ARUNDO AND SALTCEDAR: THE DEADLY DUO

A Workshop on Combating the Threat from Arundo & Saltcedar

PROCEEDINGS OF THE ARUNDO AND SALTCEDAR WORKSHOP

June 17, 1998
Ontario Hilton Hotel
Ontario, CA

Presented by:

California Exotic Pest Plant Council
Monsanto Company
Riverside County Regional Park & Open Space District
Team Arundo
The Nature Conservancy
University of California Cooperative Extension, Imperial County

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Introduction

Arundo and saltcedar are two of the most serious invasive exotic pest plants in California. This workshop was held to present new information regarding the impact and management of these plants as a follow-up to two very successful workshops, one on Arundo in 1993 and one on Saltcedar in 1996. The workshop attracted 136 people and would not have happened without the dedicated effort of the organizing committee and the contributions of the invited speakers and poster contributors. This Proceedings presents written versions of these oral presentations and posters. Addresses and contact information for the authors is available from the list of participants at the back of this document.

The Organizing Committee for the workshop were Nelroy Jackson, Monsanto Company; Paul Frandsen, Riverside County Regional Parks and Open Space District; Valerie Vartanian, The Nature Conservancy; and Carl E. Bell, University of California Cooperative Extension, Imperial County. The Editor for the Proceedings is Carl E. Bell. Additional copies of the Proceedings are available; to order, send a check payable to the Ag Extension Trust Fund for $10.00 per copy to Arundo/Saltcedar Proceedings, Cooperative Extension, 1050 E. Holton Rd., Holtville, CA. 92250-9615. Copies of the Proceedings of the 1996 Saltcedar Management Workshop are also available for the same cost from the same source.

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ARUNDO AND SALTCEDAR: THE DEADLY DUO
A WORKSHOP ON COMBATING THE THREAT FROM ARUNDO AND SALTCEDAR

Ontario Hilton, Ontario, CA
June 17,1998

BIOLOGY AND ECOLOGY OF GIANT REED[1]

Joseph M. DiTomaso
University of California, Davis

Giant Reed (*Arundo donax*)

Native Distribution

Arundo has three species native to warmer tropical and temperate regions of the Old World (Hoshovsky 1989). *Arundo donax* is the largest and most widespread member of the genus and is commonly referred to as giant reed, wild cane, or Spanish cane. It is native to several countries from the Mediterranean Sea to the Lower Himalayas (Rieger and Kreager 1989).

Introduction and Spread

In Europe, *Arundo donax* was probably cultivated as far back as the 1600s. It is not certain, however, when *Arundo* was introduced into the US. It has been suggested that it was first introduced in the 1700s. Others indicated that it was brought into the US for use as a windbreak by French immigrants in the 1800s. It appears that the first introduction of *Arundo donax* into California probably occurred from the Mediterranean in the 1820s by the early Spanish settlers in the Los Angeles areas (Bell 1993, Iverson 1993). Its primary use for erosion control in drainage canals. It was similarly introduced for this purpose in other southwestern states. It has also been widely planted as an ornamental in other warmer areas of the US.

It soon spread throughout, mostly through intentional human introductions, and is now distributed from Arkansas and Texas to California, where it is found throughout the state, and in the east, from Virginia to Kentucky and Missouri and generally southward.

Taxonomy

Arundo donax and *Phragmites communis* (common reed) are difficult to distinguish vegetatively (Ollendorf et al. 1988). The leaves of *Arundo* may be slightly larger and more scabrous along the margin than *Phragmites*. Culms also tend to be somewhat larger in *Arundo*. Both species have rhizomes, although *Phragmites* can also have stolons. *Arundo* can form clumps, whereas *Phragmites* occurs in extensive colonies. These

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[1] Dr. DiTomaso also presented similar information on the biology and ecology of saltcedar (*Tamarix spp.*). Published reviews of saltcedar by Dr. DiTomaso are available: 1) Proceedings of the Saltcedar Management Workshop an 1996 UC Cooperative Extension, Rancho Mirage, CA pp ; and 2) highlighted above.

characteristics are not often of diagnostic value. It is important to note, however, that *Phragmites communis* is a native California grass. Thus, it is essential to be certain of the proper identification of *Arundo donax* prior to implementing control strategies.

Ethnobotany

Arundo has historically and currently used in many ways. Egyptians used giant reed as early as 5000 BC to line underground grain storage. Mummies of the fourth century AD were wrapped in *Arundo* leaves (Hoshovsky 1989).

Arundo donax was commonly grown in Europe, China, Japan and India, because of its usefulness. Industries bases on fishing-poles, paper-making, rayon-making, and musical-reeds are the most important uses of the stem of this grass. Stems serve as support for vines and similar climbing plants, and for making trellises for climbing cultivated plants. Stems are also used for garden fences, measuring rods, walking sticks, baskets, chicken pens, arrows, livestock fodder, crude shelters, thatching for mats and roofs of sheds, barns, and other buildings (Bell 1993). It makes a good quality paper, and in Italy the plant is used in the manufacture of rayon. Variegated and glaucous-leaved varieties are still used as ornamentals.

Arundo donax also had medicinal applications (Hoshovsky 1989). The rhizome or rootstock was used as a cure for dropsy. Boiled in wine with honey, the root or rhizome were used for cancer. An infusion of the roots was also considered to be an effective depurative, diaphoretic (increase perspiration), and diuretic (increase urine production).

Giant reed has played an important role in the culture of the western world through its influence on the development of music, which can be traced back 5000 years (Hoshovsky 1989). The basis for the origin of the most primitive pipe organ, the Pan pipe or syrinx, was made from *Arundo donax*. Even today, all of the musical instruments which have a vibrating reed use *Arundo donax*, including oboes, bassoons, clarinets, and saxophones (Perdue 1958). The cultivation of *Arundo donax* for this purpose is primarily in the south of France.

Impact

Arundo readily invades riparian channels, especially in disturbed areas, and reduces ground-water recharge, compromised water quality, chokes riversides and stream channels and interrupts surface water flow and flood control, contributes to mosquito habitat, displaces native plants, provides habitat for exotic and feral wildlife, and increases fire potential (Jackson 1993). Stands of *Arundo* form an explosive fuel and pose a serious threat to life and property along the urban/forest interface.

The long, fibrous, interconnecting root mats of giant reed form a framework for debris dams behind bridges, culverts, and other structures that lead to damage. When *Arundo* debris is dislodged, it will eventually float downstream and, when combined with sand and trash, form into huge debris piles for removal by work crews (Douce 1993). Thus, the plant can be just as much a problem when dead as when alive.

All evidence indicates that giant reed does not provide either food or habitat for native species of wildlife (Bell 1993). Dense, homogenous stands of *Arundo donax* create zones essentially devoid of wildlife and its presence is viewed as being potentially disastrous for the overall habitat quality of the riparian system (Rieger and Kreager 1989). Infestations have threatened the nesting ground of the Least Bell's vireo, a small songbird that is listed as endangered by both federal and state agencies (Frandsen and Jackson 1993). In Simi Valley, giant reed has choked the habitat of the 3-spine stickleback, an endangered fish species.

Biology and Ecology

Giant reed is a hydrophyte, growing along lakes, streams, drains and other wet sites (Bell 1993). It grows best in well drained soils along river banks and in other areas where abundant moisture is available, particularly where water tables are close to, or at, the soil surface (Hoshovsky 1989). *Arundo* is best developed in poor sandy soil and in sunny situations, but tolerates all types of soils, from heavy clays to loose sands and gravelly soils. It also tolerates a wide range of environmental or human related stresses, including extreme temperatures, drought, floods, damage, diseases, fire, and bulldozers (Bautista 1994). *Arundo* survives in areas with average annual precipitation of 3 to 40 dm, pH values between 5 to 8.7, and high salinity. It can spread from the water's edge up the banks and far beyond the zone previously occupied by riparian woody vegetation.

Establishment

Giant reed can be seriously retarded by lack of moisture during its first year, but drought causes no great damage to patches two to three years old. Once established this species tends to form large, continuous clonal root masses, sometimes covering several acres, usually at the expense of native riparian vegetation which cannot compete with *Arundo*.

Growth

Culms of *Arundo* can reach a height of 20 ft tall and grow 2.5 to 3 inches per day under optimal conditions (Rieger and Kreager 1989). Weedy stands in the US have been reported to yield 8.3 tons of oven-dry cane per acre. Its extensive rhizomes allow it to resprout very quickly after disturbances and out-compete the slower responding native riparian vegetation (Rieger and Kreager 1989). Because it propagates vegetatively, it can form rather pure stands, often at the expense of other plants (Hoshovsky 1989). When established, it has a strong ability to out-compete and completely suppress native vegetation. *Arundo* can survive very low temperatures when dormant but is subject to serious damage by frosts after the start of spring growth. Individuals will survive extended periods of severe drought accompanied by low-pressure humidity or periods of excessive moisture. The ability of *Arundo* to tolerate or even grow well under conditions of extreme drought is due to the development of coarse, drought resistant rhizomes and deeply penetrating roots that can reach deep soil moisture.

