecological impacts from both direct and indirect effects. A switch from an indigenous forage fish diet to one of rainbow smelt may cause further elevation of mercury levels in walleye and northern pike, the park's primary piscivores.

Aquatic systems in Texas and Colorado (with 105 and 106 nonnative fish species, respectively) have the most diverse nonnative fish populations in the region. Twelve additional States in the Central region each have more than 40 species of exotic fish. The introduced species displace many endemic fish species, causing the rapid decline of the native species due to competition, predation, and hybridization. The establishment of nonnative aquatic turtles in several Southwestern river systems has been verified, but the effect of these introductions on native turtle fauna is largely unknown.

Management-Related Problems Cited Across Biomes

A number of common problems related to management responses that might be addressed by research were identified as this strategy was developed in collaboration with DOI land managers. Several issues emerged concerning biological weed control. Because the aim of biological control is generally not to eradicate the weed, but to reduce its dominance in the community, it has been difficult to define success. In addition, it has become clear that plans need to be in place to restore the desired community after the weed has been reduced, lest another weed take its place. Finally, when biological control options fail, or when biological control is not an option, there are few alternatives to herbicides. Many refuges depend on mechanical control approaches (e.g., mowing, grazing, or burning) rather than herbicides or biological controls. Integrated pest management approaches are needed, but appropriate weed control methods for natural areas are limited.

Restoration of treated sites is another common concern. Not only must the desired species be reintroduced, ecosystem level properties must be reestablished in severely infested sites. Criteria for evaluating the success of restoration are needed, as well as methodologies for achieving these endpoints. Integral to restoration is an understanding of how the invasive species has affected the ecosystem, for example, in terms of nutrient cycling, plant and animal interactions, or species diversity. Predicting the vulnerability of a management unit to invasion, and, in turn, knowing which alien species constitute threats are keys to early detection and prevention of invasions. Often, basic life history information about incipient invaders is lacking, making it difficult to gauge the threat they pose. Information needs include environmental conditions and species biology in areas where the species is native and descriptions of impacts in other areas of the world where it is invasive. Techniques for monitoring that are not prohibitively expensive are also necessary; knowing which species to look for and where and when to look can help hold down costs of monitoring. The DOI bureaus identified the need for plant materials for restoration and the need to maintain local and historical genotypes for threatened native species.

Management practices designed to improve habitat for wildlife may have unanticipated consequences in the presence of invasive species. Not only must the effect of management practices on invasive plants and animals be taken into account, but the effect on other organisms must also be considered. Simultaneously assessing these various contingencies can bring management to a standstill, or worse, result in bigger problems in the future if they are ignored.

Summary of Invasive Species Impacts on DOI Lands

Listed below are eight categories of invasive species impacts that have been observed on DOI lands in the Central Region.

Habitat Alteration and Loss of Native Biodiversity

Invasive species have outcompeted and displaced a wide range of native species in all Central Region biomes, altering habitat at many scales. In many cases the indigenous species have diminished in range or population size, but in some cases, native species have been nearly or totally eliminated as their ecological niche has been filled by invasive species. Introduced disease organisms have also affected populations of many native flora and fauna and, in some cases, extirpated local populations.

Loss of Native Genetic Diversity

One of the more subtle effects of introduced species is loss of native genetic diversity. For example, only 15 of 32 lakes in Glacier National Park, Montana, contain pure genetic strains of the native cutthroat trout. The others contain totally nonnative fishes or hybrids with the introduced Yellowstone cutthroat trout or rainbow trout.

Altered Disturbance Regimes

A dense cover of European cheatgrass has increased the potential fire frequency in many central grassland ecosystems. With each fire, the dominance of nonnative annual grasses is enhanced at the expense of native perennial grasses. Much of the arid West has significantly higher fuel loads today compared to those at the turn of the century. The Chinese tallowtree has altered fire frequency in mixed forests and Coastal Prairie ecosystems through its fire suppressing properties.

Effects on Grazing, Agriculture, and Human Health

Livestock grazing is an important aspect of DOI land use, particularly in the Central Region and Western regions. Many exotic plant species are noxious (poisonous) to native wildlife and livestock. For example, leafy spurge is poisonous to cattle, and bison avoid areas high in spurge. European cheatgrass is less palatable than many native forage species, and its spread is thought to be enhanced by livestock grazing. Cattle, while not by definition an invasive species, is an economically important introduced species that causes deterioration of riparian vegetation, soil erosion, and siltation in many streams in the Central and Western Regions. The

blood fluke planorb (an introduced snail) has infiltrated Texas and Florida; it serves as an intermediate host for blood flukes that cause debilitating diseases in humans. Africanized bees have moved north from Mexico into Texas and Arizona since the late 1980's. Their sting is dangerous to humans, livestock, and wildlife, and they cause severe economic losses to the honey industry. They also threaten those crops grown in the Southwest that depend on honeybees for pollination like almonds and melons.

