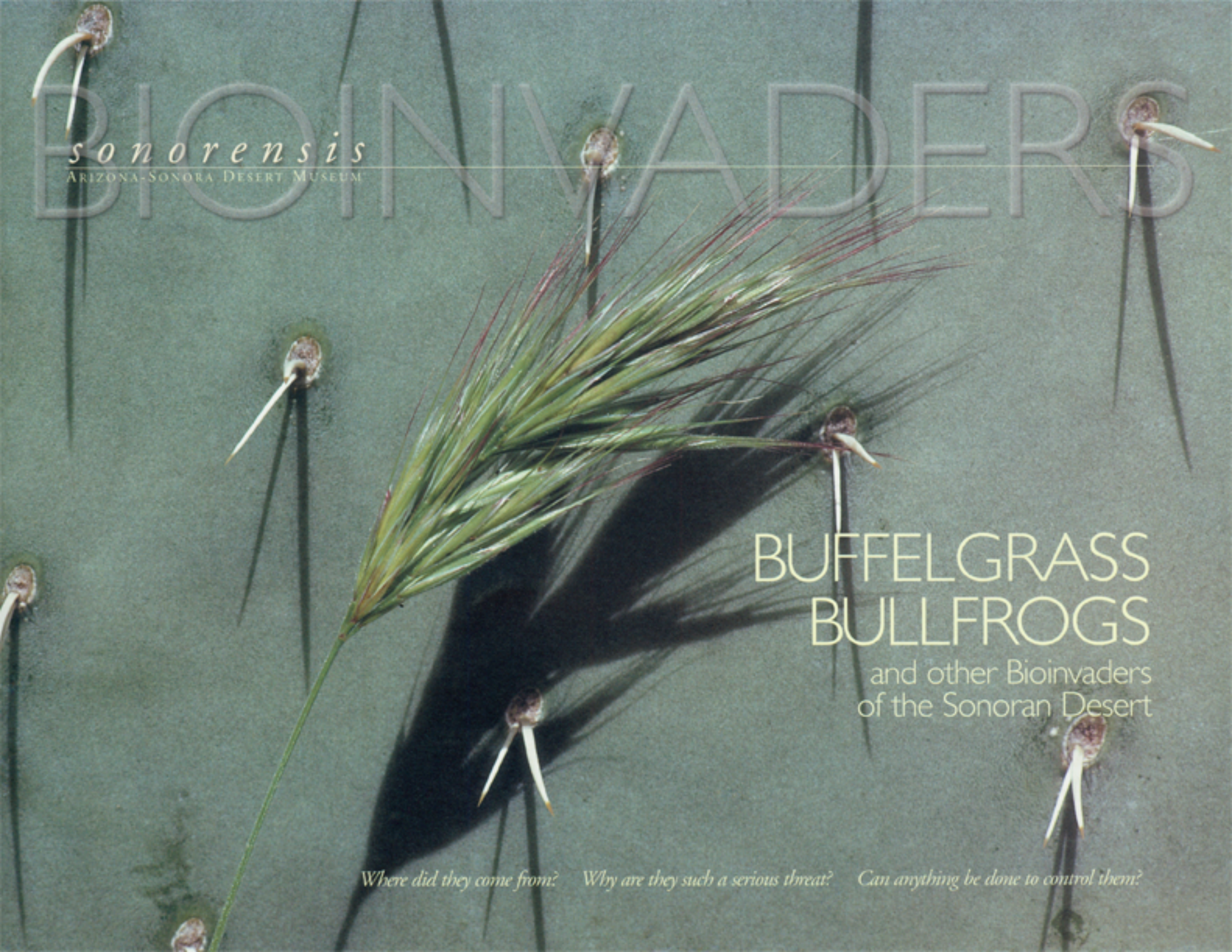

sonorensis
ARIZONA-SONORA DESERT MUSEUM

BUFFELGRASS BULLFROGS

and other Bioinvaders of the Sonoran Desert

Where did they come from? *Why are they such a serious threat?* *Can anything be done to control them?*

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The Latin term sonorensis *indicates the scientific species classification for many plants and animals of the Sonoran Desert region.*

Cover photo of red brome and prickly pear
by David W. Lazaroff

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T. R. VanDevender

red brome

Introduction

Invasive. Exotic. Non-native. Alien. Just a few of the terms that have been applied to the approximately 30,000 foreign plants, animals, and microbes that have taken up residence in the United States since Europeans first set foot on this Continent. Many of these introduced species have caused little harm; others, called "invasive species," have caused irreparable damage, displacing native plants and animals and disrupting entire ecosystems.

How serious is the problem? A study published in 1998 by *BioScience* magazine reports that invasive exotics constitute a greater threat to endangered species than do pollution, overharvesting, and disease combined; only habitat loss ranks higher. Invasive plants, for example, now infest over 100 million acres in the United States. Three million acres, an area twice the size of Delaware, is lost to these exotic plants each year.

Unlike the kudzu-draped forests in southeastern United States, invasive species in the Sonoran Desert are less apparent to the untrained eye. Unfortunately they are just as damaging to biodiversity and ecosystem processes. In this issue of *sonorensis* we'll take a close-up look at how this problem is manifesting itself in the Sonoran Desert and what control measures are available to try to stem the tide of this bioinvasion.

Successful management of invasive exotics in the future will require environmental education, policy reform, technical training, and public awareness programs. Equally important, however, is individual and community action. Humans caused this problem. Humans must now find ways to manage it.

Richard H. Daley
Executive Director

Sahara mustard

John Wiens

Invasive. Exotic. Alien.

Marvin S. Keaney

Even remote areas, such as the floor of MacDougal Crater, near the western flanks of the Sierra Pinacate, are not safe from invasive species.

"Having recently passed the great age of biogeography, we will have entered the age after biogeography, in that virtually everything will live virtually everywhere, though the list of species that constitute 'everything' will be small.... Earth will be a different sort of place—soon, in just five or six human generations. My label for that place, that time, that unavoidable prospect, is the Planet of Weeds."

David Quammen
Harper's Magazine (1998)

Jerry Ashin

View of a 1994 fire burning in Saguaro National Park. Red brome was probably the primary culprit.

Exotic species: An overview

Exotic Species: An Introduction
Native Species: An Epitaph

Gary Paul Nabhan
Director of Conservation and Science
Arizona-Sonora Desert Museum

If you climb Camelback Mountain in Phoenix, then "A" Mountain in Tucson, then the hills behind "Sandy Beach" at Cholla Bay, Sonora, you will meet some of the same stragglers in all three places—plants and animals which did not occur in the Sonoran Desert a century ago. Africanized bees may buzz around your head, or try to suck up the last bit of moisture in your coffee cup. At your feet, and in your socks, you will find the seeds of several exotic grasses and mustards. Sahara mustard. Red brome. Buffelgrass, or its ornamental kin, fountain grass. These relative newcomers to the Sonoran Desert can be found in nearby protected areas as well, from the Pinacate Biosphere Reserve, to Saguaro National Park, to the Sierra Bacha, home of the "boojums" on the Sonoran coast of the Gulf of California.

Whether we walk around in the heart of a desert city, or retreat to the most remote stretches of so-called wilderness in the U.S./Mexico borderlands, it is likely that at least one of 600 species of non-native plants and animals can be found within a few steps of where we stand. They are welcoming us to the Planet of the Weeds.

They are with us today, but are they here to stay, as David Quammen worries they will be? That depends, of course, on how honest we are in acknowledging the magnitude of this ecological dilemma and how diligent we are in our efforts to keep Sonoran Desert landscapes native.

Few people understand the severity of the current impact of exotics upon natives in the U.S./Mexico borderlands. The eco-tourist viewing desert wildlife refuges, national parks, biosphere reserves, and nature conservancy areas might well assume that large tracts of North America's desert wilderness have remained intact, unaltered by humans. In reality these desert landscapes have been shaped by thousands of years of human influence. Indigenous cultures dispersed plants and animals into desert locales far beyond their natural ranges; agaves, beans, corn, gourds, chuckwallas, macaws, spiny-tailed iguanas, and turkeys are among the many organisms which prehistoric inhabitants of the desert moved and manipulated. Soon after the arrival of Europeans, human impact intensified. Seeds and stems recovered from the adobe walls of early missions prove that Jesuits and Franciscans brought more than bibles, grape vines and bread wheat with them from Europe; weed seeds were carried along in bags of crop seeds, and in the hooves of livestock.