Reproduction

Giant reed flowers between March and September with large (12 to 24 in long) plume-like terminal panicles (Hoshovsky 1989). The seeds produced in this country, however, are seldom, if ever, fertile (Bell 1993). Even in areas were it is well adapted, *Arundo donax* does not usually produced viable seeds (Perdue 1958). Some plants have been grown in scattered locations from seed collected in Asia. Reproduction of giant reed is primarily vegetative, through rhizomes (Bell 1993). These fragments can float miles downstream where they can root and initiate new infestations. Due to its rapid growth rate and vegetative reproduction, new infestations can quickly form pure stands at the expense of other species (Bell 1993). Because the spread of *Arundo* is primarily through vegetative fragments, it is essentially an intra-basin and downstream phenomenon, often caused by flooding events.

Effect on Fire Frequency

Giant reed is highly flammable throughout most of the year, and the plant appears highly adapted to extreme fire events (Scott 1993). While fire is a natural and beneficial process in many natural communities, it is a largely unnatural and pervasive threat to riparian areas. Because it is extremely flammable, the establishment of giant reed within a riparian area redirects the history of a site by increasing the probability of wildfires and increasing fire intensity once it does occur (Bell 1993). Consequently, giant reed effectively alters riparian forests from a flood-defined to a fire-defined natural community. Burning *Arundo* only encourages further growth. Rhizomes respond quickly after fire, sending up new sprouts and rapidly outgrowing native species in a burned-over site (Bell 1993, Rieger and Kreager 1989). Thus, fire events select for pure stands of *Arundo donax.*

Water Usage

Arundo uses prodigious amounts of water to supply its incredible rate of growth. Although there are no specific studies on the evapotranspiration rates of *Arundo*, it has been estimate that it evaporates water at approximately the same rate as rice. This means that every acre of *Arundo* uses about 5.6 acre-feet of water per year. Native species use only about a third this amount, 1.9 acre-feet per year. The water lost to evapotranspiration would otherwise be available for groundwater recharge and ultimately drinking water supplies (Iverson 1993).

Water Quality

Studies indicate that giant reed lacks the structure necessary to provide significant shading of bank-edge river habitats, resulting in warmer water than would be found with native trees and shrubs (Iverson 1993). Consequently, the water is exposed to more sunlight, and subsequently higher photosynthesis activity. Warmer water in conjunction with more sunlight promotes algae growth, which tends to raise the pH of the water. High pH facilitates the conversion of total ammonia to toxic un-ionized ammonia, which further degrades water quality for aquatic species and downstream users (Bell 1993). Un-ionized ammonia is more toxic to fish and other aquatic life. As a result, aquatic areas dominated by giant reed usually have lower diversity of aquatic animals, including fishes. In the Santa Ana River system, where *Arundo* dominates, the lack of streambank structure and shading has been implicated in the reduction of rare native stream fished including the arroyo chub, three-spined stickleback, speckled dace, and Santa Ana sucker. *Arundo* therefore degrades the quality of water resources as well as the quantity (Bell 1993, Iverson 1993).

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DESTRUCTIVE NATURE OF ARUNDO AND TAMARISK

Valerie Vartanian
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Background

The Santa Ana River Watershed is approximately 60 miles long, encompassing roughly 2 million acres. This river flows through three Counties, several incorporated cities and is surrounded by nearly every land use imaginable. There are many agencies, landowners, and other stakeholders along this complicated river system. Through the efforts of several of these land managers and agencies a cooperative, proactive program has started to address invasive plant infestations. This effort has brought nearly every land manager and agency to the table to work on systematic, long term control programs.

Southern California has a combination of topography and climate, which provides for a distinct type of river system, much different than the rest of the country. Winter rains begin in October and run through April with the bulk of the precipitation happening in January and February, produce on average 10-14" a year. The rest of the year becomes quite warm with no measurable rain. The ground is baked dry for 8 months before those first few rains begin again. This type of climate supports a low, sometimes dense vegetation type that is well adapted to the fluctuations in rainfall.

Because this region is geologically active, "young" mountains rise sharply over the valley floor. Many of these ranges rise to 3,000' near the coast up to 11,000' inland. The distance to these inland watersheds is usually not very far away, typically less than 100 miles from shore. When you combine the climate and the vegetation type that is supported, you get a system that has thin soils covering steep slopes in which the rain comes hard over a short period of time. In other words, Southern California river systems are typically fast moving, seasonal, river systems that erode more sediment than is deposited. This alluvial is eventually carried out to the shore where it is extremely important to the health of the continental shelf marine ecosystem which supports a rich diversity of organisms including many of the ocean going fish that we include in our diets.

In contrast, Northern Californian and eastern river systems have a much longer reach between headwaters and ocean with much less elevational change. This means that rivers meander in their beds and waters move much more slowly, depositing sediments along the way. Typically there is more water delivered with each storm and the storms are distributed much more evenly throughout the year. Flooding in these systems occurs as bankful conditions top over and spread along the large flat river valleys. In Southern California, the rapidly moving waters challenge bank stability and cut through causing flooding in specific nearby areas.

Attempts to control flooding events here in the Southland have been less than successful in most cases. A common technique is to channelize the river bottom and sides with concrete in order to prevent the banks from eroding. This usually leads to increased erosion below the channelized reach as water shoots through much more rapidly than normal. Some rivers, like the Los Angeles River, have had most of the main stem river and many tributaries completely channelized. This has lead to the elimination of many important river functions like recharge of ground water, maintenance of natural habitat for the support of native wildlife, and transportation of sediments for the maintenance of continental shelf ecosystems and coastal strand integrity. What has increased is the transportation of non-point source pollution directly, without filtering, to the ocean ecosystem.

Luckily, not all rivers in Southern California have succumbed to concrete. The Santa Ana River, 60 miles south of Los Angeles, still offers a relatively natural river system surviving within the context of urbanization. From headwaters to the ocean, the Santa Ana River system is approximately 60 miles long encompassing 2 million acres of watershed. The headwaters begin up in the rugged San Bernardino and San Gabriel Mountains in San Bernardino County. Snowmelt and groundwater seepage provides the water source for surface water in the upper tributaries and mainstem river. Further down the main channel, the Santa Ana flows along the natural flood plain through Riverside County, an area rapidly urbanizing within the historic dairy farms and orchards. Just before the river leaves Riverside County, it is impounded behind the Prado Dam where it forms one of the largest fresh water riparian habitats in Southern California.

As the Santa Ana flows past the dam, it runs a few more miles as a natural river through the Santa Ana Mountains and then reaches Orange County. The entire length of the Santa Ana River within Orange County becomes a large concrete channel until it flows to the ocean in Huntington Beach.

Some of the land use immediately adjacent to the river above the dam includes recreation (fishing, boating, shore play, birding, hiking, hunting), agriculture (dairy farms, cattle ranching, citrus orchards, crop farming), light industry (sand mining, industrial mills, airports), and housing developments. The cities of Corona and Norco project a 50% increase in population within the next 20 years. There are also a host of water treatment plants that discharge treated water back into the river accounting for most of the surface flow in the mainstem channel.

In spite of these rapid human changes, the river system continues to support a myriad of plant and animal species. Unfortunately, there is enough significant loss of habitat in other river systems added to the reduction of overall habitat in the Santa Ana that several native species have become threatened or endangered. Plant species such as the Santa Ana wooly star and animals like the least Bell's vireo, southwestern arroyo toad, and San Bernardino kangaroo rat are under a great deal of pressure to find that specific type of habitat needed to live or breed. Many other animal species that have come to rely on the remaining riparian habitat to nest are rapidly moving towards listings not limited to but including Cooper's hawk, yellow warbler, yellow-breasted chat, and Yellow-billed Cuckoo.

The challenge here is to coordinate all of the activities that may impact the river to address human needs while maintaining the river's integrity. Regulatory laws that help protect natural habitat and water quality include The Clean Water Act, both National and California Endangered Species Acts, and the Migratory Bird Act. California and U.S. Environmental Protection Agency, State and Regional Water Quality Control Boards, U.S. Fish and Wildlife Service, Cal. Dept of Fish and Game, and Army Corps of Engineers administer these regulations.

Within the 3 county-area there are 5 water districts who coordinate under the Santa Ana Watershed Project Authority (SAWPA) and several water dischargers (Metropolitan Water District, Department of Water and Power). Other stakeholders in this watershed include 3 county flood control districts, County/City planning departments, County/City Fire departments, County/City Public Works Departments, U.S. Forest Service, Cal. Dept of Fire and Forestry, State Parks, Mosquito Abatement Districts, 5 Resource Conservation Districts, and hundreds of private landowners. Needless to say, the list of stakeholders and other water/river users is immense.

Arundo

Giant reed is one of the largest members of the grass family. Though it puts out a flower stalk it does not appear to reproduce from seed. The thick rhizomes underground send up shoots spreading in place. The rhizomes grow relatively close to the surface and will break off during flood events sending small pieces down river to colonize new areas. When the root mass pulls away during these flood events, they break down the stability of the banks that are holding up against the flow of the water. Giant reed can cause the destabilization of banks, which is the leading cause of flooding in Southern California river systems. Occasionally the severed stalk will wash down and take root forming new plants, but this only occurs under a narrow set of conditions.