Effects on Nutrient Cycling

Some exotic plant species (e.g., clovers) increase soil nitrogen fixation, potentially enhancing the local environment for some other invasive exotic plant species. By altering the frequency of disturbance, European cheatgrass accelerates the rate of nutrient cycling and loss in many areas, adversely affecting many native plant species.

Effects on Soil Moisture and Water Resources

Nuisance aquatic plants have choked out water-borne transportation in many parts of the Coastal Plain, dramatically affecting recreational use. In more arid lands, tamarisk and Russian olive are among the key species that have altered soil moisture and ground water level. Submerged aquatic plants, particularly hydrilla and Eurasian water-milfoil, reduce water-storage capacity and boating access in many Central Region lakes and reservoirs.

Soil Erosion and Microbial Ecology

Particularly in Central grasslands and arid lands, invasive plants such as spotted knapweed have substantially increased surface-water runoff and sediment yield. This same plant has replaced normally dense vegetation along stream banks, increasing soil erosion and degrading fish habitat. Microphytic algal soil crusts in arid ecosystems can be quickly eliminated by alterations in soil moisture, soil texture, and fire regime. High nitrogen levels resulting from some invasive plants may also have detrimental effects on beneficial soil symbionts, such as mycorrhizal fungi.

Secondary and Higher-Order Effects on Ecosystem Goods and Services

The alteration of habitat by invasive plants portends changes at higher trophic levels, potentially altering populations of fish, waterfowl, and large mammals of ecological and economic importance. Wetlands infested with purple loosestrife often suffer a loss of more than half of their native plant biomass, altering a number of important ecological interactions (e.g., predator-prey relationships) and reducing vertebrate and invertebrate populations. Leafy spurge has displaced native grasses and forbs that provide habitat for grizzly bear and many other species in DOI parks and wildlife refuges from Montana to Colorado. Leafy spurge may also have important effects on populations of pollinators of many native plant species. Eurasian water-milfoil forms a canopy that prevents sunlight from reaching other plants that have a higher nutritional value for waterfowl. This plant and several other invaders clog intakes for water supplies and interfere with surface water flow. Natural regeneration in valuable bottomland hardwood and baldcypress forests has been virtually eliminated in some areas by invasive species such as the nutria, fruittree leafroller, and Chinese tallowtree.

Ongoing BRD Invasive Species Work in the Central Region

Central-region BRD research in Fiscal Year 2000 focuses on individual species and groups of species recognized as severe and present threats to native flora and fauna. These studies generally support the needs of DOI bureaus in one type of habitat or a specific land management unit. Most of these studies are classified as BRD "invasive species program" activities, but some are ancillary to other research objectives (e.g., the assessment of Chinese tallowtree invasion is a component of a United States Global Change Research Program study). Fiscal Year 2000 efforts involve a total of 47 projects (listed in Appendix 3) at Research Centers and university Cooperative Research Units in the Central Region that can be aggregated into four types:

Invasive Species Ecology (9 projects) – research on individual species introductions, population dynamics, genetics and life history, mechanisms of dispersal, and interactions among species. A variety of species are being studied, ranging from invasive plants to introduced walleye, rainbow smelt, and largemouth bass.

Impact Assessment (14 projects) – assessments of impacts generally conducted on a single or group of parks or refuges; cumulative impacts of invasive species and other stressors. Species-based assessments describe the impacts of introduced species such as nutria, tamarisk, leafy spurge, and exotic fish. Place-based assessments of invasive species problems are underway at several National Parks and in subregions of the Central United States, such as the assessment at Rocky Mountain National Park in Colorado.

Survey and Monitoring (14 projects) – occurrence and inventory of invasive species, taxonomy, and trends. These efforts generally focus on multiple species in a specific land or water management unit, with some notable exceptions such as the Chinese tallow work in coastal Louisiana. The development of remote sensing tools for large-scale survey and monitoring of invasive plants is an objective of at least two research projects.

Control, Containment, and Restoration Methodology (10 projects) – work on a species or small group of closely related species in one or several DOI land management units; effectiveness of biological and chemical control agents; registration research for several chemical controls; preventive management (e.g., fire, rangeland, and forest management); and habitat restoration.

