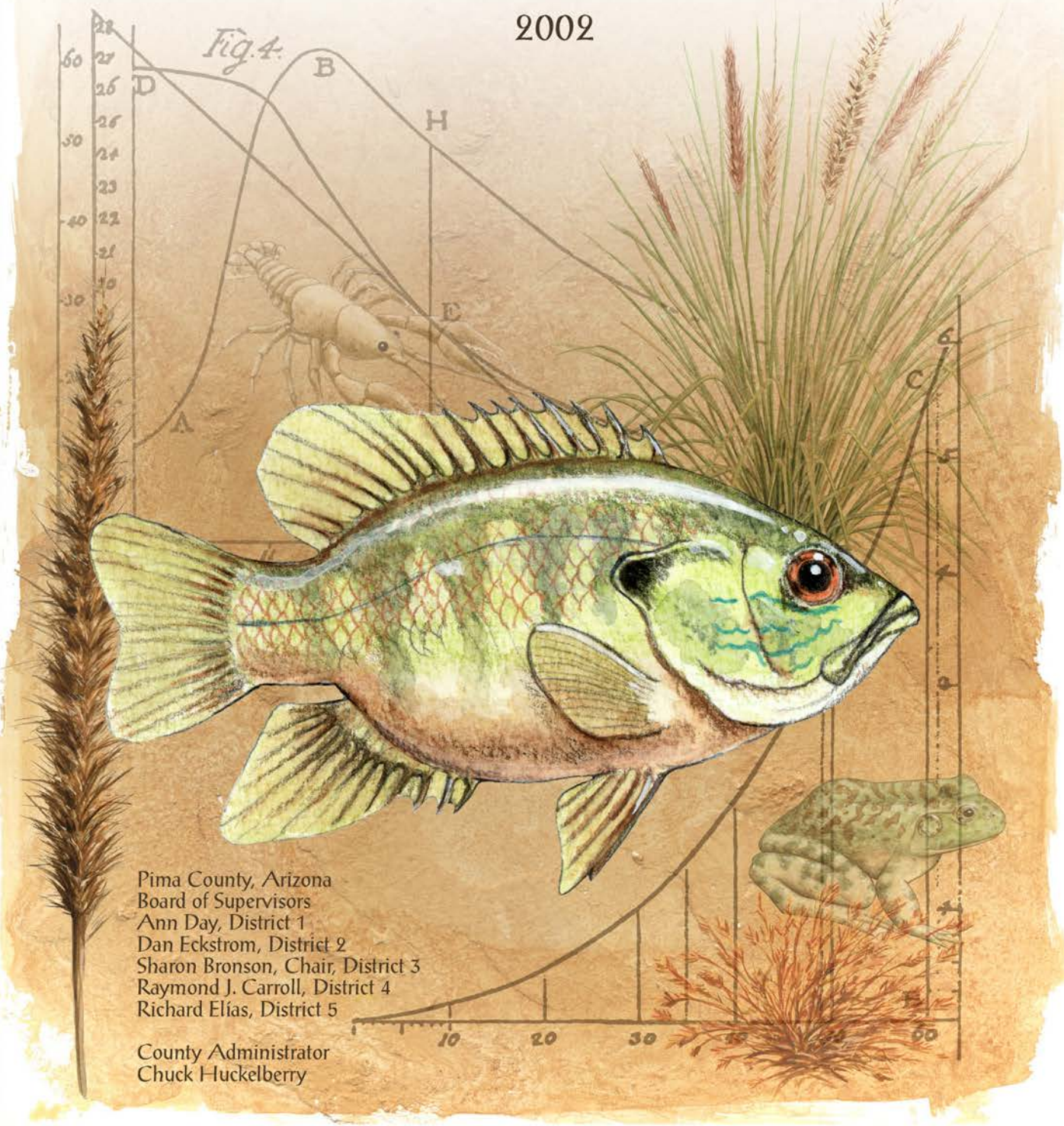
An Invasive Species Management Program for Pima County

Sonoran Desert Conservation Plan

2002



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Chapter One
Overview of Exotic Species Problems in Pima County

"We know … that the replacement of Sonoran Desert plants by buffelgrass means a large loss of species, so large that 90 of every 100 species disappear in dense buffelgrass stands. …" (Alberto Búrquez MontÍjo in Chambers 2002).

The spread of invasive species creates serious environmental problems as well as economic hazards for residents and will hamper implementation of parts of the Sonoran Desert Conservation Plan. Invasive species present severe fire hazards, destroy native species, outcompete native species, and generally change the character of the ecosystems that they invade. They can be found in almost all parts of the county, from the deserts to the mountains and at nearly all elevations, but are most common in disturbed areas and along transportation corridors. One of the most serious consequences for native wildlife is that many natives are adapted to feeding on native plants and do not switch easily to non-natives to which they are not adapted. Restoration of native species in many cases will depend on effective control of nonnative invasive species.

Pima County is not unusual in having an invasive species problem. Invasive species threaten ecosystems and economies worldwide and are a problem in every continent except Antarctica. In the southeastern United States kudzu vine covers thousands of acres of land., trees and even buildings. In the Midwest, nonnative insects have destroyed thousands of trees and mussels have invaded waterways, clogging up water intake pipes and destroying aquatic ecosystems. In northern California, eucalyptus groves dominate entire hillsides where once redwood grew. In Hawaii, there are few intact native ecosystems because of the importation of snakes and other invasive species. Starting on the east coast and moving gradually westward is the West Nile Virus, a threat to humans and wildlife

Pima County's most serious invasive species problems are:

- Invasive African and Mediterranean grasses that present severe fire hazards to the Sonoran Desert ecosystem that did not evolve with fire and cannot survive with intense fires.

Fig. 1. Bullfrog eating a bat it has caught flying over the water.
Photo; Cecil Schwalbe, USGS

- Bullfrogs that eat native frogs, fish, snakes, and even bats and birds they catch flying over the water and crayfish that devour other aquatic plant and animal life, leaving streams with little life other than crayfish and algae. (Fig. 1)
- Saltcedar that invades riparian systems and displaces native plants while offering little benefit to most wildlife.
- Africanized bees that threaten humans and animal life.

These and other invasive species problems are discussed in more detail below.

Introduction and Spread of Invasive Species

People have introduced many thousands of new species into Pima County over the past 100 years. Introductions in the early years were mostly for cattle forage. It was around the turn of the twentieth century that grasses such as Johnsongrass were brought in to feed cattle when severe drought and overgrazing led to the loss of much of the native grass. As early as 1890, however, people began to bring in many new species of landscape plants. Many of the native trees had been cut for wood so efforts were made to revegetate at least the urban area. Arbor Day became an annual event and local experts recommended a variety of non-native trees for landscaping. In the early 1900s University Extension experts imported trees such as eucalyptus from Australia, palm trees from the Middle East, and sumac from Africa. They recommended saltcedar for erosion control and landscaping. The urban native flora began to give way to plants from all over the world. New agricultural crops were also introduced and with them came weeds of many kinds.

Foreign insects and animals, too, have invaded the region. Starting in the 1900s, the Arizona Game and Fish Department brought in bullfrogs for sport and food and also began to stock streams and lakes with sport fish such as trout and carp. Mosquito fish were introduced to kill mosquito larvae in ponds. They did so, but also killed native fish in the process. European honeybees were introduced before 1800 for their honey, but the Africanized bee was accidentally released from a South American research facility and eventually made its way to Arizona. Both these new bees and their parasites and diseases adversely affect the many species of native bees.

Most of the introduced plants cannot thrive without extra care and irrigation and do not escape to become invasive. The very few species that do escape and become invaders, however, cause really serious problems in the desert and riparian ecosystems. Plants can even kill wildlife as is evident in Fig. 2 where a bat has become impaled on a burdock plant. Out of the thousands of foreign plant species in the area, less than 50 have

Fig. 2. Hummingbird impaled on the prickly seeds of a non-native burdock.

naturalized and less than 25 cause severe problems. It is not yet possible to predict for sure which species will become invasive.

Few introduced insects and animals become invasive. One of the biggest obstacles in devising management plans is predicting which species will become invasive in the future. We know which ones are problems today because the problems are so severe that they are obvious. Once the problem gets that severe, however, it is difficult and expensive to control. Prevention is far more effective and less costly.