Giant reed goes dormant during the fall and winter months leaving a dry biomass above ground. In the spring the dry stalks reactivate in addition to new shoots forming around the perimeter. This dry biomass is extremely volatile during the fall Santa Ana wind conditions. Once it has burned, the roots are protected underground and will send up new shoots very quickly, usually before any native vegetation can recover.

Most recently giant reed has been actively planted along river banks, in private landscaping, and transported in sediments during flood events or when flood control scoops up sediment and moves it to another location (like over the edge of a road cut immediately above the river channel). Once it has taken hold each plant become a constant point source with each new flood event. As these point sources continue to multiply, the overall amount of giant reed will take over the natural vegetation.

The Natural System

In a natural river system, there are many plant species adapted to live along the moving water corridor. These plants all have varying needs for water and will be found where they can set roots to take in what is needed. Many of these plants have a similar structure in that most of the plants are shrub species (some becoming quite large) that are many branched and are deep-rooted to hold them in place. After a flood event, there is a succession of plants that will colonize the open sand. Without subsequent major flood events, these plants will continue to get larger and eventually outcompete the smaller shrubs and herb understory. Finally, only the largest of shrub and tree species will dominate. For each of the plant species and successional structural habitats there is a variety of animal species adapted specifically to fulfill their needs. Many native animal species will find the open space of the newly colonizing banks to be ideal while others require a mix of overstory and understory. Still other animal species are dependent on a tall closed canopy overstory to nest or forage.

Normally, flood events occur in a mosaic pattern along the river corridor so that pockets of habitat remain while other are scoured out. This creates a dynamic habitat structure and diversity able to sustain a great diversity of animals. This too can unravel relatively quickly when the diversity of plant species and the physical structure of the community are changed.

The Unnatural System

Giant reed has several deleterious affects on a river system. It takes up 3 times more water than native plants, does not provide nesting or foraging habitats needed by native and migratory animal species, increases erosion to banks during flood events, increases destruction to infrastructure during flood events, decreases water quality, and increases the fire frequency and intensity which is a threat to urban areas.

The amount of water uptake by giant reed is somewhere in the range of three times the amount of water used by native plants. This water loss decreases the total amount of available water in the river system. Aquifers cannot be adequately recharged translating to less water for the ever-growing populations nearby. This can cost millions of dollars to water districts that have to buy additional water to add to the domestic water supply.

Giant reed does not have the typical growth form of native plants. It grows straight and tall with virtually no branching. When it grows near the river's edge the reed does not adequately shade the water's surface allowing for a drastic rise in temperature. Even a small variation in water temperature will eliminate many species of aquatic animals. This rise in temperature encourages algal blooms that will change the dissolved oxygen level and pH of the water also contributing to the decline of animal species.

The unfamiliar vegetative structure does not attract birds to utilize giant reed as a nesting site, temporary shelter, or forage area. This increases the nesting pressure pushing birds to nest in inadequate areas, which can be attributed to the decline of nest success. There is also no insect species attracted to giant reed, which would provide a food resource for these nesting birds. Therefore, infestations of giant reed represent a void in the habitat where native plants have been pushed out and native animals cannot find food or shelter.

During the winter months when we have our rainy season flood waters will dislodged the reed from the banks and carry it down river. These floating masses become lodged behind an overpass or other constriction and block the flow of water. The force of the water will eventually push the structure down river off of its foundation. Many of the infrastructure repair costs resulting after flood events are related to giant reed. Also when the clump is dislodged it decreases the integrity of the bank encouraging a breakthrough and flooding in that area. Eventually these mats of reed will end up on the beaches. Several cities have reported that the greatest expense for beach clean up after flood events is the removal of giant reed piles.

With the presence of giant reed in the system, fires increase in frequency and intensity. During the fall while giant reed is dormant, the above ground stalks are dry and susceptible to fire. When it burns, the native plant species interspersed usually will not survive. This allows for the giant reed to regrow with virtually no competition promoting its spread. Fire is not only destructive to the native plant habitat but it also threatens human habitation along the river. Many firefighters will not go into a stand of reed that is emblazoned due to the extreme threat to their own lives.

Techniques for Combating Giant Reed

So is there a solution to this insidious problem? One technique that has been successful is the use of an EPA approved herbicide, Rodeo®, sprayed on the foliage during the fall (pre-dormancy). During the fall, giant reed will move sugars from the leaves to the roots for storage. When the herbicide has been applied to the leaves, the plant will translocate the herbicide along with the sugars to the root. Once in the roots, the herbicide will prevent the roots from sprouting, eventually killing the plant.

Sometimes the giant reed is so well mixed with native plant species that spraying may cause harm to the non-target plants. In these areas a "cut-stump" method is used. Here, the stalks are cut approximately 1-3" above ground and an herbicide is sprayed on the freshly cut stumps. It has been observed that a spray window (time between cutting and spraying) of 2 minutes may still be too long and the plants will sufficiently seal off and not absorb the herbicide. Also, because there is little surface area to spray and therefore not as much herbicide is absorbed, the solution of herbicide must be very high (sometimes at full strength). This becomes a very expensive process. Environmental elements can change the spray window. If plants are in full sun the window is much shorter.

Once the plant is dead, the above ground biomass might need to be dealt with so that the stalks do not mobilize in a flood event and cause problems down river. It takes a labor force to cut the stalks and move them to a location where the stalks can be reduced to mulch. This labor and the required machinery are nearly equal in cost to the spraying.

New machines have been marketed for giant reed removal that have a mulching blade attached to the front or side and can be driven into the work site. These machines can save time and money by mulching in place, but cannot be used in every situation. Areas that have no vehicle access or have listed or sensitive plant and animal species are not recommended for use of large machinery.

Ultimately the goal for treating giant reed is to effectively push back the invasive plants so that native plants can reestablish their place. To do this, the invasive plants need to be either killed in place or removed from the area entirely. Whatever the process, it should not be more detrimental to the remaining natural environment than the infestation posed and should provide the most efficient, effective long-term control.

The Watershed Approach

The only way for a program of riparian invasive plant control to be successful is to start at the uppermost reaches of the watershed and work down river. This means there must be coordination with all of the landowners and land managers' top to bottom. The regulatory agencies must be on board to provide technical assistance and permits and the landowners must be able to arrange access to the crews.

Private lands pose a challenge in access and additional costs in liability while working on private lands. When private landowners are aware of the problems caused by giant they are usually willing to remove the plants on their property at their own cost. Some landowners have significant amounts of giant reed and the cost to remove is prohibitive. There are also some landowners that do not want to remove this plant from their land. In each case, it is important to contact the landowner and involve them in planning and educational process.

To adequately coordinate the removal of giant reed in a watershed, three programs need to be operating: 1) creating a functioning mapped data base that contains the hydrology, land ownership/use, infestations, project sites, etc.; 2) coordinating with regulatory agencies to plan mitigation project sites to fit within other current projects to fill in from the top down; and 3) All stakeholders need to meet regularly to share information regarding the threats from giant reed, control techniques, funding opportunities, and each stakeholders' direct role and responsibility.

One of the most successful approaches to perform these programs has been through the formation of Team Arundo. This team meets regularly, is voluntarily attended, and has attempted to coordinate mapping, monitoring, education, fund raising, long term strategy planning, and implementing actual work projects. Team Arundo, Santa Ana River, has continued to play a role as the informational forum. A small riparian habitat restoration project starting as mitigation for water district water conservation program, U.S. Fish and Wildlife Service, and The Nature Conservancy has evolved into a watershed-wide giant reed control program. This group joined by the Resource Conservation Districts has now formed a team to coordinate mitigation funds to work at a watershed level. This Santa Ana Watershed Association will eventually unite with Team Arundo to manage funding, coordinate projects, map and monitor projects, and perform educational programs throughout the Santa Ana River watershed.

The Team Arundo model has now been adopted in several other watersheds. Team Arundo Del Norte oversees the San Francisco Bay area and all rivers that flow into the bay; Team Arundo El Sureno coordinates activities in San Diego County; Team Arundo Angeles meets under the umbrella of the San Gabriel Watershed council and coordinates watersheds throughout Los Angeles County and nearby Ventura County; and the newest Team Arundo is forming to cover the California Central Coast. Members from these teams are working on statewide initiatives like standardized mapping and monitoring programs, regional programmatic permitting, and educational materials.

HABITAT FOR THREATENED HABITAT AND ENDANGERED SPECIES—QUARANTINE AREAS OR CONTROL EXOTIC WEEDS?

Richard Zembal
U. S. Fish and Wildlife Service

Riparian habitat in coastal southern California is being invaded and replaced by giant reed, also called Arundo (Arundo donax). This infestation follows an era of flood plain reduction, vegetational control, and channelization that have resulted in riparian habitat losses in excess of 91% state-wide (Dahl and Johnson 1991) and 95 - 97% in southern California (Faber et al. 1989). Where giant reed has gained a stronghold, it significantly threatens the survival of the remaining riparian acreage and its great diversity of dependant wildlife.

The wildlife value of a giant reed stand is close to zero, compared to the incredibly high productivity of native riparian habitat. Because Arundo is a nonnative and quite fibrous, almost nothing eats it. Consequently, it does not play a significant role in the food web. It has no structural similarity to any dominant native riparian plant and offers little useful cover or nest placement opportunities for birds. The main stems are vertical with no horizontal structure strong enough to support nests. Similarly, Arundo provides little bank overhang for shading, cooling, reducing evaporative water loss, or providing fish cover. This plant's most observed use as cover has been by feral pigs near the Riverside County Park headquarters and homeless humans in several locations. Coupled with its post-disturbance invasive ability, tendency to carry fire, interference with flood control, and excessive water use; the plant has little identified redeeming value.