These ongoing studies constitute the most significant invasive species research efforts on issues related to wildlands/conservation lands in the Central United States. They are woefully inadequate, however, given the magnitude of the problem. Most studies have not been coordinated or integrated at this point, nor are they structured around BRD's program element goals or ecosystem types to facilitate coordination across USGS regional boundaries. Even a

comprehensive assessment of potential problem species is currently lacking as are monitoring programs and assessment surveys across the region or across any major ecosystem type. At present, none of the USGS National Program Goals for Invasive Species is being adequately addressed.

Strategic Plan for Meeting Invasive Species Information Needs in the Central Region

The following strategy is recommended to integrate existing work and to guide our course of action for addressing the unmet information needs of DOI resource managers. The coordination and integration of existing work described in the first section could be implemented within existing budgets. The subsequent monitoring, research, and technical assistance elements would require an increase in the USGS budget. Funds for monitoring would also be needed for land management bureaus.

Coordination and Integration of Existing Work

First and foremost, the BRD Central Region should leverage its existing work by improving coordination among projects that are presently planned or underway. The following four activities should be undertaken to foster coordination and integration of existing work in the Central Region.

Charge BRD centers and Cooperative Research Units with improving coordination among BRD units. This can be accomplished, in part, through the activities of a Central Region invasive species team or committee.

Central Region Invasive Species Team

This group, nominated by the Center Directors and Cooperative Research Units Chiefs, should be charged with keeping abreast of all invasive species science activities underway in the region. Involving scientists from other BRD units, the group should develop a mechanism for tracking activities within each major habitat type or biome. The team should discuss work that is planned or underway in each BRD research unit. Members appointed to the team would be responsible for reporting relevant activities back to the scientists at their unit, and for encouraging collaboration where appropriate. A report for DOI management agencies should be distributed at least biennially.

Host a Central Region symposium or workshop once every 2 to 3 years to present findings to DOI land managers, State invasive species coordinators, and other partners to foster communication of findings among BRD scientists and their clients. This and other approaches for information and technology transfer to DOI land managers should include other sources of information useful to DOI personnel.

Plan and organize current work within ecological regions or biomes, as well as taxonomic divisions to aid in disseminating information to managers of DOI land units with similar habitats and to support the integration of capabilities and work across regional boundaries. Ideally, a full-time coordinator would be designated for each biome.

Integrate activities with other BRD Regions and USGS Divisions. This task is dependent upon the effective and complementary organization of work within all USGS Regions. The Invasive Species Program Coordinator at BRD headquarters should play a key role in coordinating efforts across USGS regions and with national and international invasive species initiatives.

Expanding USGS Work To Meet DOI Needs

Current BRD work provides a solid basis from which to develop a more integrated and comprehensive program to combat invasive species problems of the future. BRD has extensive capabilities to address all taxa of invasive species, from microbes to mammals in all ecosystems and at all levels of biodiversity, with some limitations at the genetic level. Considering the scope of the existing projects and the problems identified by DOI clients, three overarching themes for expanding BRD's invasive species activities have emerged in the Central Region: early detection and monitoring, research, and technical assistance. A summary of proposed activities and budget requirements in the Central Region are provided below. Considering the prevalence of invasive fish and aquatic weed problems in the Central Region, every effort should be made to emphasize aquatic as well as terrestrial ecosystems when these programs are organized.

Early detection and monitoring invasive species on DOI lands and waters

Monitoring is needed for the early detection of invasive species, to evaluate population trends, and to establish a baseline for evaluating the results of management actions. The Central Region should establish, through a cooperative venture involving other DOI entities and U.S. Department of Agriculture (USDA) bureaus, an ongoing monitoring program that would identify existing and new invasions of invasive species on DOI properties. Inherent in this strategy is the need for greater taxonomic expertise within the bureau, or extensive collaboration with others that possess such expertise.

Invasive Species: Early Detection and Monitoring Program

* establish a Steering Committee of DOI (and perhaps State) land managers
* develop common protocols for invasive species survey and monitoring
*assign teams of BRD personnel to assist DOI land managers in establishing survey and monitoring programs
* establish common data base

Estimated cost: $1.8 million/year

It is envisioned that the monitoring would be the primary responsibility of DOI land managers, with BRD assisting in

both design and establishment of field surveys. To insure both logistical efficiency and maximum compatibility with other DOI management responsibilities, a Steering Committee of representatives from the four major land management bureaus (and perhaps the States and USDA bureaus) should be formed to guide the design and implementation of the monitoring program. The Bureau of Indian Affairs should be invited to serve on the Steering Committee to encourage collaboration with and support for Native American land managers.