The California Exotic Plant Pest Council is currently developing criteria for listing plants as potential problem species and the Arizona Nature Conservancy is working closely with them in an effort to develop a list of plants of concern for this area. It is a little easier to predict invasiveness of aquatic fauna, especially if the new species is omnivorous. One consequence of climate change will be the ability of species now limited by temperature range to move to higher elevations as the area warms.

Problematic Invasives in Pima County

In 2000 the SDCP report *Potentially Problematic Species in Pima County* listed the following as the major problem species that could have adverse impacts on priority vulnerable species in SDCP: saltcedar, giant reed, Bermuda grass, fountain grass, bullfrog, green sunfish, mosquitofish, crayfish, honey bee, horses, cattle, burros, pigs, tiger salamander, non-native snails, and fire ants.

In 2002 the Sonoran Institute and others identified 21 especially problematic invasive plant species of the Sonoran Desert in the U.S. and Mexico: Bermuda grass, buffelgrass, fountain grass, giant reed, Johnson grass, Lehmann lovegrass, Mediterranean grass, Arabian grass, Natal grass, red brome, African rue, filaree, crystal iceplant, Malta starthistle, Sahara or African mustard, camelthorn, saltcedar, African sumac, Eurasian watermilfoil, giant salvinia, hydrilla, and water hyacinth.

Nonindigenous species that have contributed to the demise of native fish in Pima County, according to SDCP Report *Historical Occurrence of Native Fish in Pima County* were: catfish, bullfrogs, crayfish, goldfish, green sunfish, mosquito fish, and saltcedar. Rosen's SDCP report on aquatic species also listed the above species.

The SDCP *Issues of Non-indigenous Species in Public Reserves* noted that more than 50 species of exotic fish have been introduced in Pima County. This report contains lists of non-native plants on public lands in Pima County.

Fig. 3. A hillside in the Phoenix area where hundreds of saguaros and other cacti burned during a fire fueled by nonnative grasses.
Photo: Todd Esque, USGS.

Grasses

Some invasive grasses from Africa and the Middle East present severe fire hazards to Sonoran Desert plants, especially to saguaros and other cacti that cannot withstand much fire. Once these plants have been killed by fire, it takes many years for new ones to mature. The grasses, on the other hand, are fire-adapted and come back robustly with the next rain. This means that they will probably burn again before the cacti have had time to mature. (Fig. 5) These new fire-adapted grasslands take the place of the native flora, making it extremely unlikely that the native ecosystem will ever return in grass-infested places. Although the Sonoran Desert has native grasses of its own, the natives tend to grow in small isolated clumps. Sacaton grass (*Sporobolus wrightii*), that tends to grow near riparian areas, is the main exception to this rule. It does not occur in typical saguaro-dominated ecosystems. North and east of the Phoenix area are acres of land on which the native cacti have been burned with almost no survival. Fires had spread from roadsides into the nearby saguaro-dominated areas.

Fig. 4. Buffelgrass. Drawing: John Singleton

Buffelgrass (*Pennisetum ciliare*)

Buffelgrass (Fig. 4) is an introduction from central and southern Africa. In its native habitat more than twenty different kinds of migratory ungulates graze on this nutritious grass at different times of year. Fires sweep through the grasslands from time to time. In the 1950s the U.S. Soil Conservation Service (now the Natural Resources Conservation Service – NRCS) experimented with it in Arizona and Texas and found that it did very well as a forage grass. After the long droughts of the 1930s and again the 1950s experts were looking for better forage plants for cattle.
The Tucson office of SCS planted experimental plots on abandoned farmland in the Avra Valley and other places. ASARCO used it to vegetate mine tailings near Green Valley.

By the 1970s the Mexican government endorsed the grass and ranchers began to plant in on thousands of acres in Sonora. In some cases ranchers plowed up large plots of land with an abundance of native cacti, intentionally turning the ecosystem into a grassland. In other cases they left many of the cacti intact. In both cases, however, the result was the loss of the natives because of the massive fires that occurred. It became necessary to replace metal fence posts and utility poles with nonflammable ones. Following the plantings, buffelgrass then escaped into surrounding riparian and thornscrub areas.

There are few places in Pima County where such wholesale planting occurred, but it has spread nevertheless. It can be found through the City of Tucson in alleys and vacant land, on top of Tumamoc Hill, along roadsides on the Tohono O'odham Nation, the Saguaro National Park, Tucson Mountain Park, Organ Pipe National Monument, and many, many other places.

Thousands of volunteer hours are spent monthly in attempts to control buffelgrass. (See below). Botanists at Organ Pipe National Monument have worked hard to persuade agency officials in Washington D.C. that the grass is truly a noxious weed, but work has continued on developing a more cold-tolerant variety which the U.S. Department of Agriculture recently released in

Fig. 5. Fountain grass. A grass that can grow through parking lot pavement without irrigation is liable to be invasive. Photo: Barbara Tellman

Texas. If this variety reaches Arizona, buffelgrass will be even more of a problem than it is today because it current range is limited by frost levels.

Fountain grass (*Pennisetum setaceum*

Fountain grass (Figs. 5 and 24) is a popular landscape plant introduced from Africa. It is a close relative of buffelgrass but is far more attractive in landscapes. Both grasses grow in perennial clumps that tend to spread and both also spread through seeds. Unfortunately, it is well adapted to the Sonoran Desert and easily escapes from landscapes to roadsides and desert washes. In some washes fountain grass fills the wash from bank to bank. Fountain grass presents the same fire hazard that buffelgrass does and like buffelgrass crowds out the native plants. Although it has been prohibited in local landscape ordinances, it continues to be used in landscapes and can easily be found along roads such as Ina and Orange Grove Roads in the Catalina foothills. A red variety is considered nearly sterile and can be used safely.

The Arizona Department of Agriculture is currently going through the regulatory process to add both buffelgrass and fountain grass to the noxious weed list.

Red brome (*Bromus rubens*)

Red brome (Fig. 6) was introduced from the Mediterranean region in the early nineteenth century and is useful as forage. This annual cool season grass flourishes in the spring in wet years, but dies back in the heat of summer. It, too, competes with native species, especially the spring annuals, and is a fire hazard. A large fire at Saguaro National Park East in the early 1990s was fueled by red brome. The seeds are quite sticky and will attach to clothing, fur, and even vehicles so it is easily dispersed by humans and animals.

Bermuda grass (*Cynodon dactylon*)

Bermuda grass (Fig. 7) reached Arizona in the late 1800s and quickly established itself. It is grown commercially as a landscape plant. It spreads through seeds and also by sending out

Fig. 6. Red brome has invaded this area and the saguaro is highly susceptible to killing fires. Photo: Todd Esque, USGS.

shoots that can root far from the parent plant. Once established it is very difficult to eradicate because the roots are deep and small broken pieces of root can sprout. Chemical treatments can be successful if repeated often enough. Once Bermuda grass has become established it will outcompete most native annuals and native grasses. It can be found dominating beaches along watercourses in Pima County and as far away as the Grand Canyon.

Fig. 7. Bermuda grass dominates this remote stream side far from any city. Photo: Barbara Tellman

Lehmann lovegrass (*Eragrostis lehmanniana*)

Agricultural Extension agents introduced this African grass widely in the 1950s as cattle forage, in reaction to the droughts of the 1930s and 1950s. It grows best at higher elevations than the low desert and does well in the uplands and mountain regions. Large plots of this grass were planted at the Santa Rita Experimental Range in the 1950s and lovegrass still dominates this grassland where few native grasses and annuals can grow because of the prevalence of lovegrass. The problem here is different from the problem in the desert proper. This area was grassland historically so the switch is from a variety of grasses and annuals to nearly a monoculture of this one grass species. Like other grasses it is well adapted to fire and thrives on periodic burning. As population moves from Green Valley and Sahuarita towards those grasslands, conflicts are liable to result over whether or not to allow the fires to burn or even whether to do controlled burns.