The Riparian Community

In contrast with giant reed forests, native riparian habitat has literally been fabled for its high productivity and associated abundance and diversity of wildlife. Lacking Arundo, coastal southern California stream-side, or riparian habitat is willow- (Salix spp.) dominated with local stands of cottonwoods (both Fremont's, Populus fremontii, and black, P. tremuloides), alder (Alnus rhombifolia, more abundant at higher elevations now), and mixed woodlands of oaks (largely coast live oak, Quercus agrifolia) and sycamores (Platanus racemosa) on the higher terraces. Of the 5 common willow species, arroyo willow (S. lasiolepis) is often dominant, mixed and interchanging with red willow (S. laevigata). Largely on sandy deposits, the more diminutive sandbar willow (S. hindsiana) forms little stands and provides important structural diversity in side cover and understory with mulefat (Baccharis glutinosa) and dozens of additional, less dominant species. Where inundation and standing water is seasonally abundant, such as in the Prado Basin, black willow (S. gooddingii) can dominate the riparian forest in nearly pure stands. Prado was built for flood control, and now water conservation near the confluence of Mill and Temescal Creeks with the Santa Ana River.

Measurements of the vegetational composition along the Santa Margarita River in northern San Diego County, and Santa Ana River in Riverside and San Bernardino Counties, in and near the Prado Basin and Orange County line revealed a great diversity of plants (Zembal 1989). Along the Santa Margarita River, 520 plant species were identified, 148 of which were most commonly associated with the river bottom. However, it was also noted that the thick fringing shrublands comprised an ecological extension on the riparian edge, utilized by many riparian vertebrates. Twenty-one plant species regularly contributed to the forest canopy with over 100 species in the riparian ground cover. The study area on the Santa Ana River was smaller, more affected by the activities of people, and less diverse floristically. Of the 311 species of plants identified, 99 were most typically associated with the flood plain.

The structure of the riparian forest observed on the Santa Margarita River was typical for coastal southern California. The youngest stands are comprised of thickly packed willows with trunk diameters mostly under 1.5 inches, tree height under 15 feet, tree densities sometimes exceeding 3,000 per acre, and most of the foliage restricted to the canopy layer and stand edge. Maturation of the young stands resulted in fewer, larger trees until a gallery forest stage was reached with many trunks of 3 - 6 inch dbh (diameter at breast height), stands often exceeded 30 feet in height, with better developed but largely herbaceous ground cover, and much of the foliage still in the canopy and on stand edges with occasional small clearings of shrubbier foliage. With additional age and thinning of trees, large specimen willows emerge with foliage from the ground to over 50 feet and trunk diameters in excess of 15 in. At this stage, tree stem densities are minimal and herbaceous to sub-shrubby riparian thickets are common.

Along with the jungle-like aspect of the riparian forest, the most obvious manifestation of its productivity is the incredible diversity and abundance of its birds which is unrivaled in other southern California habitats (Zembal 1989). One hundred and fifty species of birds were found on the Santa Margarita River in breeding densities of 477 pairs per 100 acres of mixed woodlands, to 935 pairs in structurally diverse riparian habitat. There were as many as 50 breeding species of birds on one 35 acre plot. In the Prado Basin, bird densities varied from 746 to 1,013 breeding pairs per 100 acres with as many as 34 species on a single plot.

Seven species of birds were the most common and widespread in the riparian habitat examined, including the song sparrow (Melospiza melodia, which was over 3 times more abundant than any other species), common yellowthroat (Geothlypis trichas), rufous-sided towhee (Pipilo erythrophthalmus), Bewick's wren (Thryomanes bewickii), bushtit (Psaltriparus minimus), black-headed grosbeak (Pheucticus melanocephalus), and brown-headed cowbird (Molothrus ater). Dozens of riparian birds warrant special status according to several Awatch lists and at least two are endangered, the least Bell's vireo (Vireo bellii pusillus) and willow flycatcher (Empidonax traillii extimus).

A Watershed Program

The plights of several rare riparian species and threat of giant reed prompted us to establish a program with pooled mitigation money to deal with the functions of the Santa Ana River, starting with resources and issues that were in greatest need of attention. One of the more beleaguered of species at that time was the endangered least Bell's vireo, whose distribution was centered in the Prado Basin. When the vireo was rediscovered in the Basin in 1983, 25 territorial males were present (Zembal, et. al., 1985). However, even with limited management, by 1986 there were only 19. While Arundo was busily reducing the suitability of its habitat, the vireo was being preyed upon by a relentless nest parasite, the brown-headed cowbird. Initially, we found little support or money for significant management efforts. Most of the money that was available was earmarked for replacing lost habitat. Eventually, it was realized that the wetland mitigation, which was being done for the vireo, might never have vireos in it if we did not do something quick to keep them from disappearing entirely from the region. Consequently, old barriers to trust and efficiency were partly chipped away and new partnerships were formed amongst many with vested interests along the river including the U. S. Fish and Wildlife Service (Service), California Department of Transportation (Caltrans), Corps of Engineers, Orange County Water District, Santa Ana Watershed Project Authority, Nature Conservancy, local cities, counties, and significant recently, a super-organization of 5 Resource Conservation Districts, the Santa Ana Watershed Association, among many others.

With the good will to continue the partnerships; enough money in the bank for the needed field efforts; and in the hands of dedicated field biologists, the vireo population recovered dramatically to 201 pairs in 1997 (Pike, et. al. 1997). This was accomplished in spite of water conservation that inundates a percentage of the very habitat the vireo nests within. In actuality, the field efforts that rescued the vireo from the brink of extirpation were paid for with the money generated by water conservation, the flood control project, and other impacting uses. Ironically, the Prado vireo population was resuscitated on the shoulders of activities and projects that were near-prohibitively constrained by the initial vulnerability of the tiny vireo population. We are hopeful that the success of the vireo management demonstrates our ability to accommodate the other uses of the river under the Endangered Species and Clean Water Acts and recover the river system simultaneously. Of course, dealing effectively with disfunctionality over an entire watershed, the vireo and myriad of other troubled species, and melding in the complexity of other users and uses will take a long time. Dealing just with Arundo, given the size of our current endowment, will take decades but we will get there, eventually.

Because it dominates the landscape, the threat giant reed poses to native vegetation and wildlife is particularly evident along the Santa Ana River, coastal southern California's largest watershed. Giant reed has become so abundant in this watershed that it colonizes disturbed sites, often in thick monotypic stands that can be many acres in extent within a single growing season of the disturbance. The disturbances that trigger invasion include natural and people-induced fire, scour, and sedimentation. In many areas there are enough rootstocks in the ground to support a post-disturbance Arundo forest. However, enough river flow to break and redeposit pieces of stem and root is common in winter and sometimes spring. The root is thick with stored enrichment for a new plant, the beginnings of a new colony, and even the stems will root from certain nodes if the river deposits them on moist soil.

Before Arundo became so pervasive and particularly, prior to our realization of the magnitude of the problem on the Santa Ana River, there were many dozens of acres of mitigation accomplished under Section 404 of the Clean Water Act. The mitigation was also in compliance with the Endangered Species Act, the Fish and Wildlife Coordination Act, Section 1601 of the state Fish and Game Code, and other laws and regulations. Most of this mitigation was for short-term loss of wetland habitat and for effects to sensitive species, notably the endangered least Bell's vireo. The wetland mitigation was done in partnership among the Corps of Engineers, Environmental Protection Agency, Fish and Wildlife Service, California Department of Fish and Game, and many other agencies and project proponents. The approach and negotiations for each project were steeped in the rich history and tradition of the wetlands program under the Clean Water Act. Trees and other habitat components were grown as quickly as possible, in as suitable a location as was available nearest to the site of impact, in a ratio large enough to fully compensate for the pre-project wildlife values including any temporal losses due to the time required to regenerate full habitat value. This led to replacement ratios as high as 10 trees planted for each one lost and 2 to 5 acres planted for each one bulldozed in the 1980s. Monitoring, replanting, and watering were usually required for the 3 - 5 years following the project. Wetland mitigation costs ranged from $15,000 to $300,000 per acre, depending upon the speed of regrowth being sought. All of these projects were earnestly negotiated; those involved sincerely expected that full compensation for the lost wetlands would develop over time, particularly if the area was fenced to avoid human activities that might impact the wildlife. However, today millions of dollars are gone as well as most of the trees that the money helped to grow. I revisited 7 mitigation sites recently, ranging in size from under 1 acre to over 30. The sites are now dominated by giant reed with little else growing.

The magnitude of the giant reed problem on the Santa Ana River led us to a different approach there. Knowing what we know now, we wish we still had all of that mitigation money in the bank. Wanting desperately to learn from our past, saving mitigation money and doing what we can afford on the interest earned is a big part of the current approach.