Many environmental historians have thought that the aridity of deserts protects them, more than any other biome, from the effects of invasive species. Yet we find considerable evidence to the contrary: invasive species occur abundantly in Sonoran Desert habitats, even in areas remote from running rivers and flowing streams, or from metropolitan or irrigated agricultural areas. Researcher Ray Turner

Mark Dimmitt

Breathtaking Sonoran Desert wildflower displays can be threatened by invasive species.

notes that MacDougal Crater, near the western flanks of the Sierra Pinacate, now hosts Sahara mustard on the crater floor, despite the fact that grazing and other human-managed activities have been negligible there. Punta Cirio in the remote Sierra Bacha has also been invaded by this Mediterranean annual, even though it is miles away from agriculture. Tumamoc Hill in Tucson, the oldest scientific area free of domestic livestock anywhere in the deserts of the world, has added feral dogs, cats, and 52 exotic plants to its biota over the last century, but has lost at least 20 native species—18 plants and 2 mammals—over the same period, according to researchers Jan Bowers and Turner. Managers have estimated that as much as 60 percent of the vegetative cover of the Sonoita Creek-Patagonia reserve, the first Nature

NATIVE SPECIES

One that evolved in a particular region or that evolved nearby and migrated to the region without help from humans.

desert mallow

NON-NATIVE SPECIES

One that evolved in one region and was taken to another distant region by human activity where it would not naturally have migrated because of some barrier, such as an ocean. Also referred to as INTRODUCED SPECIES, EXOTIC SPECIES or ALIEN SPECIES.

rain lily

NATURALIZED SPECIES

A non-native species that is reproducing in a new region without help (for example, irrigation) from man.

African daisy

INVASIVE SPECIES

An aggressive species that displaces other species; most commonly a naturalized species occupying a disturbed niche, although the most destructive invasives also displace natives in intact communities.

redstem filaree

WEED

A native or non-native species that is unwanted and invasive in a landscape or agricultural setting.

Sahara mustard

Conservancy area in Arizona, is dominated by exotics, and that introduced fish pose a recurrent danger to its threatened native fish. Larry Stevens believes that invasives have played a major role in the continued loss of one native species per year from Grand Canyon National Park over the last two decades.

A high proportion of North America's micro-areal endemics, that is, unique plants and animals with restricted distributions, occur only in deserts. Invasive species endanger them. On the midriff islands of the Gulf of California, where endemism is highest in the region, Eric Mellink found that feral rats and cats have already threatened several small mammal and nesting bird species. The Baja California peninsula, also rich in endemics, is under conversion to buffelgrass pasture just as Sonora is, but on the peninsula this grass's escape into adjacent areas threatens many more natives with restricted ranges. Other areas rich in endemism—the oak woodlands of "sky islands," the cienegas of the Desert Grasslands, and the oases of Sonoran Desertscrub—are also vulnerable to mass extinctions as a result of accidental introductions.

While competition with natives is usually given as the blanket reason for why exotic species are "bad," their ecological impacts vary widely in effects and magnitudes. Some invasive species such as red brome, Lehmann's love grass and buffelgrass compete with natives for ground surface, soil moisture, and nutrients, but they also alter fire regimes and native plant regeneration patterns. Tamarisks not only compete for space and water in riparian habitats, they also disrupt stream flows, especially during flood stages.

In a positive initiative known as "Pulling Together," private and public U.S. organizations joined forces to map out and endorse a national strategy for dealing with invasive plants.

Secondarily, these altered regimes may reduce resources for migratory pollinators and insectivorous waterfowl, thereby having a ripple effect throughout entire regional landscapes. In short, the ecological impacts of invasives are diverse, from cowbird predation on eggs to giardia infestations in vertebrate guts.

If most invasive species are so disruptive to the health and productivity of native biotic communities, what can be done about them? The answer is complex, and we need to consider both short-term and long-term causes of habitat change. Whatever actions we take should certainly link prevention, education, detection, control, restoration, and monitoring. The location of the Sonoran Desert within the U.S./Mexico border region challenges us to detect species moving both ways across the international boundary. Although ubiquitous species such as tropical white flies and tumbleweeds cannot be stopped at the border, it may be possible to slow the intentional introduction of additional exotics by informing importers and border customs officials—as well as the public in general—of the high long-term costs of casually-introduced invaders.

The message needs to reach a wider audience. The Arizona-Sonora Desert Museum conference on the subject received front page coverage in Tucson newspapers, as well as a follow-up Sunday editorial entitled, "Beware These Invaders." It appeared that science journalists in southern Arizona were astounded by how little they had known about the economic costs of bullfrogs, carp, tumbleweeds and tamarisks. The problem was called "a subtle, late-breaking and quietly astonishing crisis of ecological identity." Many Arizonans learned for the first time that invasive plants and animals are among the top threats to endangered species and biodiversity globally, and by some accounts, the gravest threat to desert diversity.

In a positive initiative known as "Pulling Together," private and public U.S. organizations joined forces to map out and endorse a national strategy for dealing with invasive plants. An Executive Order on Invasive Species

Photos, top to bottom: Al Morgan, Steve Phillips (lily and daisy), David Lazaroff, John Wiens

Fountain grass along the King Canyon Trail in Saguaro National Park (west unit).

Steve Phillips

signed by President Clinton in early 1999 should help implement the strategy. Although Mexico does not yet have such a national agenda, it has an ambitious strategy for controlling exotics on the midriff islands of the Gulf of California that includes the use of witty and colorful comic books to alert fishermen to the perils of invasive animals. The real need is for agencies in both countries to be "pulling together" in the same direction, so that one agricultural agency is not intentionally introducing cold-tolerant buffelgrass strains while another is attempting to eradicate it from a protected area just a few miles away.

We have many questions to answer if we are to deal effectively with the ecological invasions in the region as a whole:

- Do plants invade agricultural areas first, or roadsides?
- How do exotic aquatic animals disperse from waterhole to waterhole?
- Are ungrazed desert vegetation patches less prone to invasions than grazed areas?
- How do El Niño years fuel the spread of exotic animals and plants?
- Do the same control methods work in drought years as in wet years?

We face an even tougher question with many severe infestations: Do we need to use controls that carry additional risk, such as chemicals or the introduction of natural enemies of the invaders, which are themselves exotics?

Recently 33 field scientists ranked exotic grass plantings seventh and biological invasions tenth among the greatest stresses affecting the biodiversity of the Sonoran Desert region. If these two categories are combined, exotic plantings and related invasions rank among the five worst threats to our biodiversity. It is time to concede that we are beginning far too late to grapple with a problem of this magnitude, but that starting to deal with it earnestly today is better than never acting at all.

This article is adapted from a chapter by the same name in the future Arizona-Sonora Desert Museum publication, Invasive Exotic Species in the Sonoran Desert *(working title), edited by Barbara Tellman.*

Number of Exotic Species of Various Taxonomic Groups Established in the Sonoran Desert

Controlling Invasive Exotics—The Right Tool for the Job

by Barbara Tellman
Water Resources Research Center
The University of Arizona

Mark Staley

Volunteers removing tamarisk at The Nature Conservancy's Hassayampa River Preserve.

The first line of defense in controlling invasive exotics is to not let the invasion start. Don't let potential invasives in and if they do invade, eradicate them immediately. The U.S. Department of Agriculture spends millions of dollars each year to keep plants and insects from crossing the border; but even so, many new species are brought into the country each year accidentally or on purpose. Some of these thrive at the expense of natives, resulting in infestations such as the bullfrogs in many ponds and cienegas, and buffelgrass in Sonoran thornscrub. Are invasive exotics completely out of control? In some cases the answer is probably "yes," but we can still manage a good many of them, even if we can't eliminate them completely. There is, however, no one solution that will solve all the problems.

Basically, we have several choices:

- Remove them manually or by machine. These methods are usually very labor-intensive and sometimes result in even more plants if they resprout from the roots or grow from fragments.
- Remove them with chemicals. Use of chemicals can be risky unless they are first proven harmless to desirable species and without long-term effects.
- Use other species (natural enemies) to remove problem species—"biocontrol." Because the new species may themselves become problems, biocontrol is now strictly controlled in the united States. The control agent must harm only the targeted species. Extensive trials are required. An advantage of biocontrol is that the change occurs gradually, allowing time for natives to replace the exotics.
- Interfere with their reproduction. These methods have reduced numbers of white-flies after sterile males were released. They have also successfully yielded sterile young in exotic fish species.
- Change land management practices to encourage native plants at the expense of exotics. Many exotics only thrive in situations where human disturbance has created ideal conditions for them. When disturbance is reduced, natives may be able to compete successfully.

None of these methods carry 100 percent guarantees, nor are they totally risk-free. Often it takes a combination of methods to do the job, along with a lot of money and/or a lot of volunteer hours. Often repeat treatments are needed.