Organized by taxon and habitat type, teams of BRD personnel should be established among the various BRD units based upon their expertise and proximity to key biomes and DOI lands. One BRD Center could be designated the lead for each major biome and for each major taxon, but employees at other Centers and Cooperative Research Units should be members of appropriate teams. These teams would be solely dedicated to working on invasive species. They would be responsible for training DOI personnel to conduct monitoring, assisting them in initiating field work, and evaluating the resulting data.

As requested by the DOI agencies, common monitoring protocols developed by these teams should provide consistent, reliable data that facilitate determination of current and future distributions of invasive species, the effectiveness of control actions, and the effect of control actions on nontarget organisms and components of the environment. Monitoring program data should be formatted to allow for easy incorporation into geographic information systems present in many of the Region's National Parks and Refuges. Emphasis should include remote sensing technology as well as georeferenced, ground-based surveys.

Data obtained from the Central Region's invasive species monitoring programs and other sources should be integrated through the National Biological Information Infrastructure, facilitated by USGS, so that all stakeholder groups can retrieve data and contribute their latest findings. Such a database, particularly if it were ecosystem based, could provide some predictive capability for DOI and other Federal and State natural resource agencies. This database would also be important in maintaining awareness of invasive species activity on non-DOI lands.

Research: Predicting the Spread and Effects of Invasive Species

Research should be undertaken to systematically examine the potential for invasion and impact from invasive species and to develop predictive systems for projecting population growth for potential invasives. This new work, organized by taxon within each major Central Region biome, should be undertaken in close collaboration with DOI land managers. The organization by taxon as well as biome will facilitate BRD invasive species work across USGS regional boundaries.

Understanding dispersal and establishment of invasive species is the key to predicting the likelihood that a species will colonize a given management unit. Research that would provide detailed geographic information for invasive species combined with models to predict means and extremes of transport and likelihood of establishment in habitats of interest would aid managers in determining which species pose the most significant threats.

Research Emphasis: Predicting the Spread and Effects of Invasive Species

* mechanisms and pathways of dispersal
* effects on ecosystem processes and native species
*predictive systems for invasions and impacts
* effectiveness and design of management strategies, including restoration of infested ecosystems

Estimated cost: $3 million/year

BRD research should ascertain the potential effects of invasive species on ecosystem processes and native species as well as assess mitigating factors that may influence the degree of actual impacts under different habitat and management conditions. Both short-term and longer-term cumulative effects should be considered. Aside from their obvious displacement of native species, often little is known about ecosystem-level interactions and effects of invasive species infestations. For example, research on invasive plant species should consider (1) the role of the invader in nutrient and carbon dynamics, water relations, pollination, predation, and herbivory; (2) these parameters in the same community in the absence of invasion; and (3) which of the changes are reversible if the invader is removed and which will need active restoration.

BRD should expand its invasive species research further to evaluate management approaches that may affect the vulnerability of ecosystems to invasive species. This research was a specific and repeated request of the National Park Service as this strategy was developed. Risk assessment techniques that can be used to prioritize control of invasive species are also needed. Special consideration should be give to long-term assessments of biological control, particularly when nonindigenous species are used as a control mechanism. Other suggested objectives for invasive species research include the following:

- assessing the biological and population traits that contribute to the ability of an introduced species to develop problematic population levels, and including in such analyses a genetics component that will aid in understanding potential interactions with native species.
- developing remote sensing technology to support invasive species detection and monitoring; research is needed on spectral signatures of both invasive and dominant native species and on changes in these signatures through the growing season.
- evaluating the economic impacts of invasive species and comparing economic advantages of treatment and prevention alternatives.

Technical Assistance: Science and Information Tools for DOI Land Managers

BRD should expand its capabilities to provide technical assistance to DOI land managers. Technical assistance is needed in both the prediction and prevention of invasion and in the control or elimination of populations of invasive species once established. Finally, there is a need for technical assistance to guide the restoration of affected ecosystems. For example, BLM is currently undertaking a large restoration project in the Great Basin area that borders the northwestern edge of the Central Region and desires information on restoration techniques. Restoration is likely to become a larger issue for BLM and other land management agencies as species like the prairie dog and sage grouse become increasingly rare and in need of Endangered Species Act protection.

Technical Assistance

* decision support tools
* on-site field support for DOI land managers
* handbooks, field guides, websites, and educational materials for distribution to park and refuge visitors

Estimated cost: $1.5 million/year

Technical assistance can be based on existing scientific information if available, but in many cases there is a need for demonstration projects, an assessment of historical treatment practices, or another approach to develop information and advice for land managers. DOI managers also desire decision support tools to facilitate the application of research findings to management decisions and actions. Predictive modeling tools for invasive species are in their infancy. Their development has been hampered by poor early detection, lack of coordinated/comparable surveys and monitoring efforts, limited interdisciplinary and long-term studies, and poor statistical approaches. These shortcomings would be substantially overcome if the research activities proposed herein are undertaken.