Arundo is a huge, watershed-wide issue that is preventing the river from functioning to its capacity in many ways, including reliable perpetuation of wildlife. The current watershed program focuses to its economic capacity upon this major wildlife issue, in conjunction with managing the most beleaguered of the wildlife species to ensure their survival. Because Arundo reproduces vegetatively, it spreads downstream from upstream source material. Therefor, Arundo eradication was begun in the upper tributaries at the top of the watershed. Even with limited resources, given persistence and enough time, our Arundo control efforts will reach the Pacific Ocean and we will move on to the next issue, species, and/or watershed.

The watershed program has met with success, so far but there is a lot left to do. We will have initial control of giant reed in one of 7 upper tributaries of the Santa Ana River, and on several small side tributaries by the winter of 1999.

One very important, and yet to be fully negotiated aspect of the watershed program is the maintenance or return of enough flood plain acreage to be able to support riparian habitat and all of the other values demanded of the river by people. These values include economic, recreational, flood control, water supply, aesthetic, among others. Service personnel bring vision, wildlife expertise, and advice in accordance with legal mandates to the planning arena. Those who bring the money to actually make things happen usually have a focus other than wildlife. This makes it incumbent upon us to understand the other values of the river and what it will take to keep them, as well. If the river program is successful, someday we will have maximized the size and functionality of the river and thereby have maximized all of its values. This will include many hundreds of additional riparian acres and thriving populations of species that are now endangered.

We are compelled to pursue this system-wide approach with a vision that spans well beyond the usual political and regulatory time frames because Arundo has become so obviously abundant, negatively affecting almost everyone on the river in some way. However, the wildlife side of these issues are applicable to most of southern California. Arundo is in most drainages and the activities that encourage its spread will continue. If combated early on, however, other streams may not take the many millions of dollars that the Santa Ana River will to restore.

Unfortunately, these problems also go beyond riparian habitat and Arundo. Many thousands of acres of southern California's open spaces are dominated, at least in the herbaceous understory, by introduced species. Reduced acreage of open space; bottlenecks and other poor configurations of the remainder, affecting proper function; huge edges with intensive human uses immediately interfacing with wildlife; and introduced species out competing, consuming, and/or displacing native, affects most of what remains of southern California's natural world. Most conservationists recognize the importance of retaining as much of the remaining open space as possible, if we intend to capture a fairly intact wildlife heritage to pass on to future generations. What is not as widely acknowledged, however, is the equally important need to get on with active, adaptive management of the resources we have left, to counteract the problems we have created. A program like the one we have initiated on the Santa Ana River would be beneficial in many areas and habitats. One cannot simply fence off and lock up habitat in southern California and call it adequate mitigation or wildlife protection anymore. There are far too many problems, including a growing myriad of nonnative species that have, or are capable of significantly reducing the carrying capacity of our remaining open spaces for wildlife.

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THE ROLE OF TISSUE NITROGEN CONTENT ON *ARUNDO DONAX* TRANSLOCATION RATES AND RHIZOME GROWTH.

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Abstract

The use of systemic herbicides for the control of rhizomatous, invasive plant species, such as *Arundo donax*, is expected to be most effective if the herbicide is applied when the translocation rate of photosynthates to the plant's storage tissues is highest. This is affected by many different environmental parameters, which can complicate the determination of the best time for application. Current research in the Wetlands Plant Biology Laboratory at CSULB, is directed at identifying a physiological parameter inside the plant, that can provide information about the likelihood of high translocation rates. Leaf, stem and root nitrogen contents play an important role photosynthate translocation. If the nitrogen content have been lowered to the minimum value for these tissues, their Critical Nitrogen Content (CNC), they cannot incorporate the newly produced photosynthates, which will be translocated to the storage tissues, the rhizomes. Tissue nitrogen content relative to its CNC, is the physiological indicator currently under investigation. Preliminary data estimates the CNC of *A. donax* leaves at 25 ± 2 mg N/g C.

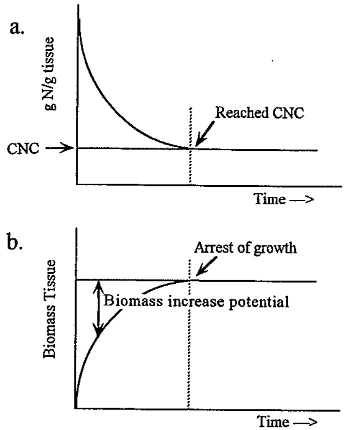
Introduction

In the struggle for control of *Arundo donax* (giant reed), spraying with a systemic, glyphosate containing herbicide has been among the most successful approaches. In order for the herbicide to be most effective, it needs to be applied when the rate of photosynthate translocation and phloem transport to the rhizomes is highest (Hay 1976, Jackson 1993). The effective time for application is dependent on many environmental factors, such as air and soil temperature, water and nutrient availability, and day length. To kill the reserve storage and overwintering structures of *A. donax*, the rhizomes, as well as the aboveground parts of the plant, the herbicide needs to be transported from the place of application, the leaves and stems, to the underground rhizomes. Translocation to and storage of photosynthate reserves in the rhizomes, a modified stem structure, occurs when the plant can no longer incorporate these photosynthates in its vegetative plant tissues, the leaves, stem, and roots. Because so many different environmental factors influence the time at which herbicide application will be most effective, it is hard for environmental resource management personnel to determine exactly when to spray.

The goal of the research currently underway in the Wetlands Plant Biology Laboratory at California State University, Long Beach is to identify a physiological indicator in the plants, that will provide information about the rate at which translocation is occurring in the plants. The physiological indicator that is the focus of our research, should indicate the ability of the vegetative tissues of *A. donax* to incorporate carbohydrates, and will effectively incorporate the varying influences of the different environmental parameters on the determination of the most effective time for herbicide application. Once this indicator is quantified, we will field test the use and usefulness of this indicator for determining the time of most effective herbicide application. This information will be shared with the people involved in management of *A. donax* control. This is a preliminary presentation, describing the regulation of photosynthate translocation to reserve storage tissues, such as the *A. donax* rhizome.

Role of Tissue Nitrogen Content

Carbon and nitrogen are among the most important elements for plant growth and function. Carbon is assimilated from the air through photosynthesis, and mainly incorporated in carbohydrates, and cellulose, thus supporting growth. Nitrogen, taken up from the soil by the roots, is essential for protein (especially enzymes), and DNA and RNA production, supporting function. As the plant grows, and becomes nitrogen limited, the plant's continued carbon supply supports tissue growth through carbohydrate, and cellulose and cell wall production. This increase in biomass leads to a reduced tissue nitrogen content (Fig. 1a, 2). All tissues need to contain a minimum amount of nitrogen, in the enzymes, DNA, and RNA to ensure metabolic functioning. As tissue growth under nitrogen limited conditions has lowered the relative nitrogen content of the tissue to the minimum value required to allow for the functioning of the tissue, tissue growth stops (Fig. 1b, 2). Under these circumstances, an individual cell contains the minimum nitrogen required for the proteins, enzymes, and nucleic acids of that one cell. Cell division is not possible, because the individual cell does not contain enough nitrogen to support the metabolism of two cells. This minimum tissue nitrogen content required to maintain the functioning of the tissue is called the Critical Nitrogen Content (CNC) of the tissue (Bradley and Morris 1992, Ingestad and Agren 1995). Addition of carbohydrates, in the form of sugars, starches, and cellulose, to this tissue would lower the relative nitrogen content of the tissue below its CNC, and tissue functioning would be impaired.



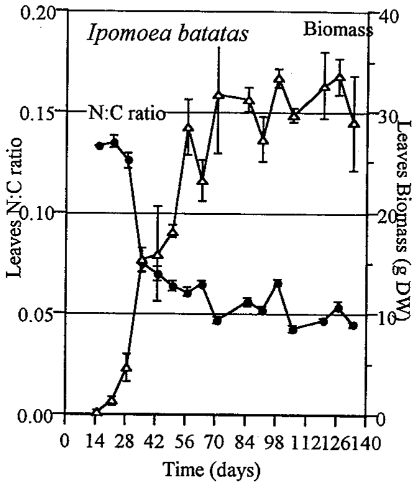


Figure 1: Theoretical relationship between
a. the pattern of tissue nitrogen content during the growing season, and b. the tissue's ability to grow.

Figure 2: Actual relationship between tissue nitrogen content during the growing season, and the tissue's ability to grow, for *Ipomoea batatas* leaf tissue (Wijte *et al.* 1997)

Tissues with different functions, and different metabolic roles, have different CNC's, as previously determined with *Ipomoea batatas* (table 1, Wijte *et al.* 1997). Tissues with extensive enzyme functions, such as photosynthesis in leaves and nutrient uptake in roots have higher CNC values, than reserve storage tissues, such as the *I. batatas* storage roots (Wijte *et al.* 1997), and *A. donax* rhizomes (Peck and Wijte, unpub. res.).

Table 1. Critical Nitrogen Content (CNC) of *Ipomoea batatas* tissues.

Tissue	CNC (mg N/g C)
Leaves	59
Stems	19
Roots	52
Storage tissue	14

When the nitrogen content of a tissue has been lowered to the CNC, it can no longer serve as a sink for photosynthates. Because the vegetative plant tissues, leaves, stems, and roots have higher CNC's, they loose capacity as carbohydrate sink relatively early in the growing season. The lower CNC of the reserve storage tissue, allows it to act as a sink for the excess photosynthate carbohydrates after the nitrogen content of the vegetative tissues have been lowered to their CNC. At this time in the growing season translocation of photosynthates to, and growth of the rhizomes reach high rates (Fig. 3).