While there are some cases where control has been tried and has not succeeded, we do have some success stories in this region. The projects described in this issue by Sue Rutman and by Cecil Schwalbe and Phil Rosen are good examples of the challenges and initial signs of success.

Some other examples:

- At The Nature Conservancy's Hassayampa Preserve volunteers cut down tamarisk (saltcedar), then treat it with chemicals to prevent regrowth. While there is still some tamarisk at the preserve, the targeted areas have been kept relatively free of it, allowing the native cottonwoods and willows to resprout in this relatively natural stream.
- In Sabino Canyon the Arizona Game and Fish Department and the U.S. Forest Service cooperated to eliminate exotic green sunfish from a three-mile section of the creek in order to improve conditions for native fish. They electro-shocked the stream so that they could catch the native chubs and move them to a safe area, then dosed the creek with a fungus-derived substance that targets gill-breathing creatures. The sunfish are gone and other creatures such as frogs and turtles suffered no ill effects. A second treatment should ensure complete eradication.
- At The Nature Conservancy's Ramsey Canyon Preserve, an introduced landscape plant, *Vinca major*, dominated many areas along the creek. Volunteers (especially one dedicated local resident) systematically uprooted plants. Native plants have begun to recolonize many areas, but planting will be also be needed. Uprooting was not successful in rocky areas where the entire root systems couldn't be removed.
- Removal of livestock that grazed along a portion of the middle San Pedro River brought about a reduction in the number of saltcedar trees.

On the other hand, The Nature Conservancy used controlled grazing to manage exotic Johnson grass at the Sonoita-Patagonia Preserve. They are replanting the area with native sacaton grass. Although they initially used fire to control the Johnson grass, it thrived on fire, coming back better than ever.

Although there is hope of control for at least some infestations, the prospects for controlling others are limited, and the costs are generally high. Prevention is still the best approach.

Arizona Game & Fish Department

Salvinia molesta—A Growing Threat to Arizona's Waterways

by Barbara Tellman

An aquatic fern from South America has land managers in our region alarmed. Sold by nurseries for use in ponds, *Salvinia molesta* has now invaded the lower Colorado River. It grows rapidly even from tiny fragments of the plant, and under the right conditions it can double its mass in one to three weeks. It can survive in any waters that do not freeze over.

Salvinia forms floating mats up to two feet thick that block sunlight and oxygen, causing problems and even death for a variety of aquatic life. Labeled the world's worst weed in the *Guiness Book of World Records*, Salvinia is a major problem in India, Subsaharan Africa, South-east Asia, and from the Southeast United States into Texas. The greatest immediate concern here is for the wildlife refuges vital to waterfowl along the lower Colorado River. Managers also fear that the weed will migrate to other rivers, lakes, stock ponds, irrigation systems, power plants, and canals. Recreational boats present the greatest potential for rapidly spreading Salvinia along the Colorado River and to other waterways.

There is no easy way to remove it. Herbicides, biocontrol, manual removal, and drying up the water body are the main choices. Since the plant grows among other vegetation—cattails, willows, and saltcedar, for example—it is difficult to spray chemically or remove manually, and the proposed herbicides damage any vegetation they touch. Biocontrol with a weevil that only destroys Salvinia has been successful elsewhere, but there is concern about introducing another exotic species.

Water removal is an option for small ponds or canals, but not for the Colorado River. Besides, even after the plant has dried it can recover once water is again available. Most of these control tactics require permits; obtaining them can be a long and sometimes difficult process.

An interagency task force is considering options. Meanwhile avoid spreading it with your own watercraft, and if you sight the weed, please report the location to the U.S. Fish and Wildlife Service, (602) 640-2720.

Arizona Game & Fish Department

Salvinia molesta (both photos)

Bullfrogs—The Dinner Guests We're Sorry We Invited!

Cecil Schwalbe
U.S. Geological Survey, Biological Resources Division

and Phil Rosen
Department of Ecology and Evolutionary Biology
The University of Arizona

Julia Rosen

This bullfrog swallowed another of its kind. Bullfrog cannibalism in Arizona allows population densities up to 30 times those reported from the bullfrog's natural range in eastern United States.

Eeeek! Splash! A bullfrog hits the water. This sound, while a fond memory of our childhood hikes elsewhere, is now a clarion call to battle in a war that our native frogs, and even garter snakes, are losing to a host of introduced aquatic predators.

All six native species of true frogs in Arizona have suffered large losses since the early 1970s, with four in danger of disappearing from the state, and one already gone. The lowland leopard frog (*Rana yavapaiensis*), still common in central Arizona, has disappeared from southwestern Arizona, California, and New Mexico. The Mexican garter snake (*Thamnophis eques*), in dire straits in the U.S., and the declining narrow-headed garter snake (*Thamnophis rufipunctatus*) of central Arizona are both affected by introduced species.

Wetland loss was important in the decline of our native frogs, but the major current problem is non-native aquatic predators (fishes, crayfish, and the bullfrog *Rana catesbeiana*) from the eastern U.S. and Eurasia. Add newly discovered frog diseases to the mix, and the threats to native frogs throughout the American West are daunting.

We became acutely aware that there was a bullfrog problem while surveying the Mexican garter snake in 1985-86. At San Bernardino National Wildlife Refuge, east of Douglas, we found bullfrogs superabundant. The Mexican garter snakes consisted almost entirely of adults too big for bullfrogs to eat, yet most of the snakes had frog-chomped tails. Leopard frogs, common at this refuge as recently as 1981, were reduced to a single site—too shallow for large bullfrogs—from which the leopard frogs disappeared during a drought in the late 1980s. Initial efforts to control bullfrogs allowed young garter snakes time to mature into adults, but these effects were not permanent.

All six native species of true frogs in Arizona have suffered large losses since the early 1970s, with four in danger of disappearing from the state, and one already gone.

The bullfrog's natural range stretched from Florida north to Canada, and west to New Mexico, but it is now established in every western state. Before 1900 the bullfrog was spread as a food and game animal. It thrives in deep, permanent, relatively still waters, most often found here in man-made ponds, lakes, or slow-flowing streams. The absence of its natural predators—especially snapping turtles and large water snakes—has helped it flourish. Arizona's garter snakes relish small bullfrogs, but large bullfrogs turn the table, eating juvenile garter snakes.

The bullfrog is the only frog or toad in Arizona that squawks when it leaps to safety—often setting off a mass bullfrog exodus—though all bullfrogs don't call

every time they flee. Leopard frogs don't squawk when fleeing; they also differ in having light-colored ridges running down each side of their backs and "leopard spots" surrounded by light halos. Bullfrogs are most commonly green, but colors vary widely, from olive to bronze to brown, sometimes with spots resembling camouflage clothing. Adult males sport bright yellow throats and conspicuous eardrums (much bigger than their eyes). Bullfrogs range from three-gram pipsqueaks to one-kilogram, eight-inch eating machines.

Our struggles to eliminate bullfrogs over the past decade and a half have taught us hard lessons. Bullfrogs seem impossible to remove from complex wetlands. Our hunting pressure produced wary frogs; we could not approach within 50 yards of some frogs before they left the water and sought refuge in pack rat nests. Merely launching a canoe spooked frogs out of a pond and into the adjacent marsh. Our intensive hunting and trapping efforts did reduce adult population numbers by 90 percent or more during the summer, but within a year, dispersal and rapid growth of young frogs almost restored adult population numbers.

Bullfrogs are extremely prolific, producing up to 20,000 eggs per clutch, five to ten times that of their native cousins in Arizona. Bullfrog tadpoles may also outcompete tadpoles of other true frogs. Additionally, unlike leopard frog tadpoles, they are distasteful to fish, which gives bullfrogs a great advantage now that introduced predatory fishes are all over the Southwest.

Unlike fish, bullfrogs travel over land, a factor complicating their removal. On a night with summer rain, we commonly see small bullfrogs a quarter to a half mile from their ponds. At Buenos Aires National Wildlife Refuge this past summer, frogs traveled as far as two miles from the "home" pond, and we found evidence suggesting that dispersal four to five miles is likely.

Bullfrogs eat any prey they can get into their very large mouths, using their front feet to shove large items into their gullets. They most frequently eat invertebrates. Interesting stomach contents have included tarantulas, beetles, moths, centipedes, scorpions, dragon and damsel flies, and toe biters (the three-inch long predacious true bugs that have been observed eating small frogs). One frog, apparently with a penchant for spicy food, had three tarantula hawks (large wasps that supposedly pack the most painful sting in the Southwest) in his stomach.