Technical assistance would be provided by BRD in several forms. On-site field support for DOI land managers would be the most prevalent type of assistance. The development, however, of management handbooks, invasive species keys, and other types of technical information would be provided. Internet-based websites dedicated to the needs of land managers are among the most promising approaches for transferring information to field sites. In addition, BRD would provide educational materials such as brochures, interactive videos and kiosks, and posters for placement at visitors' stations and for use by interpretive staff. These materials would be developed to promote awareness of invasive species and their threats to native ecosystems and to discourage purposeful and unintentional introductions of invasive species.

Coordination with Others

In addition to close coordination with DOI bureaus, the BRD must, if it is going to make a positive contribution and avoid duplication of effort, coordinate its efforts with the numerous other governmental, nongovernmental organizations, and university researchers engaged in the battle with invasive species. Especially pertinent are the activities resulting from the Nonindigenous Aquatic Nuisance Prevention Act of 1990. As a result of this Act, regional coordinating panels have been established for the Great Lakes and 19 Western States (Western Regional Panel). This latter group includes all the States in the BRD Central Region except the five lying adjacent to the Mississippi River. Similar coordination is being carried out by the Great Lakes Panel, and another panel is being formed in the Gulf Coast region.

Nongovernmental organizations, universities, and many private organizations are also actively involved in research, development and application of management techniques, and information/education activities concerning invasive species. In the Central Region, close coordination should be sought with the USDA agencies, particularly the U.S. Forest Service (USFS), the Natural Resources Conservation Service (NRCS), and the Agricultural Research Service (ARS). With the USFS, the areas of cooperation should include inventory and monitoring as well as research on forest pest and diseases of shared concern. For ARS, research on biological controls and the ecology of rangeland weeds is a logical area for collaboration. State natural resource agencies are also key cooperators, and could benefit from and contribute to many of the efforts proposed in this strategy.

In addition to the DOI bureaus referenced frequently in this strategy, there is also a need to work closely with other USGS partners, such as the National Association for Water Quality Assessment (NAWQA) program of the USGS Water Resources Division, which is monitoring instream biota within several large watersheds in the Central Region.

At the international level, cooperation is needed to obtain information on the distribution, ecology and impacts of invasive species in countries where they are native or invasive. Sharing of management experience is also an area of potential international cooperation.

Appendix 1
BRD Contributors and DOI Bureau Advisors

BRD

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Appendix 2A. Common and Scientific Names of Plants Cited in This Report