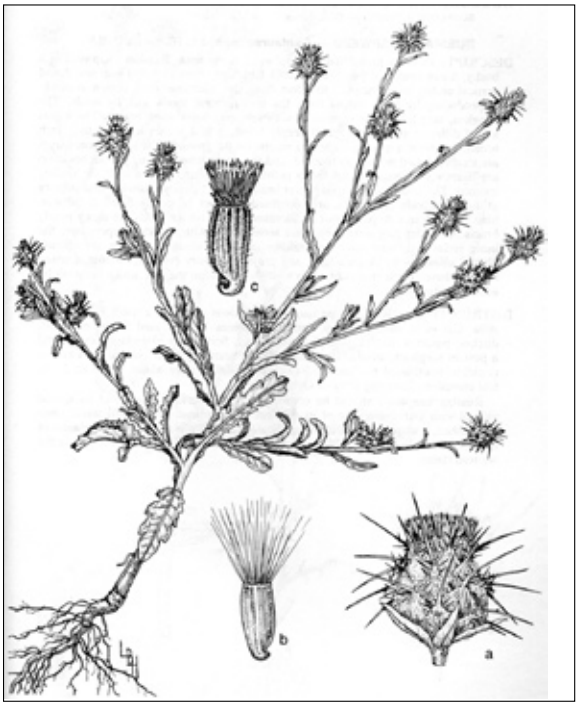

Fig. 8. Malta starthistle.
Drawing: Lucretia Hamilton.

Other grasses

Schismus barbatus, Schismus arabicus, Mellinis repens, and other grasses cause similar problems although they are not nearly as widespread yet in Pima County as the four above. A plant that resembles bamboo, Giant Reed (*Arundo donax*) is also a grass that can spread invasively, although it has not yet become a severe problem in Pima County. It is not the same type of fire hazard but can dominate washes. It spreads through seeds and sending out shoots and is difficult to eradicate once established. Pampas grass (*Cortaderia selloana*) has naturalized in a few places, but has not become invasive, although it has the potential to do so.

Mustards and Thistles

The plants in this group all arrived accidentally, probably through contaminated seed shipments of other plants. The Arizona Department of Agriculture is proposing to add all three to the noxious weed list.

Malta starthistle (*Centaurea melitensis*)

Malta starthistle (Fig. 8) and its high elevation relative the yellow starthistle can quickly invade

and dominate areas. The plants are prickly and produce an abundance of prickly seed so that one plant can have hundreds or even thousands of offspring a year. In one Pima County wash location, for example, from just a few plants in the summer of 2000, there were large clumps of plants more than five feet high in 2002 in one instance covering an area about 25' X 10'. The seeds explode off the plant and can move considerable distances. They can resprout from below ground level, so mowing is ineffective. The dry plants create a fire hazard.

Fig. 9. Sahara mustard growing along a roadside. Photo: Barbara Tellman

Sahara (African) mustard (*Brassica tournefortii*) and London rocket (*Sisymbrium irio*)

These plants in the mustard family have become widespread pests in many places in the county. The Sahara mustard (Fig. 9) tolerates a wide range of soils from sand dunes to desert soils. In the spring of 2000 there was a proliferation of Sahara mustard in the Avra Valley and elsewhere. London rocket is pervasive throughout the urban area and dominates the landscape near the Tumacacori Mission. Both mustards produce a lot of seed so quickly proliferate.

Trees

There are few problem invasive trees in Pima County even though hundreds of species are planted in landscapes. Eucalyptus, for example, is abundant in town but only a few trees are known to have naturalized outside of landscapes. One such location is along the Catalina Highway. In northern California, on the other hand, eucalyptus covers entire hillsides where once trees such as redwoods grew. There the climate is more favorable for eucalyptus than southern Arizona.

Fig. 10. Saltcedar monoculture along the Virgin River. Photo: Barbara Tellman

Saltcedar (*Tamarix ramosissima*)

There are several species of saltcedar or tamarisk in Pima County, but the problem species is *ramosissima*. (Fig. 10) It relative *aphylla* can be seen in the urban area, especially in the older parts of town where it has been planted as an ornamental starting in the late 1890s. This species grows as a large tree and does reproduce in the wild, but not to the extent that ramosissima does, although large groves are along the Colorado and Gila Rivers. It sterilizes the soil so very few other plants can grow beneath it and is allergenic.

Ramosissima, on the other hand,

is shrubbier and grows in thick clumps along riparian areas and even in fairly dry places. Along streams where the natural flow has been disrupted, it can become the only tree or shrub, replacing cottonwoods and willows. It has little value for wildlife, except that in some areas the threatened southwest willow flycatcher uses it for nesting and shelter. For this reason, some stands of saltcedar are actually protected. For the most part, however, it reduces biodiversity of flora and fauna. It, too, salts up the soil so that other plants have a difficult time surviving, although when it grows along watercourses the soils are occasionally flushed out by floodwaters.

Fig. 11. African sumac's beautiful spring blooms cause severe allergy problems for some people. Photo: Barbara Tellman

African sumac (*Rhus lancea*)

This African tree (Figs. 11 and 12) is a good example of a landscape plant that was considered relatively harmless until the 1990s when people began to notice that it had escaped into washes in the foothills and other places where it was displacing native trees such as acacias. Landscapers have been reluctant to admit that this is an invasive plant since it is easy to grow and quite attractive, especially when it blooms in the spring. Some people are highly allergic to this tree and feel that it should be banned as a tree with noxious pollen.

It has been in the Tucson area since the early

Fig. 12. African sumac invading a desert wash.. Photo: Barbara Tellman

1990s. It is highly invasive in the urban landscape and people whose neighbors have trees often find that the tree has spread to their yard uninvited. Once established it is very difficult to eradicate. It produces a large amount of seed that birds eat and then spread as they excrete, often far from the parent tree.

Tree of heaven (Ailanthus altissima)

This is another example of a tree with a long lag time between introduction and becoming invasive. It was introduced in the late 19th century as a landscape plant, sometimes brought from China by Chinese miners. It is a very hardy tree that can grow under a great range of conditions. It can be seen in landscapes in urban Tucson, especially in the older parts of town. It is the most common tree along washes and roadsides in the Globe-Miami area and is considered a problem along Sonoita Creek in Santa Cruz County and along the Verde River in Cottonwood. Although it has not yet become a problem in Pima County, it has escaped into a wash near Oracle Junction and may become a problem in the future. (Fig. 13)

Fig. 13. Tree of heaven invading a wash at Oracle Junction. Photo: Barbara Tellman

Aquatic Species

Bullfrogs (*Rana catesbeiana*)

The Arizona Game and Fish Department started introducing bullfrogs (Figs. 1 and 14) to Arizona in the early 1920s from Louisiana, considering them excellent hunting targets and good eating. They very quickly adapted to Arizona conditions, especially in disturbed watercourses and stock ponds. Bullfrogs are voracious eaters and consume practically any living thing they can get into their mouths. They can even catch bats and birds on the wing as they fly across the water. When they infest a pond or stream they are capable of eliminating the native fish, frogs, snakes and turtles.

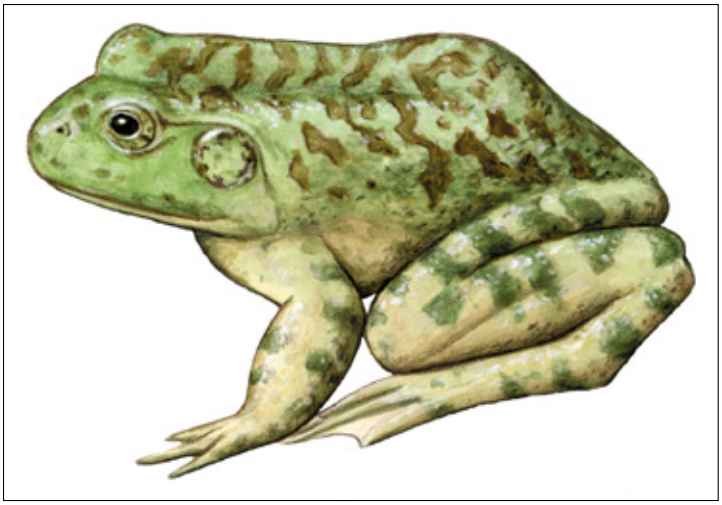

Fig. 14. Bullfrog. Drawing: Bill Singleton.

Bullfrogs are at a disadvantage, however, in streams that are relatively undisturbed and retain a normal cycle of flood and drying. Bullfrog tadpoles take about a year to mature and need to be in water during that time. Native frogs, on the other hand, mature in just a few weeks and can thus tolerate a stream that dries out part of the year. In this type of stream the native frogs are likely to prevail.

Bullfrogs are, however, able to travel considerable distances in search of water. Even if bullfrogs are eradicated or their tadpoles do not survive, a stream can be repopulated from sources miles away. Schwalbe, for example, tracked on young

bullfrog traveling 3 miles in one night in the search for water.