By weight, vertebrates play a major role in bullfrog diets. We found representatives of every non-marine vertebrate class in their stomachs. Some more spectacular items include a cotton rat, several other rodent species, bats, a nestling Red-winged Blackbird, Common Yellow-throats (warblers), alligator and lesser earless lizards, Mexican and checkered garter snakes, western patchnose snakes, Sonoran mud turtles, leopard frogs, and threatened native fish. Even small bullfrogs can be fearsome predators on vertebrates. The smallest bullfrogs eat many small fish such as topminnows and chubs—probably because the small fish frequent the same shallows—but the numbers of fish taken by bullfrogs still doesn't impact fish populations significantly. A 1.75-ounce bullfrog, at only half its weight at maturity, can easily eat newborn garter snakes or small lizards. The bullfrogs that had eaten bats were post-adolescents weighing about 3.5 ounces each. That supports observations

Bullfrog Damage

Bullfrogs have almost eliminated the Mexican garter snake from the San Bernardino National Wildlife Refuge. The snakes remaining are almost all old, large females, with tails chewed by bullfrogs (inset).

HOW DO WE GET RID OF THESE UNWANTED GUESTS?

In 1999 we started a leopard frog conservation project on Buenos Aires National Wildlife Refuge (BANWR) in the Altar Valley west of Tucson. We needed to rid the stock ponds of bullfrogs before attempting to reestablish native Chiricahua leopard frogs. Because BANWR is much drier than the San Bernardino refuge, we contend with much simpler aquatic systems there. However, eliminating bullfrogs even from individual stock ponds with no extensive springs or marshes still required a combination of techniques.

Fencing (to exclude or contain bullfrogs), drying of ponds, manual removal, and chlorination (to eliminate tadpoles or frogs hiding in the mud of drying ponds) seemed to be effective in eradicating frogs from five of six ponds on the refuge during this past summer. We will not know how effective those removals were until we re-survey the ponds next May and June. Attempting to remove bullfrogs anywhere is likely to take substantial efforts for some years, perhaps a decade or longer, and will require bullfrog-free buffers of at least several miles. The importance of livestock ponds as habitat for the threatened Chiricahua leopard frog warrants vigorous efforts to develop and maintain bullfrog-free stock ponds on both sanctuaries and working ranches.

Phil Rosen

A bullfrog exclosure fence around leopard frog ponds. Bullfrogs are so adept at climbing that exclosure fences must have eaves.

Carol Schwalbe

Chiricahua leopard frogs were eliminated from the San Bernardino National Wildlife Refuge by bullfrogs and drought. They now are found on the refuge only inside bullfrog exclosures.

The absence of natural predators and the many abilities of bullfrogs have permitted them to dominate numerous perennial wetlands in the West.

by Arizona Game and Fish personnel and our field crew that bullfrogs seen jumping out of the water to catch bats on the wing were young adult frogs, not extremely large ones.

Surprisingly, bullfrogs' most common vertebrate prey is other bullfrogs. On several occasions, we found a bullfrog within a bullfrog within a bullfrog. At Arivaca Cienega we once witnessed a medium bullfrog swallow a smaller one, and then get swallowed by a larger bullfrog, all within a two-minute time span. We only half-jokingly refer to bullfrogs as the "great white sharks of Arizona's waters."

The absence of natural predators and the many abilities of bullfrogs have permitted them to dominate numerous perennial wetlands in the West. Cannibalism enables bullfrogs to remain more abundant than their base of prey species would allow. Some of our study ponds had an adult bullfrog every two yards along the bank watching for movement of any potential food item. Adult population densities are abnormally high here—10 to 30 times those reported elsewhere. Leopard frogs, young garter snakes, or baby mud turtles have almost no chance of surviving in the waters of bullfrog-dominated ponds.

Clearly extraordinary measures are needed to eradicate bullfrogs from aquatic systems (see sidebar at left) and give native frogs, Mexican garter snakes, and other bullfrog prey items a fighting chance.

The Conservation Dilemma of Non-native Versus Native Fishes

W. L. Minckley
Department of Biology
Arizona State University

When the Spanish arrived, the pristine Sonoran Desert region had little surface water and relatively few fishes, with at most only 36 species within Arizona's present borders. Far more water is impounded today in reservoirs and the number of species has soared! About 80 species, more than 50 from elsewhere, now swim in Arizona waters. Of the original 36, only 6 species persist throughout much of their natural ranges. One is extinct, 12 are endangered, 7 threatened, and 10 are of special concern. Although 8 of the threatened or endangered species survive in adjacent states, they have vanished from Arizona.

Early in this century large dams were constructed and canals built for water delivery, disrupting natural habitats. Carp, buffalofish, and catfish were stocked as foodfish before the 1920s. Human populations skyrocketed during and after World War II, increasing demands for sportfishing. By 1960, at least 20 exotic fishes were already established. In the 1950s and 1960s non-game species were removed so that gamefish could more readily colonize. Fish toxin was applied to hundreds of miles of western rivers before diverse trouts, basses, and catfishes were planted. A few exotic species arrived accidentally with gamefish shipments, while others, such as guppies, descended from discarded store-bought pets. Some species were planted to control noxious insects or plants; shad and minnows were stocked as food for gamefish or proliferated from discarded bait. Ever-larger predators—flathead catfish, northern pike, walleye, and striped bass—were imported and stocked. People moved some illegally to bring them closer to home. The introduced species spread through canals and desert streams stabilized by dams, artificial habitats which were to their liking, and many invaded natural streams from new centers of abundance, impacting native fish populations.

George Andrejko, Arizona Game & Fish Department

Some native fish recovery efforts appear to be working. For instance, reintroductions of Gila topminnows have almost doubled the number of sites where they live.

Why were exotics promoted and natives ignored or exterminated? First, government policy was to spread the "most desirable" fishes, mostly eastern species, throughout the nation. Second, most immigrants were from eastern United States and preferred the familiar species they knew from home over natives. Finally, management agencies continued experimenting. If public interest waned or a stock declined, a "new" kind was planted; interest in novelties raised license sales.

Habitat destruction and alteration are often blamed for native fish disappearance. Clearly, as habitats dry, become polluted, or are otherwise made uninhabitable, fish die and species' ranges are reduced. Alterations such as temperature changes brought about by diversions and dams, and from watershed damage from grazing, logging, and road-building may also cause declines. Structures block migrations, a change to colder water stops reproduction by warm-water species, and streams are degraded by increased runoff and erosion from barren hillsides. Just as certain, however, is the fact that when exotics appear, as they invariably do in reservoirs or other stabilized habitats, native species decline, then vanish.

Among problems facing natives when exotics are present, predation seems most important. Carp, basses, sunfishes, catfishes, and other non-natives eat eggs and juveniles of suckers and chubs. Even though long-lived native fishes can persist for decades, too few young survive to reproduce, so populations disappear when old fish die. Alien mosquitofish eat baby topminnows and shred fins of adults, making them vulnerable to infections. Brown and brook trouts eat native trouts while also competing for space and food. Furthermore, rainbow trout, planted in

essentially all cooler waters, hybridize with native trouts to swamp them genetically. Moreover, non-native fishes carry alien parasites; an Asiatic tapeworm is presently spreading among natives, with unknown effects.

Since all native fishes tested so far do well in artificial waters without exotics, many indict non-native fish species as today's greatest deterrent to conserving our native species. Along with exotic fishes, other aliens including plants, crayfish, clams, snails, and bullfrogs, are proving just as dangerous.

Agencies charged with promoting non-native gamefish that impact natives, for which they also are responsible, have a hard time doing both jobs. The U.S. Fish & Wildlife Service (USFWS) administers the Endangered Species Act (ESA) for freshwater fishes. All federally funded programs fall under the ESA, so western states that depend heavily on USFWS hatcheries and funding are automatic partners, and managing fish resources is mostly their responsibility. State agencies sometimes resent federal control to a degree, and they may find little public support for non-game species. The USFWS has problems too. After all, it was instrumental in establishing non-native fisheries and helps maintain them. Now it must persuade development agencies, industry, sportfishing groups (the nation's most influential conservationists), and others to implement the ESA and protect native fishes as well.

Despite all this, progress is being made. Recovery efforts are underway and some are working. Naturally spawned razorback sucker larvae were captured, grown in predator-free ponds, then repatriated when they were too large to be eaten. Soon, young adults were reproducing with old ones, so a life-history linkage was re-established. Reintroductions of topminnows have almost doubled the number of sites where they live. Other species too rare to manage in natural habitats are grown in hatcheries for reintroduction, or held there as stock for the future.