Common name			
This report[a]	Integrated Taxonomic Information System[b]	North American Flora[c]	Scientific name
Alligatorweed	Alligatorweed	Alligator-weed	*Alternanthera philoxeroides* (Mart.) Griseb.
Baldcypress	Baldcypress	Bald-cypress	*Taxodium distichum* var. *distichum* (L.) Rich
Barnyardgrass	Barnyardgrass	Large barnyard grass, Barnyard grass	*Echinochloa crus-galli* (L.) Beauv.
Bermudagrass	Bermudagrass	Bermuda grass	*Cynodon dactylon* (L.) Pers.
Brazilian vervain	Brazilian vervain	Brazilian vervain	*Verbena brasiliensis* Vell.
Buffelgrass	Buffelgrass	Anjangrass, African foxtail	*Pennisetum ciliare* (L.) Link
Canada thistle	Canadian thistle	Canada thistle	*Cirsium arvense* (L.) Scop.
Cattail	Cattail	Cat-tail	*Typha* L.
Chinese privet	Chinese privet	Chinese privet	*Ligustrum sinense* Lour.
Chinese tallow tree	Tallowtree	Chinese tallowtree	*Triadica sebifera* (L.) Small[d]
Common mullein	Common mullein	Great mullein	*Verbascum thapsus* L.
Cottonwood	Cottonwood	Cottonwood, Poplar	*Populus* L.
Crested wheatgrass	Crested wheatgrass	Crested wheat grass	*Agropyron cristatum* (L.) Gaertn
Dalmatian toadflax	Dalmatian toadflax		*Linaria dalmatica* (L.) P. Mill.
Diffuse knapweed	White knapweed		*Centaurea diffusa* Lam.
Douglas-fir	Red fir	Douglas-fir	*Pseudotsuga menziesii* (Mirbel) Franco
Eurasian water-milfoil	Spike watermilfoil	Eurasian water-milfoil	*Myriophyllum spicatum* L.
European cheatgrass	Cheatgrass	Downy brome	*Bromus tectorum* L.
Field bindweed	Bindweed	Bindweed	*Convolvulus* L.
Fountain grass	Pearlmillet	Fountain grass, Pearl-millet	*Pennisetum glaucum* (L.) R. Br.
Garlic mustard	Garlic mustard	Garlic-mustard	*Alliaria petiolata* (Bieb.) Cavara & Grande
Giant salvinia	Kariba-weed	Kariba-weed	*Salvinia molesta* Mitchell
Giant sugarcane plumegrass	Sugarcane plumegrass	Giant sugarcane plume grass, Giant plume grass	*Saccharum giganteum* (Walt.) Pers.
Guineagrass	Guineagrass	Guinea grass, Guinea liverseed grass	*Urochloa maxima* (Jacq.) R. Webster (*Panicum maximum* Jacq.)
Hickory	Hickory	Hickory	*Carya* Nutt.
Hydrilla	Waterthyme	Water-thyme	*Hydrilla verticillata* (L. F.) Royle
Japanese climbing fern	Japanese climbing fern	Japanese climbing fern	*Lygodium japonicum* (Thunb. Ex Murr.) Sw.
Japanese honeysuckle	Japanese honeysuckle	Japanese honeysuckle	*Lonicera japonica* Thunb.
Johnsongrass	Johnsongrass	Johnson grass	*Sorghum halepense* (L.) Pers.
Kentucky bluegrass	Kentucky bluegrass		*Poa pratensis* L.
King Ranch bluestem	Yellow bluestem	Turkestan beard grass	*Bothriochloa ischaemum* (L.) Keng
Kleberg bluestem	Kleberg's bluestem	Kleberg's bluestem	*Dichanthium annulatum* (Forsk.) Stapf
Knapweed species	Knapweeds	Knapweeds	*Centaurea* L.
Kochia	Prostrate summercypress	Prostrate summer-cypress	*Kochia prostrata* (L.) Schrad.
Kudzu	Kudzu	Kudzu	*Pueraria montana* (Lour.) Merr.
Leafy spurge	Leafy spurge	Spurge, Wolf's milk	*Euphorbia esula* L.

Lehman's lovegrass	Lehmann's lovegrass	Lehman's love grass	*Eragrostis lehmanniana* Nees
Live oak	Live oak	Live oak	*Quercus virginiana* P. Mill.
Macartney rose	Macartney rose	Chickasaw rose	*Rosa bracteata* J.C. Wendl.
Mesquite	Honey mesquite	Honey mesquite, Screw-bean	*Prosopis* L.
Missouri bladderpod	Missouri bladderpod	Limestone-glade bladderpod	*Lesquerella filiformis* Rollins
Multiflora rose	Multiflora rose	Rambler rose	*Rosa multiflora* Thunb. Ex Murr.
Musk thistle	Nodding plumelessthistle	Nodding plumeless-thistle	*Carduus nutans* L.
Oak	Oak	Oak	*Quercus* L.
Orchardgrass	Orchardgrass		*Dactylis glomerata* L.
Osage orange	Osage orange	Osage-orange	*Maclura pomifera* (Raf.) Schneid.
Ox-eye daisy	Oxeye daisy	Ox-eye daisy	*Leucanthemum vulgare* Lam.
Pine	Pine	Pine	*Pinus* L.
Ponderosa pine	Ponderosa pine	Ponderosa pine	*Pinus ponderosa* var. *scopulorum* Engelm.
Purple loosestrife	Purple loosestrife	Purple loosestrife	*Lythrum salicaria* L.
Red-horned poppy	Blackspot hornpoppy	Rudolph black-spot horn-poppy	*Glaucium corniculatum* (L.) J.H.
Russian knapweed	White knapweed	Diffuse knapweed	*Centaurea repens* L.
Russian olive	Russian olive	Russian-olive	*Elaeagnus angustifolia* L.
Ryegrass	Ryegrass	Rye grass	*Lolium* L.
Sagebrush	Sagebrush	Sagebrush	*Artemisia* L.
Scotch thistle	Scotch thistle	Scotch-thistle	*Onopordum acanthium* L.
Sericea lespedeza	Chinese lespedeza	Chinese bush-clover	*Lespedeza cuneata* (Dum.-Cours.) G. Don
Small-leaved salvinia	Water spangles	Water-spangles	*Salvinia minima* Baker
Smooth brome	Smooth brome	Smooth brome	*Bromus inermis* Leyss.
Spotted knapweed	Spotted knapweed	Spotted knapweed	*Centraurea biebersteinii* DC.
Sweetclover species	Sweetclover	Sweet-clover	*Melilotus* P. Mill.
Tamarisk	Tamarisk	Salt-cedar, Tamarisk	*Tamarix* L.
Water hyacinth	Common water hyacinth	Common water hyacinth	*Eichhornia crassipes* (Mart.) Solms
Water lettuce	Water lettuce	Water-lettuce	*Pistia stratiotes* L.
Whitebark pine	Whitebark pine	Scrub pine	*Pinus albicaulis* Engelm.
Whitetop species	Whitetop	Heart-pod hoarycress	*Cardaria* Desv.
Willow	Willow	Willow	*Salix* L.
Yellow sweetclover	Yellow sweetclover	Yellow sweet-clover	*Melilotus officinalis* (L.) Lam.
Yellowstar thistle	Yellow star-thistle		*Centaurea solstitialis* L.
Yellow toadflax			*Linaria vulgaris* P. Mill.