Successful reintroduction of native frogs, fish, water snakes, and turtles depends on continued bullfrog control.

Crayfish (*Orconectus virilis*)

Crayfish (Fig. 16), too, can be devastating to the plant and animal life in a stream as they are omnivorous and eat both plant and animal life in a stream or lake. They most commonly reach watercourses when people who are fishing empty out their bait buckets into the stream. Fortunately, they cannot travel across land to populate a water body.

Crayfish-infested streams characteristically have little or no life other than algae and crayfish making the stream s both unattractive and uninhabitable for native species. Insects, especially in the larval form, cannot survive and thus disturb the entire food chain for native birds and fish that feed on insects. Once they have cleared a stream of other life forms, they are cannibalistic. The Arizona Game and Fish Department has an active educational program to inform people of the danger of introducing crayfish into streams and about how to catch and eat them. Successful reintroduction of native species depends on successful crayfish prevention and eradication.

Cecil Schwalbe and Phil Rosen at the University of Arizona have done pioneering research into these issues.

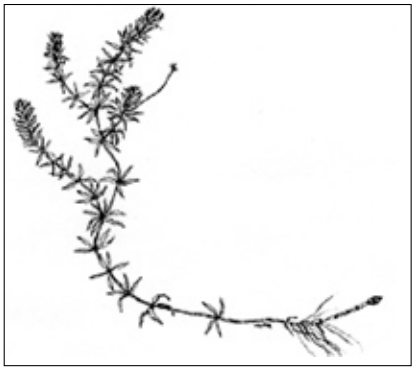

Fig. 15. Hydrilla. Aquarium and pond plants can also severely damage waterways. *Hydrilla verticillata*, a noxious weed, can completely take over a pond, making it impossible for native fish and native plants to survive. Water milfoil, salvinia, water hyacinth, and others can cause problems for native species.

Non-native fish

At least 30 nonnative fish live in southern Arizona streams, but the most problematic are the green sunfish (*Lepomis cyanellus*) and the mosquito fish (*Gambusia affinis affinis)* (Fig. 23). Green sunfish were introduced for sport purposes and mosquito fish were and continue to be introduced for mosquito control purposes. The mosquito fish as quite effective at control of mosquito larvae in many situations, but also can eliminate the native fish, some of which are equally effective at mosquito control. Green sunfish are voracious eaters and can eliminate native fish populations relatively quickly. Under current state regulations they may be used as fishing bait. A Sabino Canyon green sunfish eradication program is described below.

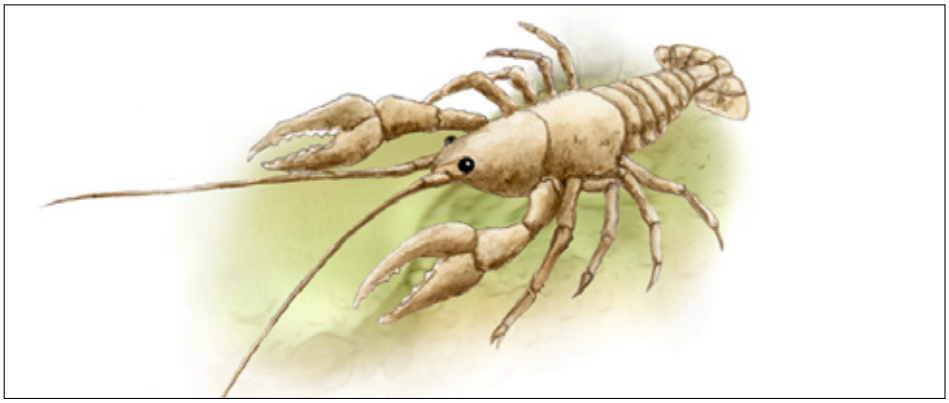

Fig. 16. Crayfish. Drawing: Bill Singleton.

Snails

The Fish and Wildlife Service and Arizona Game and Fish consider a snail from New Zealand (*Potamypyrgus antipodarum*) a major threat to Arizona streams and prohibit intentionally importing it or releasing into waterbodies. This tiny snail is voracious and causes severe problems with aquatic ecosystems. One of the major routes of transmission is on the boots of people fishing or taking water quality samples, moving from one stream to another.

Insects

Honeybees (*Apis mellifera* and *A. mellifera scutellata*)

Europeans introduced honeybees into Arizona at least 300 years ago. They play an important role in pollination as well as produce significant amounts of honey, but they have also negatively impacted the many species of native bees. The Africanized honeybees escaped from a research facility in South America and gradually made their way through Central America into Arizona. They have caused numerous problems for humans and pets. Parasites and diseases that accompany these nonnative bees may also impact the native bees.

Fire ants (*Solenopsis invicta*)

Fire ants have not yet been recorded in Pima County, but the threat is real. They have been found and eradicated in Yuma and are a serious problem for humans and wildlife in Texas where they have seriously impacted wildlife that they attack and overwhelm in huge numbers. In some areas they have nearly eliminated ground-dwelling wildlife. They migrate along watercourses and if they reach Arizona are expected to cause serious problems unless checked in time.

Fig. 17. *Cactoblastis cactorum*, a potential menace for prickly pear is moving towards southern Arizona. This South American pest is on the federal noxious pest list and is already a problem in parts of Mexico.

Chapter Two
Existing Invasive Species Programs in Pima County

Many agencies and groups are involved in invasive species management in this area. Because invasive species do not respect political boundaries, it is essential that Pima County cooperate with and supplement existing programs where appropriate. A 2000 SDCP report discussed programs of various agencies and included their invasive species lists. The following is a very brief summary of the major programs in place. Much of this information is from that source and from *Resource Book for Invasive Plant Management*.

Federal Agencies

President Clinton issued an Executive Order in 1992 directing all federal agencies with appropriate jurisdictions to inventory the invasive species problem in their areas and develop management programs. One result of the EO was formation of an interagency committee whose job is to develop policies and programs and cooperative efforts among agencies. Some agencies were already deeply involved in these issues while others had to start from scratch. The involved agencies have developed programs, but in some cases are limited by a shortage of funds.

U. S. Department of Agriculture - APHIS program

The Department of Agriculture operates under laws designed to keep harmful species from crossing U.S. borders into the country. Species on an official noxious weed list or on a list of noxious insect pests may not be imported. The emphasis is on weeds and pests that cause economic problems, especially to agriculture. Plants on these lists may not be sold in interstate commerce. Commercial shipments are subject to inspection at the border and individuals are questioned to determine if inspection is warranted. The Nogales border station has the greatest traffic of the APHIS inspection stations along the U.S. border because of the large amount of produce grown in Mexico and Central America and imported to the U.S. APHIS does not have authority to restrict importation of weeds and pests not on the official lists. Additions to the list are proposed for the near future, but proposed additions must go through the regulatory process so the ability to react to new invasions is somewhat compromised.

USDA also is responsible for research into biocontrol organisms and for approving the release of such organisms.

U.S. Forest Service

Like other federal land management agencies, the Forest Service inventories invasive species problems and attempts to deal with problems that occur, but a lack of funding makes this difficult. Two projects to eliminate invasives in Sabino Canyon, however, appear to be relatively successful. In the first, the Forest Service, in cooperation with Arizona Game and Fish Department, used chemicals to remove non-native green sunfish (Fig. 18) from the creek to encourage the very small population of native fish in the stream. The configuration of the recreation area, with bridges across the creek that act as dams in low water times made it possible to isolate specific pools and treat the non-natives in

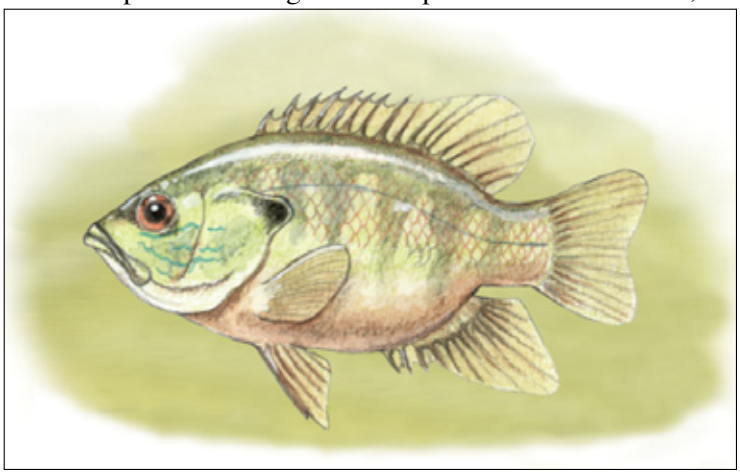

Fig. 18. Green sunfish. Drawing by Bill Singleton.

the expectation that in high water times the native population would move down from the higher elevations where non-natives do not prevail. The second project was utilization of volunteers to remove fountain grass that had spread along the road and from down to the creek and up the hillsides. Under Forest Service leadership monthly volunteer Saturdays resulted in removal of many of the worst infestations. This is an on-going effort.