Here rises the dilemma. Non-natives impact natives in so many ways that only one solution seems to exist to ensure native species' survival — remove non-natives or provide habitats from which they are excluded. But exotics already are so wide ranging that total eradication is impossible, and furthermore, connections through canals, along with non-natives' invasiveness, make exclusion difficult at best. But isolation is possible. Exotics can be removed by the same chemical method used in the past to clear the way for gamefish. Stocks of imperiled natives, genetically pure trouts, for example, are then reintroduced. Now such efforts to renovate streams are being extended to benefit native warm-water species, most recently at Bylas Springs and in Sabino and West Turkey creeks, Arizona. Barriers such as artificial waterfalls are installed after renovation to stop invasion or reinvasion by non-natives. "No-fishing" rules and bans on transport of live fish or use of live baitfish are designed to stop reintroduction.

Non-natives impact natives in so many ways that only one solution seems to exist to ensure native species' survival — remove non-natives or provide habitats from which they are excluded.

All these changes in regulations require cooperation among conservation authorities, land managers, and private landowners, and reflect a positive change in attitude toward native fishes. A number of places are set aside for native fish conservation; Aravaipa Canyon, San Bernardino-Leslie Creek National Wildlife Refuge, Canelo Cienega, and West Turkey Creek are some examples in Arizona. But even in such refuges, invasive exotic species remain major problems.

This is not to say that attitudes and practices have turned around entirely. Continued use of mosquitofish by public

Exotic green sunfish removal project in Sabino Canyon. The stream is being electroshocked so that native chubs can be removed before eradicating the sunfish.

Will Hayes, Arizona Game & Fish Department

health agencies to suppress insects is a case in point. Mosquitofish are advertised in the public media as available on request for pickup or delivery. Such stocking violates ESA rules against "take" if the known predator is planted with topminnow, perhaps even if the introduction results in later invasion of topminnow habitat. A conservation-minded citizen might easily contaminate a topminnow refuge by mistake. Who would then be responsible? Other problems exist, examples being a lack of agency emphasis on native fishes in the controversial San Pedro River and exclusion of the Colorado Delta in Mexico from imperiled-species plans.

The ESA has been manipulated, amended, and indicted, but it remains the most significant environmental law yet enacted. Funding to conserve native fishes is mostly from development agencies, industry, and conservation groups, sometimes under pressure to comply with the ESA, but often voluntarily. Many concerned people are confident that enough is known to perpetuate most Sonoran Desert fishes, but support for new or revised conservation legislation is imperative if progress is to continue.

Finally, native fish survival depends on human wants, needs, and understanding. Explosive growth in human populations is placing ever-greater demands on the environment. And most human residents are new to the desert, with little understanding of resource limitations and certainly no idea that the familiar trouts, basses, catfishes, and other fishes they caught elsewhere as kids are not natural here.

Thus, education is sorely needed. Differences between natives and non-natives and contrasts between natural and artificial aquatic systems must be made clearer, and the roles and importance of native species better communicated. Life underwater is largely out of sight, thus out of mind. The growing public desire to perpetuate wildness and wilderness must be extended under water if native fishes are to remain part of our Sonoran Desert biotic heritage.

Will Hayes, Arizona Game & Fish Department

A green sunfish removed from Sabino Creek.

U.S. Bureau of Fisheries delivery car and fish-delivery truck. Arizona Game & Fish Department photo, ca. 1918.

Native fishes

THE SONORAN DESERT'S TEN

1 SAHARA MUSTARD
Brassica tournefortii

ORIGIN: Probably native to North Africa and central Asia

DESCRIPTION: Sahara mustard is a pernicious weed with no natural controls in North America. Known here for less than half a century, it now dominates thousands of square miles of sandy, low elevation desert, often to the nearly complete exclusion of native annuals. It is a major threat to our famous spring wildflower displays.

2 BUFFELGRASS
Pennisetum ciliare

ORIGIN: Native to eastern Africa's Great Rift Valley

DESCRIPTION: Buffelgrass was introduced by government and private agencies in Sonora and Arizona during the last four decades as a forage crop for lower elevation areas. It has become a scourge from Hermosillo, Sonora to central Arizona, reducing biodiversity by outcompeting native plants and by fueling fierce fires that cacti and other natives are not adapted to withstand.

3 JOHNSON GRASS
Sorghum halepense

ORIGIN: North Africa

DESCRIPTION: Johnson grass was brought to the U.S. during the late 1700s by a South Carolina family; it was introduced to Arizona as cattle fodder in the 1890s. It spreads quickly and is very difficult to eradicate, although many attempts have been made. It is common throughout southern Arizona at low- to mid-elevations. When under stress (frost or drought) the plant can become toxic to cattle and wildlife.

4 RED BROME
Bromus rubens

Origin: Mediterranean region

DESCRIPTION: This weedy annual was established in California by 1848; it is seasonally abundant and widespread in the Sonoran Desert region. Red brome's propensity to carry fires represents a real and growing danger to cacti and other native Sonoran Desert plants, which are not fire-adapted.

5 TAMARISK (also called saltcedar)
Tamarix ramosissima

ORIGIN: India

DESCRIPTION: This deep-rooted shrub or small tree consumes a great amount of water, thus leaving some areas high and dry. Its ability to out-compete willow, cottonwood, and other riparian plants has a dramatic effect on wildlife as well. During the winter, for instance, tamarisk stands have only 39 percent of the density of birds as other vegetative communities. Only a few native animal species use tamarisk.

6 FOUNTAIN GRASS
Pennisetum setaceum

ORIGIN: Africa

DESCRIPTION: This robust perennial clumping grass is a common landscape ornamental in southern Arizona, where it is slowly spreading into natural habitats, including the Tucson Mountains, especially washes. A few plants found in 1986 in Organ Pipe Cactus National Monument suggest that it may be spreading southward into Sonora, Mexico.

7 ARABIAN/MEDITERRANEAN GRASS
Schismus arabicus, S. barbatus

ORIGIN: Africa and Mediterranean region

DESCRIPTION: During years with wet winters, these closely-related winter annual grasses can be abundant across much of the northern part of the Sonoran Desert, forming extensive, dense carpets. The first stems and leaves often spread out close to the ground, effectively excluding or preventing other annuals from sprouting.

8 FILAREE
Erodium cicutarium

ORIGIN: Mediterranean areas

DESCRIPTION: Filaree made the trip here on Spanish ships and quickly spread along California migratory flyways before 1700. Nineteenth century explorers found it covering the ground in the Sierra Nevada foothills. It was brought to Arizona as fodder in the 1880s. In some areas filaree displaces native plants and can often be found in disturbed locations.

LEAST WANTED

9 BULLFROG

Rana catesbeiana

ORIGIN: eastern United States

DESCRIPTION: This is the largest frog found in the United States. All bullfrogs west of the Rocky Mountains are the result of artificial introductions. Bullfrogs were introduced into Arizona as a food animal by the Game and Fish Department in 1926. These extremely prolific breeders are ravenous feeders, eating small rodents, lizards, snakes, turtles, fish, insects, and frogs, including other bullfrogs. They are quite detrimental to populations of native frogs, fishes, and aquatic snakes.

10 CRAYFISH

Procambarus clarki and Orconectes virilis

ORIGIN: Many species are native to the bayou country of the southern U.S.

DESCRIPTION: Crayfish have been introduced into freshwater systems around the United States. In the Santa Catalina Mountains near Tucson, they are common in most drainages with permanent water and can easily be observed in the biologically diverse Sabino Canyon. Sonoran Desert fishes evolved without such predators that also feed on plant material and compete for the substrates on which endangered or threatened species lay their eggs.


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Desert Landscaping with Exotics

Mark Dimmitt
Director of Natural History
Arizona-Sonora Desert Museum

Mark Dimmitt

Ruellia nudiflora

In recent decades desert gardeners have found ways to combine attractive plantings with low water use. A concept called XeriscapeTM has been promoted throughout the arid West. While this design concept includes a small, water-rich oasis, it encourages the use of low water-use plants in a second zone. And in a third, outermost zone the plants ideally require little or no irrigation after they are established. The plan reduces overall water consumption far below that of more traditional landscaping.

Among the benefits of Xeriscapes and other water-thrifty strategies is that they encourage the use of native plants which are adapted to the local climate and soils. Thus they have led many people to notice and to appreciate the natural botanical heritage of their deserts. However, few gardeners are satisfied with only the local plant palette. It is human nature to be fascinated by diversity and novelty. More than 90 percent of the world's arid land plants occur outside the Southwestern deserts, and many of these non-natives are beautiful and almost irresistible to plant lovers. (One term for a non-native plant is *exotic*. While the first definition of "exotic" is "foreign," a definition that applies to all non-native plants, the word also means "excitingly different," an apt description for many of these plants.)