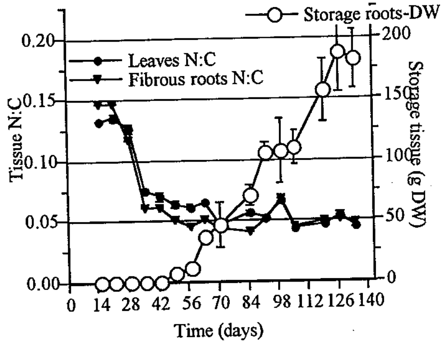


Figure 3: Vegetative tissue nitrogen content, and storage tissue growth of *Ipomoea batatas* during the growing season.

Knowledge about plant tissue nitrogen contents and CNC's can be advantageous when timing herbicide applications. When leaves have reached their CNC, carbohydrates produced will be transported from the leaves to the reserve storage and overwintering tissues of the plant. Therefore, the most effective time for herbicide application on rhizomatous invasive plant species, will be when the nitrogen content of the leaves first has been lowered to their CNC, and newly produced photosynthates will immediately be translocated to and incorporated into the rhizomes. Herbicide translocated to the rhizomes in this phloem stream, can kill that plant structure from which *A. donax* and other rhizomatous invasive plant species, such as *Spartina alterniflora* and *Phragmites australis* (Hellings and Gallagher 1990, 1992), usually regrow after unsuccessful eradication attempts.

Critical Nitrogen Content of *Arundo donax* leaf tissue

The current research in the Wetlands Plant Laboratory at CSULB is directed at determining the CNC of the different *A. donax* tissues in a greenhouse experiment, and field sampling. After the determination of *A. donax* leaf CNC, the effectiveness of an application time based on leaf nitrogen content and CNC will be compared to the effectiveness of a traditionally timed application.

Tissue nitrogen content is fairly easy to determine. Tissue samples, ranging from 5 g to 100 g in biomass can be collected in the field, and dried to constant weight at 60 °C in a drying oven. The dried sample is ground to a powder, and analyzed for their carbon and nitrogen (in addition to hydrogen, sulfur and oxygen) content using a CHN(SO) analyzer.

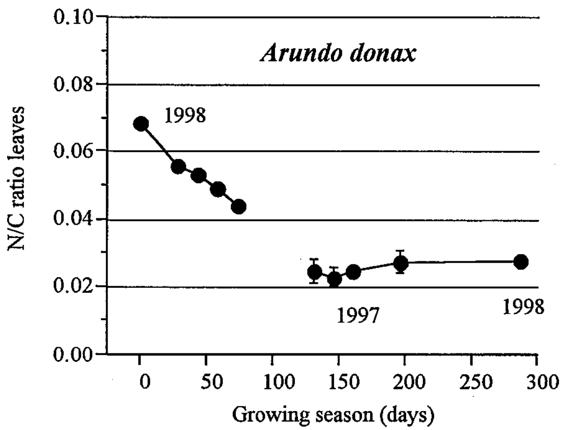


Figure 4: Tissue nitrogen content of *Arundo donax* leaves during growing season in Santa Margarita river at Marine Corps Base, Camp Pendleton.

Data collected thus far on *A. donax* leaf nitrogen content in the Santa Margarita at the Marine Corps Base Camp Pendleton shows a similar pattern as was previously observed for *I. batatas* (Fig. 4). The CNC of *A. donax* leaves, determined based on this preliminary data, is significantly lower than that of *I. batatas* leaves (two sample t-test, $p < 0.01$). *A. donax* leaf CNC is approximately 25 ± 2 mg N/g C (mean ± S.D.). Based on this preliminary data, our laboratory advises not to spray *A. donax* plants if the nitrogen content in the leaves is above 3-3.5 mg N/g C.

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INVASIVE WEED CONTROL AS MITIGATION - A SHIFTING PARADIGM

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Introduction

Federal and State regulations, guidelines, and Memorandum of Agreement (MOA) allow the Corps of Engineers and the California Department of Fish and Game to require compensatory mitigation to be performed in order to offset the unavoidable impacts associated with permitted fills of wetlands and watercourses. Mitigation often is in the form of creation or restoration of degraded wetlands or riparian areas. Unfortunately, past wetland mitigation projects have experienced a fairly high failure rate. A functional analysis of past mitigation sites in Orange County, CA showed that 85% of the sites failed to provide the functions they were intended to replace, resulting in a net loss of 241 acres of wetlands and riparian resources (Sudol, 1996). Similarly, Allen and Feddema (1996) evaluated 75 Section 404 permits issued in Southern California between 1987 and 1989 for mitigation success and found a 96% failure rate. The primary reasons for failure of past mitigation are poor site selection, inappropriate or inadequate hydrology, and invasion of noxious weeds. These problems appear to be amplified in small mitigation sites.

The failure of past mitigation projects, combined with the realization that comprehensive, watershed-scale invasive weed control programs are often beyond the means, motivation, or responsibility of a single entity has led to the consideration of invasive weed control as an option for wetland compensatory mitigation. The environmental benefits of eradicating invasive weeds have been well documented. Infestation of waterways or wetlands with invasive weeds depresses the function of the affected resource by altering ecosystem processes, displacing native plant communities, decreasing habitat suitability for sensitive species, upsetting the natural disturbance regime, increasing rates of evapotranspiration, changing flow patterns, and raising the elevation of channel beds (Flack and Benton, 1998). The Nature Conservancy and Environmental Defense Fund analyzed Federal Register notices listing species as threatened or endangered under the Endangered Species Act and found that the impact of invasive weeds was a major cause of endangerment for 18% of listed species and a contributing factor in the decline of another 24% of listed species. In addition, *Arundo donax* and *Tamarix* spp. infestations clog channels and burn more frequently than native plant communities, resulting in increased public safety hazards associated with floods and fires (Scott, 1993; Iverson, 1993; Weisenborn, 1996).

Two Opposing Views

Although conversion of areas infested with invasive weeds to native plant communities has clear environmental and public interest benefits, there is disagreement over whether it is an appropriate mitigation strategy for permanent wetland loss. Restoring a riverine community from a system dominated by Arundo and Tamarix to one dominated by native riparian and wetland plant species results in measurable gain in habitat functions. However, increases in hydrologic and biogeochemical functions, such as energy dissipation, detention of elements and compounds, organic carbon export, and dynamic surface water storage, do not appear to benefit as much from the conversion from exotic to native plant communities (USACOE, unpublished data). The primary reason for this is that hydrologic and biogeochemical functions are driven by the physical condition of the stream (*e.g.*, stream geometry and topography) and the amount of gross biomass in the system. The specific composition of the plant communities does not influence hydrologic and biogeochemical function to the same degree as it does habitat function. In addition, restoration of wetland or riparian areas via conversion from invasive to native plant communities typically results in an increase in wetland function, but may not result in an increase in wetland acreage. The differential functional gain and the lack of an increase in acreage associated with invasive weed control projects has resulted in challenges from some resource agencies that invasive weed control is not wholly appropriate as a mitigation strategy for permanent fill of wetlands or watercourses because it does not achieve the goal of no net loss of wetland acreage and function.

Those with the opposing viewpoint argue that systemic invasions of exotic weeds, such as Arundo and Tamarix, have resulting in drastic modification of functions at an ecosystem scale. By changing the processes required to sustain native wetland or riparian communities, invasive weed infestation shifts system dynamics to favor further weed infestation, resulting in complete collapse and functional loss of the ecosystem. Bell (1997) asserts that the real threats to the integrity of riparian systems is habitat fragmentation and introduced exotic species that have altered the successional dynamics and stability of the natural communities. Hundreds of thousands of dollars have been spent reforesting riparian areas, only to have those areas convert to Arundo or Tamarix dominated systems over time. In many cases, riparian communities are limited not by their capacity to regenerate, or the available area in riparian zones, but by the capacity of native species to compete with aggressive invasive exotic species. The logistic, administrative, and economic challenges of implementing a large-scale, ongoing invasive weed control program may be beyond the means of local jurisdictions or private individuals. Therefore, Bell (1997) concludes that the limited resources for management (or mitigation) should be directed at managing for the dynamic process of riparian systems by removing the key perturbation from the system (invasive weeds), thereby allowing natural flood dynamics to operate and the natural communities to recover.

A New Paradigm

In many instances removal of invasive exotic weeds from river systems can have a far greater beneficial effect than planting of riparian vegetation, yet in some cases, relying on invasive weed control as mitigation for permanent wetland fill may result in a net loss of wetland acreage. To reconcile this dichotomy, the philosophy of the Los Angeles District Corps of Engineers is that invasive weed control is an effective and appropriate approach to wetland compensatory mitigation in certain circumstances; however, for some types and of impacts more traditional approaches to wetland mitigation may be preferable. The general guidelines that should be employed when determining whether to use invasive weed control as a mitigation strategy are:

1. To ensure the goal of Ano net loss of wetland function and acreage is achieved, large scale permanent impacts to functionally significant resources should be mitigated through creation or physical restoration (*e.g.* re-establishing an isolated floodplain) in conjunction with invasive weed control efforts. Creation or restoration projects must include an aggressive invasive weed control element as part of the ongoing management of the site.