Other projects include an interactive display on 'alien species" at the Sabino Canyon Visitor Center, a 1999 weed survey with information entered into the Forest Service GIS system, and preparation of a management plan.

National Park Service

Organ Pipe National Monument

Staff at Organ Pipe NM have been very active in control of buffelgrass at the Monument in the belief that if buffelgrass were to get a strong foothold the Organ Pipe cacti and other native plants would be jeopardized by fire. Since the purpose of the monument is to protect this ecosystem, control of invasive species is vital.

The highway and the illegal crossing corridors are ideal mechanisms by which buffelgrass can invade the area. Park staff monitor areas where buffelgrass occurs and organized volunteers to pull out the plants. They have been quite successful, but new infestations continually cross the border so monitoring and vigilance are necessary.

Saguaro National Park

The west unit of the park has been quite active in eradicating buffelgrass in cooperation with the Arizona-Sonora Desert Museum and the Weedwackers (see below). Park staff has utilized students in these efforts as an educational program. The east unit of the park had a major fire that was fueled by red brome grass, another native. Staff have monitored the changes from the fire, including the build-up of ash and sediment in pools that used to contain native fish and frogs but have filled up making the pools unusable for those species.

U.S. Bureau of Land Management

BLM, too, operates under a mandate to deal with invasive species problems. BLM lands are often more difficult to deal with than Forest Service or National Park lands because they may spread out in non-contiguous bits of land interspersed with other lands. The primary emphasis is on species listed as noxious, but attention is paid to nonlisted species such as buffelgrass where they cause problems. The main problem in addressing these issues is lack of funding and staff.

U.S. Fish and Wildlife Service

The Service has responsibility for protecting threatened and endangered species and also manages wildlife refuges. The Buenos Aires Wildlife Refuge has major problems with non-native grasses introduced in the past for forage, but so far has not found an effective way to control them, although staff has used controlled burns as a management tool with very limited success. The Service also has had an active bullfrog control program. Bullfrogs dominate ponds in the refuge and University of Arizona herpetologists have established projects to eliminate bullfrogs and reintroduce natives, with Heritage Fund grants. They developed techniques to capture the bullfrogs and then fence the ponds to keep more bullfrogs from moving into them. Lack of funds and restrictions on stocking the threatened and endangered species, however, have postponed completion of the project.

U.S. Department of Transportation

The U.S. Department. of Transportation has an active program for control of invasive weeds along highway corridors. Weeds along highways present safety problems as well as aesthetic ones. Highways are ideas areas for proliferation of weeds because they are subject to disturbance. In 2002 the Department sponsored an international conference in Tucson to discuss ways of dealing with roadside weeds. Assistance is available to deal with weeds along highways.

Tohono O'odham Nation

The main plant species of concern are buffelgrass and Malta starthistle. Due to lack of staff and funding, control is not a high priority, but summer youth crews are one method of eradication.

State Agencies

Arizona Department of Agriculture

This department implements both the native plant laws and the noxious weeds and pest control laws. As is the case with the U.S. Department of Agriculture, enforcement is limited to plants on the official lists of noxious species. Adding species to the list is a lengthy process that must go through the state-approved system. In the past, listed species were mainly those of economic concern to agriculture, but in 2002 the Department proposed listing species such as saltcedar that have impacts beyond direct economic ones. Depending on the category, listing of a plant means that it cannot be imported into the state, that it cannot be sold in nurseries, and/or that serious infestations must be eliminated.

Department staff is active in weed management statewide.

Arizona Department of Transportation

The Arizona Department of Transportation is deeply involved in weed control along state highways for safety and aesthetic reasons. In southern Arizona, buffelgrass and fountain grass are the most problematic nonnative roadside weeds. If they are allowed to proliferate along the roadsides, fires can result when a cigarette is tossed out or when a car pulls onto the shoulder and sparks from the catalytic converter ignite the dry grasses. (Fig. 19) this is an unacceptable risk to the driving public. In addition, ADOT controls some native trees such as palo verde where they present safety hazards to the traveling public. ADOT uses an integrated approach to weed management and reseeds with natives where appropriate.

Fig. 19. Roadside fire hazard along the Sells Highway. Photo: Barbara Tellman

Arizona State Parks

Catalina State Park has serious infestations of non-native grasses and other weeds, especially mustards. Funds are limited to deal with these problems even though the weeds are a fire hazard.

Arizona State Land Department

This department has problems similar to BLM's because its land is so spread out in noncontiguous parcels that a management program is difficult. The department has one employee whose primary job is to deal with invasives but funding problems make it difficult for this one person who is not based in Pima County to work effectively statewide. The department has been involved in control programs in various areas of the state. It cooperates with other agencies, especially where WMAs are established.

Arizona Game and Fish Department

The Game and Fish Department has over the years been responsible for introduction of a number of aquatic invasive species. In recent years the department has played an active role in combating problems caused by those same species and in efforts to bring back some native fish species by control of invasive species. The department has funded invasive species research projects through the Heritage Fund, especially ones dealing with bullfrogs and crayfish.

Regulations require a permit for stocking aquatic creatures on waterbodies and this applies to individuals emptying out their aquariums or releasing pet aquatic creatures such as frogs and turtles. There are also laws and regulations governing introducing wildlife into waterbodies where they do not currently exist and against bringing certain nonnative wildlife into the state.

Current laws and rules allow use of certain nonnatives as bait, however, although recently new restrictions on crayfish were implemented in most of

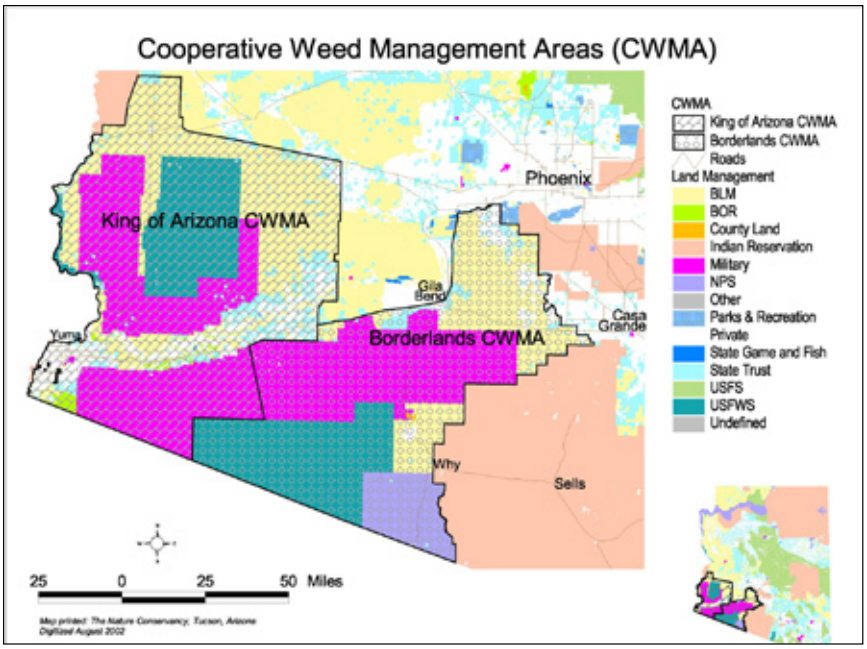

Fig. 20. Weed Management Areas in southwestern Arizona. The Borderlands CWMA includes portions of western Pima County. There is no WMA for other parts of Pima County.

the state. Game and Fish also actively stocks nonnative sport fish in urban and rural recreational lakes.