When desert gardeners import an exotic rose or another plant that requires considerable water, there is little danger of its escaping from cultivation into the surrounding desert. But what about plants from other arid regions? They are preadapted to our low, unpredictable rainfall and usually to our very alkaline soils. Are many of them capable of escaping cultivation and becoming invasive pests in natural communities? Do imported desert plants therefore pose a threat to our wild lands? If so, how great is the threat?

In the Tucson Mountains alone 83 plant species (13 percent of the total) are exotic. Fortunately only a handful are serious pests. Most escapees remain uncommon, controlled by native herbivores or diseases. But the few exceptions are devastating. Sahara mustard (*Brassica tournefortii*) is a pernicious weed with no natural controls in North America. Known here for less than half a century, it now dominates thousands of square miles of sandy desert, often to the nearly complete exclusion of native annuals. It is a major threat to our famous spring wildflower displays.

About 15 percent of the exotic wild plants in North America have escaped from cultivation (the rest are from contaminated crop seeds, pre-1900, and unknown sources). It is likely that some of the new imported arid-land plants will escape into the wild, but it is almost impossible to know which ones will do so. Weed science students at the University of Arizona are asked to develop a list of criteria that will reliably predict which plants will become invasive. Thus far the students have been unsuccessful, because traits of invasive species are not always reliable indicators. Invasive species usually produce lots of seeds within short life spans, and also have high genetic variability, high dispersal capacity, and broad environmental tolerance. But when cultivated exotic plants are evaluated by these criteria, some species that seem innocuous have spread into the wild, while others that appear to be major threats have not escaped from cultivation, or at least have not become pests.

Two examples will help illustrate the situation. One plant is a native, *Ruellia nudiflora*, an herbaceous perennial with attractive large violet flowers in summer. In the Tucson Mountains where I live there are only a few, small populations. Some years ago I collected some seeds, hoping I could grow the plant for some native color. It was a mistake.

Like many species in the acanthus family, this ruellia produces seed nearly year-round—the buds self-pollinate without ever opening. (Flowers appear only during very wet weather.) The seed capsules explosively fling seeds for several yards. With the extra irrigation in my yard, this plant rapidly became an aggressive, abundant weed (a "weed" because it is now a problem). Without frequent thinning the thousands of volunteers would smother many other plants in my landscape. This outcome was unpredictable from observing the plant in its nearby natural habitat. If the ruellia were

One term for a non-native plant is exotic. While the first definition of "exotic" is "foreign," a definition that applies to all non-native plants, the word also means "excitingly different," an apt description for many of these plants.

an exotic species, its aggressive spread would have been cause for alarm.

The other example is evening-scented stock (*Matthiola longipetala bicornis*), a winter-growing European annual, cultivated worldwide for its attractive lavender flowers and heady nocturnal fragrance. It's pollinated by abundant native moths in Sonoran Desert gardens and sets huge quantities of tiny seeds. It's also suspect because it is a member of the mustards, a family notoriously weedy in non-native habitats. But this stock does not seem to be an invasive threat. Small wild patches are occasionally found in the desert, but mostly on road shoulders. It is abundant in my fenced back yard and yet virtually nonexistent in the front yard or in the surrounding desert. The foliage of evening-scented stock is highly palatable to rabbits, deer, and javelina, which apparently keep it from becoming well established in undisturbed desert communities.

These two stories illustrate the dilemma for horticulturists—both amateur and professional. It seems likely that bringing arid-adapted, exotic species into cultivation increases the probability of introducing new noxious weeds, but which species pose such a threat to natural communities cannot be reliably predicted. Tighter regulations (for example, quarantine and testing) of new introductions are not feasible, because the horticulture trade is a huge business (gardening is the most popular leisure-time activity among Americans) as well as a diffuse enterprise (thousands of amateurs and small business people are searching the world for new species). Because we can't predict which plants may become problems, we would have to quarantine and test all introductions—a daunting if not impossible task.

Moreover, legislatures tend to be too poorly informed and agricultural agencies insufficiently staffed to keep up with developments. For example, decades ago the state of Arizona outlawed the import and sale of all morning-glories in the genus *Ipomoea* because one species is a pest in agricultural fields. This prohibition includes not only Arizona's own native species, but also delicate exotics that are difficult to grow anywhere. On the other hand, the law does not prohibit the related bindweeds, many of which are noxious weeds (the common name refers to what the wiry vines do to threshing machines). Finally, taxonomic changes alter law enforcement. When some African morning-glories were reclassified from *Ipomoea* to *Stictocardia*, the same plants became legal to import.

What is the solution then? Vigilance seems to be the most practical answer. Horticulturists and amateur gardeners need to pay close attention to every new plant that goes into the garden. We need to watch carefully for signs of aggressive spread, and take appropriate action if it is observed. Even with this course of action it is a given that additional exotics will escape into the wild, and perhaps a few will become pernicious weeds. The cost of controlling them will be great, but the alternative, the curtailment of our freedom to explore, would also be a great price to pay.

This article is adapted from a chapter that will appear in the future Arizona-Sonora Desert Museum publication, Invasive Exotic Species in the Sonoran Desert *(working title), edited by Barbara Tellman.*

Evening-scented stock
Matthiola longipetala bicornis

Mark Dimmitt

Battling Buffelgrass: You Can't Win If You Don't Play

Sue Rutman
Organ Pipe Cactus National Monument

Sue Rutman

Volunteer Tom Wilder holding a large buffelgrass plant that is several years old. Plants this size can produce thousands of seeds per year.

A side-blotched lizard three inches long challenged my walk in the desert. His blue shoulder markings flashed as he did his push-ups to impress me with his vigor and to defend his territory. I posed no threat to him, but a more serious and silent intruder was on its way. Buffelgrass was invading Organ Pipe Cactus National Monument.

Buffelgrass was brought to Tucson from Africa, the Middle East, and India in 1939. Scientists with the U.S. Department of Agriculture, Plant Materials Center in Tucson experimented with buffelgrass for decades. They hoped this rapidly growing, drought-tolerant grass would provide abundant livestock forage and stop soil erosion. Buffelgrass inevitably escaped from the experimental plots and began spreading exponentially. Only 45 years or so after its arrival in Tucson, buffelgrass was found more than 100 miles away at Organ Pipe Cactus National Monument. In the mid-1980s, Dr. Richard Felger described the species as being "uncommon, perhaps rare" but increasing at Organ Pipe. Over the next 10 years, buffelgrass populations rapidly expanded and the species became established on more than 20 square miles of wilderness.

Buffelgrass aggressively colonizes and rapidly alters Sonoran Desert communities. Mature plants can be as tall as three feet, larger than most native grasses. Buffelgrass competes with native plant species for water, nutrients, and space. Seedlings of many native plants can not survive under the thick layer of buffelgrass. Neither can many lizards, which depend on sunny areas when they need to raise their body temperatures. Rodent populations shift from species that prefer open desert habitats to species more typical of grasslands. Gambel's quail and other ground-feeding birds have difficulty moving through the dense grass and lose their access to a nutritious mix of seeds, greens, and the invertebrates important to hatchling diets. It's no surprise that nectar-feeding birds and insects also lose their food sources when wind-pollinated grasses take over. Monotonous grass fields replace winter and summer wildflower shows.

Of all the effects African grasses have had on the Sonoran Desert, fire is the most serious. Fire did not naturally occur in the desert because plants are too far apart for fire to spread. Grasses and other non-native plants provide the fuel that connects the sparse native plants. Since the arrival of non-native grasses, fires in the desert have increased in frequency and magnitude. Most native desert plants die when burned and do not re-establish quickly in burned areas. Burned buffelgrass can push up new stalks within days after a fire and new seedlings sprout

The arrival of buffelgrass on Organ Pipe evoked visions of a dismal future. If uncontested, the ecological effects of this species would be severe, widespread, and perhaps permanent.

readily on the barren ground. Burned areas become fields of buffelgrass that are difficult to eradicate.

The arrival of buffelgrass on Organ Pipe evoked visions of a dismal future. If uncontested, the ecological effects of this species would be severe, widespread, and perhaps permanent. The National Park Service would fail at its most fundamental mission: to preserve and protect the area for future generations. Would we soon be presiding over an African savanna? The risk of doing nothing was too great, but how were we to respond?

Experts were doubtful or pessimistic about controlling buffelgrass. No one had tried eradicating the species on a large scale. Academic ecologists advised against mechanical control (digging up plants) because the disturbance of digging would likely favor the species, not eradicate it. But herbicides didn't kill the plants and neither did burning. Given no other options, we started experimenting with mechanical control.