2. Permanent impacts to smaller, fragmented, isolated, or less significant resources can be mitigated through invasive weed control. Invasive weed control should always be a component of restoration of temporary impact areas.

3. Anderson (1995) cautions that some areas of extensive Tamarix infestation provide habitat for sensitive species, such as the southwestern willow flycatcher (*Empidonax extimus traillii*). In these areas invasive weed removal followed by revegetation cannot be expected to succeed due to changes in the system resulting from autoecological influences of the invasive plant (Anderson, 1995). In these situations, invasive weed control should be phased so that habitat being utilized by sensitive species is not eliminated before proximate native habitat is in place. This approach will allow for experimentation with soil remediation and other techniques to combat the autoecological effects of Tamarix.

When using invasive weed control as mitigation, it should be part of a coordinated, watershed-scale program that begins control efforts high in the watershed and works downstream, and should include long-term follow up of treated areas to prevent reinfestation. Treating disjunct patches of invasive weeds should be avoided as these efforts often result in reinfestation from upstream or adjacent source populations.

Because a comprehensive program is beyond the means of many landowners and small jurisdictions, mitigation banks and in-lieu fee mitigation programs can be critical in enabling invasive weed control to be used as mitigation. Mitigation banks involve in advance creation, restoration, enhancement or in special circumstances preservation of aquatic resources for the purpose of mitigating impacts resulting from multiple projects. The 175-acre Santa Ana River Mitigation Bank (SARMB), sponsored by Riverside County Parks and Open Space District, sells mitigation credits accrued from converting a portion of the Santa Ana River from a monotypic stand of Arundo to a diverse native riparian community. The SARMB is a component of the comprehensive Santa Ana River invasive weed control program. In-lieu fee mitigation programs involve mitigating impacts to aquatic resources by paying funds to a natural resource management entity for implementation of either specific or general aquatic resource management programs. The

Mission Resource Conservation District sells mitigation credits and uses the funds to support the Santa Margarita invasive weed control program. This program complements a watershed-wide invasive weed control effort by removing patches of Arundo and Tamarix in the upper watershed and by educating landowners about the problems of using invasive plants for landscaping.

Conclusion

Next to habitat loss and fragmentation, invasive weed infestation poses one of the greatest threats to wetlands and riparian areas. One of the most productive uses of scarce mitigation funds is to help achieve watershed-scale control of invasive weeds, thereby allowing natural successional processes and riparian dynamics to flourish. Restoration of dynamic processes throughout a river system can help ensure long-term self-sustaining recovery on a scale that cannot by duplicated by isolated mitigation areas. Unlike creation of isolated mitigation areas, the positive impacts of invasive weed control efforts are not limited to the footprint of the restoration. In many cases, invasive weed control is an appropriate mitigation strategy for permitted wetland impacts. However, for larger wetland impacts every effort should be made to include wetland creation or restoration projects that contribute to overall function of the entire watershed as the primary component of wetland compensatory mitigation.

Disclaimer

The statements and opinions expressed in this paper represent those of the author. Nothing in this paper should be construed to represent an official policy or position of the U.S. Army Corps of Engineers or its Los Angeles District, Regulatory Branch.

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CHEMICAL CONTROL OF GIANT REED (*Arundo donax*) AND SALTCEDAR (*Tamarix ramosissima*)

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INTRODUCTION

Many exotic pest plants were introduced into California, with very admirable goals. Unfortunately, several of them that succeeded too well as colonizing species crowded out native species and degraded wildlife habitat. *Arundo donax*, also called giant reed or wild cane, and *Tamarix* spp., also called saltcedar or tamarisk were introduced into the American Southwest from the Mediterranean region, and have become two of the most destructive invasive weeds found in many riparian areas. Saltcedar has taken advantage of the man-made changes in water movement, both quantity and velocity to explode its range and has gained the attention and concern of people who live in and enjoy native habitat in the Southwest.

The initial requirement for good weed management is to identify and classify the weeds to be controlled. Are they annuals or perennials? Or grasses, forbs, brush or trees? Or are they sprouters or resprouters? Do they grow primarily from seed?

Arundo donax is an exotic perennial grass species. It is a very rapidly spreading plant, reaching upward of 25 - 30 feet tall, often growing as much as 10 inches per day under ideal conditions. Because of it's aggressive nature, Arundo produces large amount of biomass. One single plant can have a root span of up to 40 feet in diameter. *A. donax* reproduces vegetatively from underground stem structures (rhizomes) and by stems rooting at the nodes along the stalk. It produces large whitish plumes as flowers 2 or more feet in length in late summer and early fall but reproduction by seed is limited by low seed viability.

Saltcedar grows as a brush or tree with small leaves that exude salt. It flowers throughout the year and is a prolific seed producer. It resprouts after fire or mechanical damage. Saltcedar may grow in sparse, isolated clumps or in heavy to pure stands. Because of it's aggressive nature, saltcedar produces large amounts of biomass.

METHODS OF WEED MANAGEMENT

There are essentially 4 methods of weed management - mechanical, biological, competition, and chemical. Complete success of a weed management program depends on the integration of all methods of weed control.

Mechanical weed control, including hand-pulling, digging, use of weed eaters, axes, machetes, bulldozers, and fire, may not be the most efficient method for removal of Arundo or saltcedar. In addition, some mechanical weed control methods do not give long-term weed control, are not cost-effective and pose a substantial accident risk to humans. For example, after giant reed is cut, the plant simply regrows from corms and rhizomes. Hand labor is not always available and is costly unless it is volunteered. When heavy equipment is used, soil is often disturbed with consequences such as disturbing invertebrates and other denizens of the ecosystem.

Biological weed control is part of the ecosystem under climax natural stands of vegetation. However, it is rarely efficient or effective as a tool in destroying introduced exotic species. Because species were not introduced with their natural pests, specific agents have to be imported from the country of origin for each species. No effective biological control agents for Arundo and saltcedar have been introduced or established in the Southwest.

Good growth of desirable native species, once they are re-established, may compete effectively and crowd out exotic species. Unfortunately, at the start of a restoration project, the reverse situation exists - where exotic and/or undesirable species have outgrown and out-competed desirable native species. Therefore, alternative methods of weed control have to be used in order to give the re-introduced or existing native species a chance to grow and prosper. After re-establishment, competition as a means of weed control achieves a high degree of success.

In many situations, weed control with herbicides is the most efficient and effective method of weed control for removal of exotic plants during the restoration process. The chemical method allows regeneration and/or re-population of natives or re-vegetation with native species. The use of herbicides can be specific, selective and fast.

WEED MANAGEMNT WITH HERBICIDIES

The most critical step is the selection of an appropriate herbicide. Specific factors to be considered in a herbicide program are:- efficacy, environmental safety, soil residual activity, operator safety, application timing, and cost-effectiveness. In most situations, the initial treatment in removal of exotic plants is postemergence to the weeds. Since preemergence herbicides may control seedlings of desirable species, postemergence treatment of seedlings is preferable in situations where growth from a seed source in the soil is a problem.

Arundo donax management with herbicides:

Roundup® and Rodeo® are efficacious broadspectrum postemergence herbicides that have no soil residual activity. Because of these properties and a favorable environmental profile, these herbicides are chosen most often for use by managers of native habitat restoration projects. Rodeo is registered for use in aquatic sites, including estuaries and riparian areas, and may be applied to emerged weeds growing in water. These are critical factors in many native habitat restoration projects.

APPLICATION METHODS

Versatility of application methods is also important in the choice of herbicide. In the case of Roundup and Rodeo, these choices include:- broadcast and spot treatment foliar sprays by ground equipment, cut stump treatments, wiper treatments and aerial application where appropriate.

There are several conditions that have to be addressed when implementing an *Arundo donax* control program. Firstly, the level of infestation at the site must be considered. A control program should be based upon whether the level of infestation is sparse, in isolated clumps, light, heavy, or in pure stands. A program directed at light infestations will be a failure if used for combating pure stands. A successful program will use the appropriate methods and tools for the appropriate level of infestation.

Secondly, the correct method of treatment must be chosen for *A. donax* control. Several methods are available including foliar application by backpack, handgun or handwand or by aerial application (fixed or rotor wing). Additionally, there is a cut-stump application. Many factors determine the method chosen including the infestation level, site geography, desirable non-target vegetation and wildlife, habitat of surrounding areas and general ease of the chosen control method.

APPLICATION RATES

The herbicides that are labeled for control of *Arundo donax* are in the glyphosate family; Roundup herbicide for terrestrial locations and Rodeo Aquatic herbicide for aquatic, riparian, estuarine and terrestrial areas where water may occur. Most often, Rodeo herbicide will be used because *A. donax* is usually located near water.