Weed Management Areas (WMA)

WMAs are useful tools for cooperative weed management in large areas. An example of a successful WMA program is the Sweet Resinbush and Karoo Bush WMA. Sweet resinbush (*Euryops subcarnosus*) forms monocultures completely eliminating competing plants and offering virtually no value for wildlife. This WMA was established to deal with two specific species regardless of geographic area, whereas most WMAs are geographically based. The WMA managed to add sweet resinbush to the Arizona noxious weed list and developed a management plan for eradication with the help of volunteers. The WMA produced educational materials and successfully eradicated sweet resinbush from several sites in southern Arizona, including ones at Sabino Canyon and the Santa Rita Experimental Range. Efforts depended on cooperation among a great variety of agencies including federal and state land management agencies, two counties, local ranchers and farmers and the University of Arizona. As is so often the case, the main obstacles were funding and staff.

A recently formed WMA for the western portion of the Sonoran Desert, Borderlands Cooperative Weed Management Area (CWMA), includes a small part of Pima County in the Ajo area. (Fig. 20) This WMA has identified camelthorn (*Alhagi maurorum*), iceplant (*Mesembryanthemum crystallinum*), Malta starthistle (*Centaurea melitensis*), garden rocket (*Eurca vesicaria*), salt cedar (*Tamarix ramosissima*), buffelgrass (*Pennisetum ciliare*), fountain grass (*Pennisetum setaceum*), Lehmann lovegrass (*Eragrostis lehmanniana*), Mediterranean grass (*Schismus barbatus*) and Arabian grass (*Schismus arabicus*), red brome (*Bromus rubens*), Sahara mustard (*Brassica tournefortii*). Agencies involved include BLM, Department of Defense, State Land Department, U.S. Fish and Wildlife Service and others. Plans include development of educational materials, inventories, and eradication programs.

WMAs are very useful tools in weed control and involve cooperative efforts so necessary to success. Determination of the goals and most problematic plant species to target are important first steps in an effective program. Formation of a WMA can open up new avenues for funding of weed control efforts.

Professional and Non-profit Organizations

The Tucson Mountain Weedwackers

This group began as a collaboration between the Arizona-Sonora Desert Museum, Pima County Parks, and Saguaro National Monument

to eradicate buffelgrass in the Tucson Mountains. (Fig. 21) The group maps infestations and holds monthly eradication days at which volunteers pull out clumps of the grass in selected areas. They also pull out fountain grass. Recently they have branched out to do projects in other areas and are now partially sponsored by the Arizona Native Plant Society instead of the Desert Museum. (See Sabino Canyon below).

The Nature Conservancy (TNC)

Nationally, TNC considers invasive species one of the greatest threats to biodiversity and has active programs to deal with these problems. Locally, TNC is working closely with the California Exotic Plant Pest Council and others to develop criteria and programs for dealing with exotic species issues. TNC also works with many other agencies to establish Weed Management Areas.

The Sonoran Institute

The Sonoran Institute works closely with TNC on Weed Management Area establishment and has produced two invasive species publications in cooperation with other groups. The first was a survey of groups and agencies working on invasive species issues and the second a field guide to the most problematic ones. (See Chapter 4).

Pima Invasive Species Council (PISC)

PISC is a local group that meets monthly to exchange information among the many groups and agencies concerned about invasive species. PISC cooperates with groups doing volunteer eradication projects.

Professional Organizations

The Southwest Vegetation Management Association provides information to professionals and the public, works with the legislature on needed regulations and laws, holds conferences, and exchanges information about weed issues. Members are mostly professionals working on invasive plant issues. The Arizona Interagency Weed Management Group is made up of federal and state agency representatives with invasive species responsibility. This new group is identifying priorities for activities in southern Arizona.

Fig. 21. Weedwacker volunteers clearing out buffelgrass in Tucson Mountain Park. Photo: Weedwackers

Local Ordinances

Weed Ordinances

Cities and the county have weed control ordinances. While these are not targeted towards non-native species, most of the problem weeds are in fact not natives. (County Code 17.33)

Landscaping and Native Plant Ordinances

Pima County and the cities have landscape ordinances that require the use of a certain percentage of low water use plants in certain types of landscaping. The lists use a low water use plant list developed by the Arizona Department of Water Resources (ADWR). This list notes especially invasive species but does not distinguish between natives and non-natives. Many of the low water use plants listed are native to other arid and semi-arid areas and may easily adapt to naturalizing in Arizona conditions. Pima County also has a native plant ordinance that has regulations for treatment of native plants during development. There are no special provisions regarding invasive species. (County Code 18.22 & 23)

Non-Native Plants Known to Produce Allergenic Pollen in Southern Arizona

Bermuda Grass	*Cynodon dactylon*
Johnson Grass	*Sorghum halepense*
Buffelgrass	*Pennisetum ciliare*
Bur clover	*Medicago sativa*
Cocklebur	*Xanthium strumarium*
Lambsquarters	*Chenopodium album*
Russian Thistle	*Salsola kali*
Elm, Chinese	*Ulmus parvifolia*
Mulberry	*Morus alba, rubra*
Olive	*Olea europaea*
Canary Island Date Palm	*Phoenix canariensis*
Pecan	*Carya pecan*
Pepper Tree	*Schinus molle*
Privet	*Ligustrum*
Sumac, African	*Rhus lancea*
Saltcedar	*Tamarix aphylla*

"Epidemiological studies in Tucson have shown that allergic rhinitis occurs in approximately 35% of the population, and asthma occurs in approximately 7% of the population. ... Airborne pollen allergens in the Southwest are mainly, but not exclusively, from introduced species."
Source: Asthma/Allergy Department, College of Medicine, University of Arizona, web site.

Chapter Three
Pima County Programs under SDCP

Pollen Control Ordinances

Pima County's pollen control ordinance (County Code 7.41) prohibits the planting of two tree species whose pollen is know to cause serious allergy problems: olives (other than Swan Hill), and mulberry. It also requires that Bermuda grass be kept mowed and flowering prevented to avoid spread of pollen.

Multi-Agency Cooperation - The Key To Long Term Success

Considering the inherent invasive nature of the species that are the subject of this report, all land stewards within the geopolitical boundaries of Pima County should be encouraged to participate in a regional effort to coordinate inventory and control efforts. A control failure in one area will likely lead to the continual eradication needs of an adjoining area. The mutual exchange of ideas and research, along with the creation of cooperative educational and eradication programs, may produce an efficient region-wide approach to the problem.

Pima County consists of 9,184 square miles, including state, and federal lands including parks and monuments. Also included are two Native American nations, and several municipalities. Pima County has governmental jurisdiction over the private land in the county, but only in the unincorporated areas. Land owned by Pima County includes parks, floodprone land, roads, government offices, and rights of way. Because invasive species problems are so pervasive across administrative lines, it is vital that Pima County work with other agencies to prevent and control the spread of invasive species.

The Importance of a Volunteers

Most successful invasive species management programs have relied substantially on seasonal or volunteer field crews working under trained supervision. The success of volunteer assisted programs has enabled many agencies with limited financial and personnel resources, to initiate specific control efforts. The use and support of outside resources is necessary and Pima County should actively participate in any regional organizations created to encourage open cooperation between resource managers on these issues.

Educational Programs - Increase Public Awareness

Many people living in Pima County are probably not familiar with the non-native invasive species issue. As a result, plans to challenge the invasives threat will require a substantial education and public outreach program. If given the level of outreach extended to water and recycling programs, the general public may in time become the greatest contributor to the reduction in the spread of exotic invaders. A general public awareness program is badly needed, but special educational programs are needed to target specific audiences. This would include targeting residents in areas where invasives are becoming problematic.

Educational programs on invasive species issues should be designed for various groups of people, including landscapers, homeowners groups, aquarium owners, government employees working with outdoor facilities, and others. These programs include public speakers, web site information, volunteer weed removal programs, brochures, and other activities. Education programs aimed at school children should be a part of the environmental education program currently implemented by the Pima County Natural Resources and Parks Department.

Pima County should cooperate with and assist local groups and agencies already doing or designing educational programs and should initiate programs of its own to fill gaps.

Following are some suggested programs:

Youth Programs

These programs should be designed to educate the community's young people about

the invasive threat. This would include school programs, youth volunteer opportunities, and an effort to encourage teachers to add habitat issues to their curriculum. This should be part of the County's current education program with the County Natural Resources and Parks Department.