[a] Because of the great variety in common names, those used by the committee appear in the text and are presented here with corresponding names found from standard sources. Any corrections should be sent to gaye_farris@usgs.gov.

[b] Integrated Taxonomic Information System (www.itis.usda.gov).

[c] Kartesz, J.T., and Meacham, C.A. 1999. *Synthesis of the North American Flora.* [CD-ROM, Version 1.0]: Chapel Hill, NC. North Carolina Botanical Garden.

[d] Also *Sapium sebiferum*.

Appendix 2B. Common and Scientific Names of Animals Cited in This Report

Common name used in this report	Scientific name[a]	Common name used in this report	Scientific name
Barbary sheep	*Ammotragus lervia*	Moose	*Alces alces*
Bass species	Moronidae	Mountain goat	*Oreamnos americanus*
Bighorn sheep	*Ovis canadensis*	New Zealand mud snail	*Potamopytgus antipodarum*
Bloodfluke planorb	*Biomphalaria glabrata*	Northern pike	*Esox lucius*
Bullfrog	*Rana catesbeiana*	Norway rat	*Rattus norvegicus*
Burro	*Equus asinus*	Nutria	*Myocastor coypus*
Cabbage butterflies	Pieridae (*Pieris* spp.)	Perch species	Percidae
Carp species	*Cyprinoidei*	Prairie dogs	*Cynomys*
Cat	*Felis catus*	Rainbow smelt	*Osmerus mordax*
Cattle	*Bos taurus*	Rainbow trout	*Oncorhynchus mykiss*
Crab	Decapoda	Rats	*Rattus*
Cutthroat trout	*Oncorhynchus clarkii*	Red deer	*Cervus elaphus*
Dog	*Canis familiaris*	Red fire ant	*Solenopsis invicta*
Feral hog	*Sus scrofa*	Reticulate collared lizard	*Crotaphytus reticulatus*
Formosan termite	*Caoptotermes formosanus*	Rudd	*Scardinius erythrophthalmus*
Fruittree leafroller	*Archips argyrospila*	Ruffe	*Gymnocephalus cernuus*
Gemsbok	*Oryx gazella*	Rusty crayfish	*Orconectes rusticus*
German brown trout	*Salmo trutta*	Sage grouse	*Centrocercus urophasianus*
Greenback cutthroat trout	*Oncorhynchus clarkii stomias*	Sheep	*Ovis*
Grizzly bear	*Ursus arctos*	Spiny water flea	*Bythotrephes cederstroemi*
Horse species	*Equus*	Spot-tailed earless lizard	*Holbrookie lacerata*
House mouse	*Mus musculus*	Sunfish	Centrarchidae (*Lepomis* spp.)
House sparrow	*Passer domesticus*	Turtle species	*Anapsida*
Ibex	*Capra ibex* (*Capra hircus*)	Walleye species	*Stizostedion*
Lake trout	*Salvelinus namaycush*	Zebra mussel	*Dreissena polymorpha*
Mice	*Mus*		

[a]Major sources: U.S. Department of Agriculture's Integrated Taxonomic Information System (www.itis.usda.gov); U.S. Fish and Wildlife Service's *Checklist of Vertebrates of the United States, the U.S. Territories, and Canada* (1987); and American Fisheries Society's *Common and Scientific Names of Fishes* (5th edition).