We started work on a conveniently located test area in November 1994. Sixteen employees and volunteers removed buffelgrass from along Arizona State Route 85 near the visitor center at Organ Pipe. In two hours we removed more than 50 large trash bags of buffelgrass from about 0.1 mile of roadside. The bags were taken to the municipal dump and were buried.

The results gave us reason to be optimistic. One year after the test project, we spent one day removing seedlings. Two years after the test project and thereafter, we removed one to three seedlings per year.

Buoyed by the success of the test project, we moved on to a large infestation covering several square miles west of Quitobaquito Springs along the U.S./Mexico International Boundary. During the spring of 1996, a group of students from Earlham College, Illinois, spent two days in the area and removed several tons of buffelgrass. We were surprised to see very little reestablishment, even now after several years.

These small and encouraging efforts implied that mechanical removal could be successful if eradication sites were visited for at least two years. During the second year, seedlings could be removed before they produced seeds. With no input of seeds the buffelgrass population could not reestablish or expand. With continual, but low-effort maintenance, buffelgrass control seemed possible and effective.

The buffelgrass control program at Organ Pipe shifted into high gear during the winter of 1997-1998. That winter, two volunteers and employees spent a total of 890 hours removing buffelgrass. By the spring of 1998, nearly the entire Monument, with the exception of the extreme southwestern corner, had been cleared of buffelgrass. During the winter of 1998-1999 volunteers and employees spent about 1,000 hours removing buffelgrass from the southwest corner and Dos

Because of frequent and severe buffelgrass fires (left), many wooden fence posts in Sonora have been replaced by concrete ones (right).

In this monotonous buffelgrass field in Sonora, Mexico, the needs of one species—cattle—has left few resources for native plants and animals.

Constant vigilance will be necessary to protect and preserve this beautiful desert landscape from buffelgrass and other invasive species.

Buffelgrass

It is unlikely that Organ Pipe will ever be able to totally escape this potentially devastating species. But if we remain vigilant against new occurrences and root them out when we find them, our goal of minimizing buffelgrass infestations seems attainable—at least for now.

Lomitas area (the southeast boundary), and surveying areas in the west-central and northwestern part of the Monument. Small (room-sized) outlying populations were found and eradicated. By the spring of 1999, we estimated that 100 tons of buffelgrass had been removed from Organ Pipe.

The buffelgrass control program on Organ Pipe Cactus National Monument has been a success so far. Time and monitoring will determine how long the success story will last. Of particular interest will be the response of buffelgrass to the above-average rainfall of the summer of 1999.

Given the vast populations of buffelgrass in neighboring Sonora, Mexico, their seeds will surely hitch rides into the Monument with truck tires and dust devils. It is unlikely that Organ Pipe will ever be able to totally escape this potentially devastating species. But if we remain vigilant against new occurrences and root them out when we find them, our goal of minimizing buffelgrass infestations seems attainable—at least for now. We owe as much to that side-blotched lizard!

Red Brome and Wildfires

Jerry Asher
USDI Bureau of Land Management
Oregon State Office

Unprecedented and unnatural wildfires are destroying native plant communities of the Sonoran Desert. Within the last seven years destructive wildfires have consumed large tracts of some of the most scenic and species-rich parts of the desert.

Red brome, an annual grass native to the Mediterranean region, arrived in southern Arizona around 1900. It grows in dense stands of closely spaced, erect stems, providing abundant fuel between the widely-spaced native plants. Red brome grows back more vigorously after fire, and with more red brome, there's more fire—an accelerating self-perpetuating fire cycle.

Even though some native plants resprout, populations of most perennial plants are catastrophically reduced or eliminated, especially after repeated fires. Many mature saguaros and most young saguaros are often killed with a single fire. Smaller cacti such as pincushions, hedgehogs, prickly pear, and all species of cholla are usually killed, as well as palo verde trees. While the damage from red brome (and to a lesser degree other non-native grasses) is already extensive and landscapes permanently altered, we have only begun to see the scope of the degradation that is set to occur on a grand scale.

Red brome

The top photograph was taken 22 miles north of Oracle, Arizona, prior to a May 1995 fire involving red brome. The middle photo shows the aftermath of the fire and its devastating effects on native vegetation. The bottom photo was taken less than one year after the fire. Note the increased abundance of red brome.

Pulling Together: The Desert Museum Battles a Biological Wildfire

Patty West
Research Associate
Arizona-Sonora Desert Museum

Ron Lefkowitz

If you think that controlling weeds in your yard or garden is a challenge, consider the immensity of controlling over 220 non-native plants in the Sonoran Desert region. These plants have hitched rides here by nestling in socks, sticking to dogs, hiding between the treads of tires, or traveling in human hands. If you add to this number over 40 fishes, 7 mammals, 7 birds, 130 invertebrates, and 13 reptiles and amphibians that have hopped, swum, flown, crawled, or been transported to the Sonoran Desert region you have a number of exotic species estimated to be about 400. This overwhelming menagerie of creatures that have invaded an area more than ten times the size of Connecticut can only be addressed by cooperation between the agencies and countries that span this region. The Arizona-Sonora Desert Museum is one of the many private organizations and public agencies that are working together to identify which plants and animals may cause ecological and economic problems. Collectively, we hope to implement the most effective, most efficient and least disruptive ways to deal with these species.

The Arizona-Sonora Desert Museum has facilitated much of the cooperation needed to address these biological invasions. In May of 1998 the symposium "Invasive Species in Sonoran Desert Ecosystems" brought together researchers, government officials, and concerned citizens to address the problems of non-native biological invasions in the Sonoran Desert region. Further cooperative efforts are an ongoing result of the symposium. Since that seminal gathering of interested people, our staff has initiated and participated in related projects on the Museum grounds and in the greater Sonoran Desert region. The projects mentioned below reflect a multi-pronged approach, including prevention, education, research, monitoring, control, and eradication of non-native species.

Mary Cordes

Staff monitors and evaluates the invasiveness of exotic spiny-tailed iguanas found on Museum grounds (left). Control methods at the Desert Museum usually involve removing invasive species by hand (right).

ON THE GROUNDS

On the Museum grounds we continually remove invasive non-native plants, primarily pulling them by hand or using other mechanical means. We feature native plants on the grounds in an effort to promote their use in home landscapes. We are also monitoring spiny-tailed iguanas—introduced to the Museum grounds 20 years ago—to evaluate their potential invasiveness.

Elsewhere we're cooperating with Tucson Mountain Park and Saguaro National Park to control non-natives on lands adjacent to the Museum, and individuals from the Museum have been assisting a citizens' group with non-native plant and animal eradication in the habitats of ash meadows pupfish.

We generated comprehensive, definitive lists of non-native plants and animals in the Sonoran Desert, and plan to create other educational materials on invasives, among them a guide to threatening non-natives on islands in the Gulf of California. We contributed to a management plan for these islands that emphasizes non-native species control.

We have begun a program in which members of the Seri Indian community are trained in methods to control non-native weeds and rats by integrating modern biological techniques and ideas with traditional Seri knowledge. The trainees are uniquely qualified to fill research and conservation posts on the islands and coast of the Gulf of California, a benefit to their economy as well as to their environment. When possible, we will participate in other international efforts to coordinate invasive species control efforts.

Extensive information about non-native invasive species is available on the Museum's website (http://www.desertmuseum.org/ISSDE). The Museum will continue to make information on invasive plants and other species more accessible to the public through the publication of a weed identification guide and the expansion of our website.

WITH OTHER AGENCIES

The Desert Museum is committed to cooperating with other agencies and organizations, and with people in desert communities, in their efforts to keep the unique habitats of the Sonoran Desert from being further invaded by non-native plants and animals. We hope that by working together, we can succeed in bringing this biological "wildfire" under control.

Kevin Keckler

Para-ecologist courses are training Seri Indians in methods for controlling non-native plants and animals.

ASDM efforts

Out on a Limb–Does Saving the Southwestern Willow Flycatcher Conflict with Efforts to Eradicate Tamarisk?

Noah Greenwald
Center for Biological Diversity

Tamarisk, a Middle Eastern tree well adapted to arid conditions, is one of the most invasive species in the South-west, having taken over thousands of miles of streambanks, to the exclusion of native plants and animals. It has chiefly colonized riparian areas that have been disturbed or altered by dams, livestock grazing, or development. Because of its devastating effect on native species, efforts are underway to eradicate tamarisk both locally and regionally.