Educational Programs for Landscape and Plant Nursery Professionals and Staff

Plant professionals should be provided quality educational programs designed to teach about the undesired use of potentially invasive landscape plants and trees and acceptable alternative landscape plants. Programs specifically directed to backyard pond planting and stocking are needed. Integration of invasive species information into existing programs such as the Cooperative Extension Smartscape Program or the Master Gardener Program is an effective mechanism.

Certification programs can be established listing successful participants as being trained in sound environmental techniques and planning, thus adding marketable skills to their resumes. These courses can be established with the help of Tucson Botanical Gardens, the Cooperative Extension Service, Arizona-Sonora Desert Museum, Arizona Native Plant Society, and others.

Training for Real Estate and Development Professionals

Classes or seminars can do much to inform developers about the problems, their environmental responsibilities, and the aesthetic benefits of maintaining the natural beauty of the Sonoran Desert, stressing viable alternatives to potentially and actually invasive plants. Such classes can be designed to satisfy continuing education requirements for some professionals.

Educational Programs for Pet Stores and Backyard Pond Dealers

The County should cooperate with Arizona Game and Fish Department and managers of pet and backyard pond stores to help educate customers on the dangers and illegality of releasing nonnative animals in lakes and streams. Printed materials and workshops should stress the need to

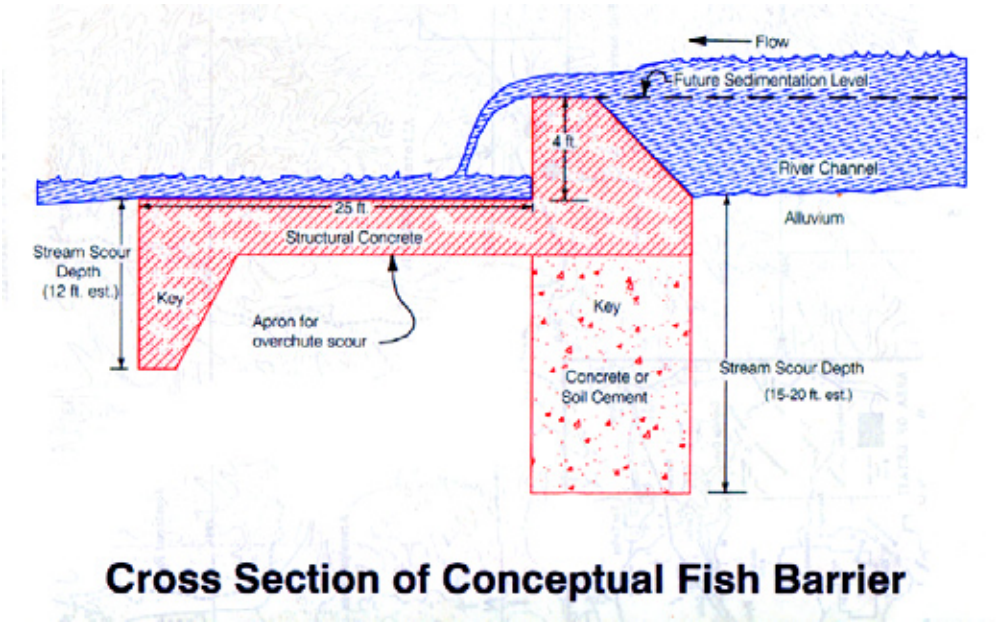

Fig. 22. Diagram of a U.S. Fish and Wildlife Service fish barrier to keep nonnative fish from swimming upstream and damaging native fish habitat. Such barriers can cost up to $1 million each and illustrate how seriously the Service considers the threat to native fish. The Service is considering installing barriers in Pima County to counter possible threats from accidental importation of fish in Central Arizona Project water.

inform customers of the dangers of releasing pets such as turtles and bullfrogs into the wild. Sale of invasive species should be discouraged or banned.

Training for Appropriate County Employees

Education about invasive species, and the Sonoran Desert Conservation Plan can be provided for all county employees through various means including a regular column in The Scoop. Classes pertaining to the control of exotic invasive species should be included within the Pima County Conservation Education Program. Employees can also learn ways to be more conscious of invasive species issues at home.

An intensive education program should be made available to public works employees at all levels. Public Works employees are often at the front lines of the battle. In fact, public right-of-ways and easements are a major contributor to the rapid spread of invasive species. Educating operations crews, supervisors, and engineers, to recognize problem invasives is a significant first step in the implementation of control programs for county projects. As these departments strive to comply with ever growing environmental regulation, they will need educational materials, and clearly written operating procedures for compliance with the SDCP and other conservation concerns. Public works employees are already subject to many education requirements such as defensive driving, forklift training and certification, and many other occupational training programs. Education at the management and field operations level will help insure environmental compliance.

County Cooperative Publications Program

The county can use its publishing capabilities to help sponsor conservation outreach publications, educational posters, and other SDCP related issues.

Fig. 23. Mosquitofish. Reintroduction of native fish requires that the watercrouse is free of non-native fish such as this.

Many local conservation groups have the expertise to produce excellent educational materials, however, they lack the financial resources to publish. If the County could assist with publishing some of these items, then the County would be generating substantial information at little expense.

Assistance from the county will greatly improve these programs, especially with help from county publishing capabilities. Education should be a key component of any region-wide conservation plan.

Workshops

In 2001 Pima County held a day long workshop about aquatic exotic invasives for professionals. Additional workshops on other kinds of invasives will provide useful information for people working on these issues.

Reintroduction of Native Species

1. The recently established native plant nursery on Pima County Wastewater property will continue to provide a basic stock of native plants for use on county-owned properties. Reintroduction of plant species that have been rare or extirpated in Pima County will be most successful if non-native species are controlled in conjunction with the introduction.

2. Several projects are planned to reintroduce native fish and amphibians to selected watercourses in the region. Successful implementation will require removal of invasive species where they occur, especially bullfrogs, and, where needed, improvement of watershed conditions to encourage native species and discourage invasive ones.

Policies on County-owned lands

Some county departments are already beginning to include invasive species awareness into landscaping and weed management practices. These departments should cooperate with other departments to develop a comprehensive countywise approach.

1. Guidelines for landscaping on county properties including parks, wastewater rights-of-way, floodplains, roadsides, and waste disposal sites should call for the use of native plants unless there is an overriding reason for using non-natives. Where non-natives must be used, these species

should not have invasive characteristics.

2. Adopt weed management practices to reduce the threat of invasive weeds on County-owned properties to help prevent the further spread of invasives. Special emphasis should be placed on those weeds that present a fire hazard to public or private property.

3. Cross-train County employees in recognition and management of invasive species to facilitate implementation of the above policies. Employees whose work involves management of county property subject to weed invasions should receive updated information on the problems of invasives, identification of problem species, control methods, and county policies on management.

4. Develop and enforce a policy prohibiting dumping by individuals of nonnative aquatic species of plants and animals in county parks and preserves. An active educational program should accompany this program so that people will understand why it is necessary. Cooperation with the Arizona Game and Fish Department and local pet stores in this effort is essential.

5. Work with the County's youth and adult jobs programs to accomplish weed removal projects and to incorporate weed removal into other community projects.

Policies on Private Lands

1. Landscaping and native plant ordinances and plant lists (County Code: 18.72 and 18.73) will be reviewed and updated to assure that invasive species are not used in new commercial plantings.

2. The list of plants prohibited because of allergenic properties will be updated to assure that all non-native invasive plants that present significant pollen problems are included. (County Code: 7.41).

3. An updated version of Chapter 7.33 of the County Code, which includes provisions for weed control, will be revised further encourage removal of invasive weeds from private property.

4. The Grading Standards Ordinance (County Code 18.81) will be reviewed and revised to include invasive weed control. General land clearing and grading encourages the proliferation of weeds and invasive species. Grading creates the need for monitoring and inspection requirements during, and for some time after, property development. This is not a major financial burden on the county, or developers, who should also be required to eradicate invasive plants and weeds on sites for a specified period following development.

5. Modify Pima County Code 7.41, to include the prohibited marketing of potentially invasive landscaping plants from area nurseries. The numbers of marketed landscape plants that are, or may be invasive, are probably very few with no significant economic impact. Local nursery and plant professionals should be encouraged to participate in designating restricted species.