Appendix 3
FY2000 Central Region BRD Projects Related to Invasive Species

Invasive Species Ecology (9)

Integrated Strategies for Plant Management Practices in the West
Ecology of Tall Whitetop in the Upper/Middle Rio Grande Ecosystem
Effect of Exotic Rainbow Smelt on Nutrient/Trophic Pathways and Mercury Contaminant Uptake in the Aquatic Food Web of Voyageurs National Park
Competitive Interactions between Native Northern Pike and Introduced Largemouth Bass under Low-light Intensities
Development and Potential Management of an Illegally Introduced Walleye Population in Canyon Ferry Reservoir, Montana
Population Dynamics and Ecology of Local Giant Canada Geese in Central Missouri
Plant Population Studies in the Greater Yellowstone Ecosystem
The Invasiveness and Ecological Effects of the Exotic Snail, *Potamopyrgus antipodarum*, in the Greater Yellowstone Ecosystem: Year 2
Development and Potential Management of an Illegally Introduced Walleye Population in Canyon Ferry Reservoir, Montana

Impact Assessment (14)

Assessing Ecological Impacts of Exotic Rainbow Smelt (*Osmerus mordax*) in the Major Lakes of Voyageurs National Park
Modeling Nutria (*Myocastor coypus*) Impacts on Marsh Loss
Gulf of Mexico Program Environmental Assessment Project
Global Change Impacts in the Colorado Rockies Biogeographical Area: Phase II
Dynamics of Tamarix-invaded Riparian Ecosystems in the Western United States
Effects of Leafy Spurge (*Euphorbia esula*) Infestation on Breeding Birds of the Sheyenne National Grassland, ND
Evaluation of Trout Stocking in Northeastern Oklahoma
Landscape-scale Assessment of Native and Exotic Plant Diversity and Microbiotic Crusts in the Grand Staircase-Escalante National Monument (GSENM)
Evaluation of Habitat Restoration in Fire-Dependent Ecosystems
Climate Change, Sediment Transport Capacity, Arroyo Development, and Vegetation Change in Streams of the Southwestern United States
Evaluation of the Relation between Exotic Rainbow Smelt, *Osmerus mordax*, and Native Cisco, *Coregonus artedii*
Effects of Prairie Dog Disturbance and Ungulate Grazing on Native and Nonnative Propagule Banks in Badlands National Park
Vulnerability of Rare Southwestern Fishes to Exotic Species – Bioassessment of Multiple Stressors Influencing Endangered Aquatic Species of Southeastern Ecosystems
Population Structure and Habitat Use of Lake Clark Sockeye Salmon

Survey and Monitoring (14)

Use of Hyperspectral Imagery To Identify and Map Leafy Spurge Infestations at Theodore Roosevelt National Park
Technical Assistance to the National Park Service
Taxonomic Resources and Expertise Directory (TRED)
Forest Health Monitoring Vegetation Indicator Pilot
Plant Community Monitoring in Prairie Cluster Long Term Ecological Monitoring Parks
Monitoring and Modeling the Rate and Fate of Tallow Invasion in Coastal Louisiana
Rapid Assessment and Monitoring of Exotic Plant Diversity in the Central Region
Declining Native Plant Diversity Caused by Invasive Weeds and Interactions with Grazing: a Multi-State and Multi-Agency Approach
Big Thicket Habitat Monitoring for Global Climate Change
Remote Sensing as an Integrated Approach to Monitoring Vulnerabilities and Predicting Changes in Wetlands
Projecting Climate and Vegetation Change for the Central Grasslands Region
The Ecology of Fishes in McKittick Creek, Guadalupe Mountains National Park, Texas
Approaches to Interpreting Environmental Data
Detecting and Mapping Chinese Tallow with High Spatial and Spectral Resolution Remote Sensing Data

Control and Containment Methodology (10)

Response of Giant Salvinia (*Salvinia molesta*) to Alternative Glyphosate Application Strategies in Laboratory and Field Experimentation

Plant Community Response to Biological and Chemical Control of Leafy Spurge in Theodore Roosevelt National Park, North Dakota

Prescribed Burning of Decadent Cattail Stands: Effects on Waterfowl Usage, Aquatic Invertebrates, and Water Chemistry

Riparian Restoration Using Hydrologic Manipulation and Physical Disturbance

Evaluation of Woody Riparian Vegetation Response Following Garlon 4 Herbicide Application to Saltcedar (*Tamarix* spp.) as an Emulator of Biological Control

Beaver Control of Tamarisk: Mechanisms and Management Applications

Integrated Strategies for Weed Control in Palustrine and Riparian Wetlands

Effectiveness of Habitat Restoration for Plant Communities at Risk

Evaluating Impacts of an Introduced Biological Control Agent, the Seven-spotted Ladybird Beetle (*Coccinella eptempunctata* L.), on Natural areas of the Northern Rocky Mountains

Nonindigenous plants in the Northern Great Plains: Ecological Effects of Infestation and Control

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