These efforts have led to concern over impacts on the Southwestern Willow Flycatcher, which is known to live and nest in tamarisk. The Southwestern Willow Flycatcher is likely the most endangered songbird in North America. It has been reduced to fewer than 600 pairs in widely scattered locations because its prime habitat—native riparian cottonwood-willow forests lining streams—has been devastated. Livestock grazing, dams, and urban and agricultural development have damaged most riparian habitat in the Southwest. Probably partly in response to this severe loss of native habitat, the flycatcher now occupies tamarisk in several locations. For example, according to Arizona Game and Fish, dense stands of tamarisk at the Salt River and Tonto Creek inflows to Roosevelt Lake harbored 43 pairs in 1998, the second largest population of flycatchers in its range. Significantly, this population has had a high rate of nest success and has been increasing each year. Given the perilous status of the flycatcher, this population and others found in tamarisk are clearly important to its survival. Thus, at least in the short-term, tamarisk has a role to play in keeping the flycatcher from going extinct. This is why there is concern about efforts to eradicate tamarisk in locations where the flycatcher nests, despite all the problems the plant causes. Fortunately, most efforts to eradicate tamarisk are not in conflict with recovery of the flycatcher.

Tamarisk is physically removed or reduced by chopping it down, applying herbicides to it, or burning it. Another means of removal currently undergoing controlled trials is the introduction of a beetle that preys specifically on tamarisk. A much broader approach is restoring natural river flows and removing livestock or other disturbance factors. Combined approaches might try to eradicate tamarisk using one or more of the above removal methods and also at least partly restore the conditions that allow native species to thrive. To date, most efforts have emphasized physical removal, probably because approaches which require landowners and management agencies to alter current practices—such as water use or livestock grazing—are often met with resistance. Physical removal, however, poses the greatest risk for the flycatcher.

Obviously, removing or reducing the density of tamarisk through beetle introduction or otherwise, in places where the flycatcher is using the invasive, will harm the species. Fortunately, plans call for beetle introduction release sites to be farther than 100 miles from occupied flycatcher habitat. Also, there are no current plans to remove tamarisk for restoration purposes from areas occupied by flycatchers. It therefore appears that current efforts to

Al Morgan

Tamarisk

There is concern about efforts to eradicate tamarisk in locations where the flycatcher nests, despite all the problems the plant causes. Fortunately, most efforts to eradicate tamarisk are not in conflict with recovery of the flycatcher.

remove tamarisk pose only a slight risk to flycatchers.

There still remains the possibility, however, that removing tamarisk could pose a risk to the flycatcher. This is because stands that don't currently support flycatchers could act as recovery habitat in the future. In some areas, but not all, it is likely that conditions have been so altered (with severely reduced river-flow or increased salt content in soils, for example) that even if tamarisk were removed, native trees would not replace it. For these reasons, strategies which try at least partially to restore native riparian ecosystems are better than removal alone, because they provide a higher likelihood that native trees will thrive in the long term. If successful, such efforts would not only reduce risk to the flycatcher, but in all likelihood would benefit this rare bird. After all, the same factors led both to the loss of flycatcher habitat (native riparian trees) and to the spread of tamarisk. Therefore, as long as measures continue to be taken to ensure that tamarisks are not removed from occupied flycatcher habitat, and that corresponding efforts are being made to restore native riparian species and waterways, then efforts to eradicate tamarisk are in line with recovery of the flycatcher.

Southwestern Willow Flycatcher

George Andrejko, Arizona Game & Fish Department

Tamarisk and flycatchers

Exotic Grasses & Native Wildlife

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Plains lovegrass

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A cotton rat is the only common rodent in exotic grasslands at the Research Ranch.

Exotic lovegrasses, purposely introduced in the 1940s, have spread through southeastern Arizona, crowding out native plants in some of the state's most productive grasslands. Casual observations made us suspect that the diversity of living things might be reduced in the areas dominated by these exotics.

At the end of the nineteenth century overgrazing by domestic livestock coupled with a prolonged drought denuded large areas and greatly reduced plant cover in others. In an effort to restore the range for cattle, the Soil Conservation Service planted two species of African grasses—Lehmann's lovegrass, *E. lehmanniana*, and Boer lovegrass, *E. curvula*. The grasslands were formerly a mixture of native grasses, including plains lovegrass (*E. intermedia*), and other plants. Now African lovegrasses almost totally dominate parts of some mesas.

In the mid-1980s we compared plants, birds, small mammals, and grasshoppers living in stands of native grasses with those in adjacent areas covered with exotic grasses. Our studies took place at the 8000-acre Appleton-Whittell Research Ranch Sanctuary of the National Audubon Society in the foothills of the Huachuca Mountains.

Plants were much less diverse in the exotic grass stands. Not only were the native grasses rare in the exotic stands, but native wildflowers and shrubs were missing or scarce as well. Only mesquite trees did equally well in both. Since exotic lovegrasses form very dense patches, it is not surprising that most native plants were unable to grow among them.

With one exception, the summer resident birds preferred native grassland. (If you want to see such species as Eastern Meadowlarks and Cassin's Sparrows in the summer, visit native, not exotic, grasslands.) The exception is Botteri's Sparrow, which appears to prefer the exotic Boer lovegrass stands instead of areas covered with native grasses. These sparrows also favor bottomlands covered with sacaton grass (*Sporobolus wrightii*), a native floodplain species that also occurs in dense,

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tall, somewhat uniform stands. Birds present in the winter have the same preferences as the summer residents.

We found a similar pattern in the rodents. Most rodents, including the insectivorous pygmy mouse (*Baiomys taylori*), preferred native grassland. The only rodent that favored exotic stands was the native Arizona cotton rat (*Sigmodon arizonae*). Like the Botteri's Sparrow, this animal is also common in sacaton bottomlands. Twice as many kinds of grasshoppers, important in the food chain of our grasslands, were common in native than were common in exotic stands.

Ironically cattle, too, prefer the native grasses, turning to the African grasses only when nothing else is available.

Areas with diverse native species are more interesting and aesthetically pleasing than are uniform stands of African grasses. But more importantly, diverse native communities are a natural gene bank—one that has passed through an evolutionary sieve that allows them to survive under our extreme conditions. The lesson is clear: Learn from the past. Foster diversity in both plants and animals by planting natives.

The Botteri's sparrow (foreground) is one of the few animals more common in exotic grasslands, whereas the closely-related Cassin's sparrow (background) is one of a variety of birds that are much more common in native grasslands.

Carl Bock (both)

Stands of Boer lovegrass, such as this one at the Research Ranch, support a much reduced variety of native plants and animals, compared to native grasslands.

Al Morgan

What Can You Do?

At Home

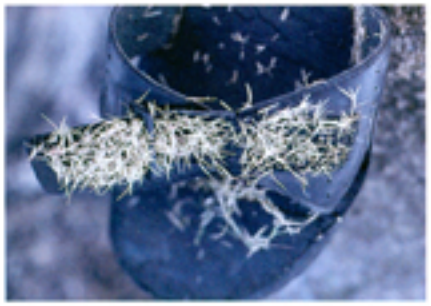
- Begin with your own yard. Landscape with native species or non-invasive plants appropriate for your area, and keep your property free of invasive weeds.
- When you plant exotics in your yard watch carefully for signs of aggressive spread; take appropriate action if it is observed.
- Neuter your pet cats and dogs or keep them confined. Don't release pets into the desert, or aquarium plants and fish into desert waterways.
- Avoid disturbing natural areas—disturbed ground favors invasive exotics.
- Be careful not to send or receive potentially harmful plants or animals through the mail. Know what you're sending and receiving!

Ron Lagins

Native plants are beautiful! They can bring year round color and texture into your yard and your community (left and above). Desert hikers and campers should be careful to clean their gear and clothing before returning home (top right).

In the Community

- Adopt a local roadside, trail, park area, or riparian area. Develop a program for detecting, reporting, and possibly controlling weed infestations. Work with community leaders or land managers in developing such a program.
- Document the location of noxious weeds in your community through the use of maps, photos, and survey forms. Share the information with community planners and land managers.
- Native plants are beautiful! Prove it to your community by starting a native plants demonstration garden.
- Go public. Conduct a public awareness campaign to educate local citizens about steps they can take to stem the spread of exotic plants and animals.
- Work with county extension agents and local land management agencies to put up informational signs where weed infestations occur.
- Tell your friends and relatives about this problem.



When You Travel

- Clean all camping gear, clothing, and shoes before leaving an area to avoid inadvertently taking seeds along to the next campsite, county, or state.
- Don't camp in or hike through weed infested areas. Stay on designated trails.
- Refrain from picking wildflowers or digging up plants.
- Don't bring plants, fruits, soil, or animals into the country from abroad illegally or without having them inspected by quarantine officials; fill out agricultural declaration forms completely and honestly.
- Completely wash down boats and boating equipment and blow out personal watercraft intakes before transporting them from one water body to another. Don't dump bait in the water!