Intergovernmental Agreements (Federal, State, Tribal, Municipal)

1. Intergovernmental agreements with other governmental entities in the region should include coordination of activities to control invasive species with agencies such as the U.S. Fish and Wildlife Service, National Park Service, USDA Forest Service, The Tohono O'odham Nation, the Arizona Departments of Agriculture and Transportation, The Arizona Game and Fish Department, the State Land Department, and cities.

2. Agreements on the species most in need of and susceptible to control and on feasible control methods will facilitate reduction programs. The Arizona Nature Conservancy and others are developing lists of the most problematic species, and criteria for determining which species should be included. This list should serve as a basis for coordinated control efforts in Pima County.

Cooperative Activities with Nonprofit Groups

Many community and statewide groups are already working on invasive species issues as described in the previous chapter. Improved communication and coordination will make these efforts more successful. These groups include the Southwest Vegetation Management Association, Arizona Native Plant Society, the Tucson Herpetological Society, Cooperative Extension, Tucson Botanical Gardens, the Arizona-Sonora Desert Museum, The Nature Conservancy, the Sonoran Institute, and many others. Cooperative activities will involve education (as discussed below), communication, volunteer programs, weed removal projects, establishment of and

participation in weed management areas, and other kinds of activities.

Enforcement

Enforcement of policies concerning exotic invasive species is fundamental to the success of the effort. However, with so many different stakeholders involved, enforcement efforts will be hard to coordinate except on an individual basis. With this in mind, it is the education component of the plan that may yield the greatest long term results and thus reduce the staff necessary for enforcement. This in no way diminishes the need for adequate penalties and enforcement staff necessary to carry out the intention of the County policies.

Research and monitoring

Organizations dealing with invasive species issues have long recognized the importance of monitoring and mapping exotics as a means to gauge long-term success. Existing regional mapping efforts should be included in any Pima County management program. The availability of GIS data and GPS technology has provided a useful means for the inventory and monitoring of invasive species.

The county should support and benefit from continued outside research at institutions such as the University of Arizona. Continued cooperation with the School of Renewable Natural Resources is essential. Areas where programs have been implemented should be monitored to determine long-term effectiveness of programs.

County Staffing to Implement the Program

Serious efforts to control invasive species will require professional and technical level staffing to implement monitoring and mapping programs, research, and to manage the overall efforts of the invasive species program. The Department of Natural Resources, Parks and Recreation should be responsible for generating a Pima County Invasive Species Management Plan, and for overseeing invasive species programs implemented by the various county departments.

The different departments should establish their own programs for controlling invasives within their areas of responsibility. Actual fieldwork can be carried out by trained field personnel, who can also serve as team leaders in volunteer efforts. Departments can also consider using trained and certified landscape or biological consultants to help control exotics within their domains. However, individual department programs should coordinated by a SDCP technical advisory group under the Parks Department

Fig. 24. Fountain grass invading a wash in the Tucson Mountains. Photo: Barbara Tellman

Chapter 4
References

Sonoran Desert Conservation Plan Reports

Seven SDCP reports deal with invasive species issues, four as the main subject, and three as part of a larger topic.

Issues of Non-Native Species in Public Reserves (2000)

This report looked at invasive species issues in public preserves, including Coronado National Forest, Saguaro National Park, Organ Pipe National Monument, Catalina State Park, and various country preserves. This report discusses policies of those agencies and provides lists of non-native species detected by those agencies on their lands In Pima County.

Potentially Problematic Species in Pima County: Ecological Effects and Management Strategies, (2001)

This study identified 45 potentially problematic species in Pima County in areas prioritized for biological conservation purposes. These species of greatest concern were: bullfrog), green sunfish, western mosquitofish, red shiner, crayfish, tamarisk, fire ant, Africanized bee, non-native grasses, Asian mustard. The author recommended that problems be considered by impacts of specific ecosystems, not by individual species.

Aquatic Vertebrate Conservation in Pima County (2000) and Species Re-establishment within Pima County 2001

These reports identified the prevalence of some non-native aquatic species as significant barriers to successful conservation and reintroduction of native species. Bullfrogs, crayfish, and several species of fish present the greatest problems, according to these reports. Reintroduction of certain native plants will be most successful if competing non-native plants are eliminated or reduced, along with improvement of stream conditions, which may be necessary to produce conditions that will encourage natives rather than non-natives.

Riparian Protection, Management, and Restoration (2000)

This report identified a number of issues related to riparian restoration and management, including the negative impacts of invasive species of plants and animals and discussed the need to manage for natives rather than non-natives.

Historical Occurrence of Native Fish in Pima County (2000)

This report documented accounts of native fish in the past and discussed the role of nonnative species in the demise of the natives.

The Effects of Roads on Natural Resources (2002)

Among the many effects that roads have on natural resources, their tendency to serve as corridors for the spread of non-native species was discussed in this report.

Potential Impacts of the Sonoran Desert Conservation Plan on Invasive Species in Pima County (2002).

This paper discusses ways in which SDCP will impact invasive species in Pima County and was designed as bacground material for the Environmental Impact Statement for SDCP.

Other Sources

In addition to the SDCP reports listed above, useful references are:

Anon. 2001. *Guidelines for Coordinated Management of Noxious Weeds: Development of Weed Management Areas*. USDA.

Anon. 2001. *Meeting the Invasive Species Challenge*. *Management Plan*. National Invasive Species Council. Washington D.C.

Arizona Game and Fish Department. Arizona Lobster: Tips on Catching and Cooking Crayfish. video. 2002.

Arizona-Sonora Desert Museum. 2002 edition. Bioinvaders of the Sonoran Desert. *Sonorensis*. Arizona Sonora Desert Museum.

Baskin, Y. 2002. *A Plague of Rats and Rubbervines*. Island Press. Washington D.C.

Chambers, N. and Hall, J. 2002. *A Resource Guide for Invasive Plant Management in the Sonoran Desert*. Sonoran Institute and The Nature Conservancy. Tucson.

Chambers, N. and T. Oshant. 2002. *Invasive Plants of the Sonoran Desert: A Field Guide*. Sonoran Institute. Tucson

Esque, T., and C. Schwalbe. Alien annual grasses and their relationship to fire and biotic change in Sonoran Desertscrub. Pp. 165-194 IN Tellman, B., ed. 2002.

Esque, T. et al. 2002. Effects of desert wildfires on desert tortoise (*Gopherus agassizii)* and other small vertebrates. *Southwest Naturalist*. in press.

Felger, R. 1990. *Non-Native Plants of Organ Pipe Cactus National Monument, Arizona*. Cooperative National Park Resources Studies Unit. University of Arizona. Tucson

Howery, L.D. and Ramos, G. 2001. *Arizona's Invasive Weeds*. University of Arizona Cooperative Extension. Tucson.

Lady Bird Johnson Wildflower Center. 2002. Invaders Among Us: Controlling Invasive Species. A Special Issue of *Native Plants* 18:4. Austin Texas.

McNeely, J.A. et al. 2001. *Global Strategy on Invasive Species*. IUCN. Cambridge, England.

Mooney, H.A. and Hobbs, R.J. 2000. *Invasive Species in a Changing World*. Island Press. Washington D.C.

Rosen, Phil and Schwalbe, C. 2002. Widespread effects of introduced species on reptiles and amphibians in the Sonoran Desert Region. Pp. 220-240 IN Tellman, B., ed. 2002. Tellman, B., ed. 2002.

Shine, C., Williams, N., and Gundling, L. 2000. *A Guide to Designing Legal and Institutional Frameworks on Alien Invasive Species*. IUCN – The World Conservation Union. Bonn.

Tellman, B., ed. 2002. *Invasive Exotic Species in the Sonoran Region*. University of Arizona Press. Tucson.

Tellman, B. 2002. Is your landscape threatening the desert? *Desert Plants*. *18:2*.

Tellman, B. ed. 2002. *Weeds Across Borders: Proceedings of a Conference Held in Tucson May 2002*. Arizona Sonora Desert Museum. Tucson.

Todd, K. 2001. *Tinkering with Eden*. Norton & Co. New York.

Westbrooks, R.G. 1998. *Invasive Plants: Changing the Landscape of America*. Federal Interagency Committee for the Management of Noxious and Exotic Weeds. Washington D.C.

Wilson, M.F., et al. 2002. Invasive exotic plants in the Sonoran Desert. Pp. 281-90 IN Tellman, B., ed. 2002.

Fig. 25. The aftermath of a grass fire in the Sonoran Desert. Photo: Todd Esque, USGS.