Recommended application rates for Rodeo and Roundup herbicides to mature stalks of Arundo are given below:

Rodeo Emerged Aquatic Weed and Brush Herbicide:

Spot Treatment: 1½% v/v Solution plus ½% v/v Nonionic Surfactant
Broadcast Treatment: 7½ Pt./Acre plus ½% v/v Nonionic Surfactant
Cut Stump Treatment: 100% v/v Solution (Full Strength)

Roundup Herbicide:

Spot Treatment: 2% v/v solution
Broadcast Treatment: 5 Quarts/Acre
Cut Stump Treatment: 100% v/v Solution (Full Strength)

Recommended application rates for Rodeo and Roundup herbicides to immature stalks of Arundo, e.g. regrowth 1 to 6 feet tall, are given below:

Spot treatment: 5% v/v solution of either Rodeo or Roundup herbicide.

Some of the symptoms associated with glyphosate applications to Arundo are yellowing and browning of the leaves, death of the meristem (growing point), "abnormal" regrowth, multiple budding (grass-like shoots) and white leaves in new shoots. Any of these symptoms indicate that the herbicide has had an effect upon the plant.

Timing of application for optimal control is important. Best results from foliar applications of Rodeo or Roundup are obtained when the herbicides are applied in late summer to early fall, when the rate of downward translocation of glyphosate would be greatest.

Herbicides used for Saltcedar Management:

Herbicides with three different active ingredients, totaling six tradenames are being used for weed management of saltcedar. These are shown in table 1.

Table 1. Trade and common names of six herbicides used for saltcedar control.

TRADENAME	COMMON NAME	AQUATIC REGISTRATION
Arsenal®	Imazapyr	No
Garlon® 3A	Triclopyr	No
Garlon® 4	Triclopyr	No
Pathfinder® II	Triclopyr	No
Rodeo	Glyphosate	Yes
Roundup Pro	Glyphosate	No

Some of the factors to evaluate when choosing a herbicide are:- efficacy, application flexibility, operator exposure, cost-effectiveness, aquatic registration, toxicology, environmental fate and safety to endangered species. Additional characteristics of the herbicides are given in table 2.

Table 2. Some characteristics of six saltcedar herbicides.

HERBICIDE	SIGNAL WORD	FORMULATION	CONCENTRATIO N (lb.ae/gln)
Arsenal	Caution	ipa-salt	2
Garlon 3A	Danger	amine	3
Garlon 4	Caution	ester	4
Pathfinder II	Caution	ester	0.75
Rodeo	Caution	ipa-salt	4
Roundup Pro	Caution	ipa-salt	3

Roundup Pro and Rodeo are efficacious broadspectrum postemergence herbicides that have no soil residual activity. Arsenal is a broadspectrum herbicide that has residual soil activity. Garlon 3A, Garlon 4 and Pathfinder II are effective on broadleaves, with safety to many grass species and no soil residual activity.

Rodeo is the only herbicide of the group that is registered for use in aquatic sites, including lakes, ponds, canals, estuaries and riparian areas, and may be applied to emerged weeds growing in water. These are critical factors in many native habitat restoration projects.

MODES OF ACTION

The modes of action of the three active ingredients are given below:

Imazapyr: Inhibits synthesis of the amino-acids -- valine, leucine and iso-leucine at the ALS enzyme, leading to non-production of proteins.

Triclopyr: Auxin-type action, leading to inhibition of cell division and growth.

Glyphosate: Inhibits synthesis of the amino-acids -- tryptophan, phenylalanine and tyrosine at the EPSP synthase enzyme, leading to non-production of proteins.

METHODS OF APPLICATION

Versatility of application methods is also important in the choice of herbicide. These choices include :- broadcast and spot treatment foliar sprays by ground equipment, cut stump treatments, basal bark treatments and aerial application where appropriate. The choices for the six herbicides are summarized in the table below.

HERBICIDE	FOLIAR	CUT STUMP	BASAL BARK	AERIAL
Arsenal	Yes	Yes	No	Yes
Garlon 3A	Yes	Yes	Yes	No
Garlon 4	Yes	Yes	Yes	No
Pathfinder II	No	Yes	Yes	No
Rodeo	Yes	Yes	No	Yes
Roundup Pro	Yes	Yes	No	Yes

SALTCEDAR MANAGEMENT WITH HERBICIDES

There are several conditions that have to be addressed when implementing saltcedar control program. The level of infestation at the site must be considered. A control program should be based upon whether the level of infestation is sparse, in isolated clumps, light, heavy, or in pure stands. A program directed at light infestations will be a failure if used for combating pure stands. A successful program will use the appropriate methods and tools for the appropriate level of infestation.

APPLICATION RATES

Recommended application rates for Rodeo and Roundup herbicides are given below:

Rodeo Aquatic Herbicide:

Spot Treatment: 1½% V/V Solution plus ½% V/V Nonionic Surfactant
Broadcast Treatment: 7½ PT./Acre plus ½%V/V Nonionic Surfactant
Cut Stump Treatment: 100% V/V Solution (Full Strength)

Roundup Pro Herbicide:

Spot Treatment: 2% v/v solution
Broadcast Treatment: 5 QT./Acre
Cut Stump Treatment: 100% v/v Solution (Full Strength)

Arsenal Herbicide:

Ground: 0.75 to 1%V/V solution + 0.5% surfactant
Aerial: 1.5 to 2 QT../Acre
Cut Stump: 12 OZ. per gallon of water

Rodeo and Roundup Pro + Arsenal Tank Mixes:

a. Broadcast rates:

Monsanto: 2 QT. Roundup Pro or 3 PT. Rodeo + 1 PT. Arsenal /Acre (light infestations)

Monsanto: 4 QT. Roundup Pro or 6 PT. Rodeo + 2 PT. Arsenal/Acre (heavy infestations)

AmCy: 1 PT. Roundup Pro + 1 QT. Arsenal/Acre (all infestations)

b. Spot Treatment rates:

Monsanto: 1% Roundup Pro or Rodeo + 0.25% Arsenal

AmCy: 0.5% Roundup Pro + 0.5 to 0.75% Arsenal

There is not total agreement between Monsanto and AmCy on the optimum rates of the products for use in tank mixes. All the recommended ratios work faster and better than either product alone. The enduser will have to decide on the cost per acre as well as the degree of residual control that is acceptable for a site. Roundup Pro and Rodeo treatments tend to release grasses and forbs in treated sites, whereas Arsenal at the higher end of the rate spectrum tends to control this type of vegetation the following year.

Garlon and Pathfinder II:

Foliar Treatments: 2 to 4 QT./ACRE of Garlon 4 or 3A. Dilutions with diesel are not recommended.

Modified Cut Stump Treatments: Undiluted Pathfinder II or 50% solution of Garlon 4 or 3A

Basal Bark Treatments: Undiluted Pathfinder II or a 20 - 25% solution of Garlon 4 in natural oil or diesel.

Garlon has been used successfully for many years, particularly as a basal treatment. Only triclopyr is effective in this type of application. There are no timing restrictions for application of Garlon 4 or Pathfinder II. Garlon 3A should be applied during the growing season. Volatility of triclopyr at higher ambient temperatures could lead to undesirable effects on adjacent vegetation.

Some of the symptoms associated with glyphosate or imazapyr applications to saltcedar are yellowing and browning of the leaves, death of the meristem (growing point), "abnormal" regrowth, and multiple budding. Any of these symptoms indicate that the herbicide has had an effect upon the plant. Regrowth from stumps and roots is, unfortunately, often a symptom of a less than lethal dose of any of the herbicides.

TIMING OF APPLICATIONS

Timing of application for optimal control is important for optimum control of saltcedar. Best results from foliar applications of Rodeo, Roundup and Arsenal are obtained when the herbicides are applied in late spring to early fall, particularly when adequate soil moisture is available for good growing conditions. This is shown in figure 2.

POST-SPRAY MANAGEMENT

Arundo donax:

When sufficient time has elapsed for the herbicide to kill the plant, there is a need to remove the large amount of biomass left on the site. Several alternatives are available. Burning may be possible when no danger of spreading fires will occur and when the necessary permits have been acquired. Chipping can be used but need to be properly disposed of or composted due to rooting of pieces of nodes. Dead cane can be left to decompose on site but large amounts of cane and low moisture and humidity may limit this alternative. Finally, removal of the cane from the site can be done. This is somewhat costly and locations for disposal may not be available.

After initial application of either herbicide to *A. donax*, retreatment of newly emerged giant reed and "escapes" that were missed during the first application, will likely be necessary. This is due, in part, to the density of the viable root mass and the germination of non-committed rhizomes. The amount of re-treatment necessary in the second and third years will be drastically reduced, provided there is no re-invasion of giant reed.

Saltcedar:

After initial application of a herbicide to saltcedar, retreatment of escapes, resprouts and new germination of seedlings may be necessary. The amount of re-treatment necessary in the second and third years will be drastically reduced, provided there is no re-invasion of seeds of saltcedar. Re-vegetation of the site may be done by either natural means or by planting native species.

SUMMARY

Chemical weed control may be the optimal method for control and removal of salt cedar during the establishment of native habitat restoration projects. Roundup, Rodeo, Arsenal, Garlon 3A and 4, and Pathfinder II herbicides are the products most often chosen by managers of native habitat restoration projects because these herbicides are efficacious and cost-effective, with favorable environmental and toxicological properties.

Herbicides may be used effectively, within a defined management plan. Individual products may be applied as a foliar treatment by hand or aerially, or as a Basal Bark or Cut-Stump treatment, based on label recommendations. Post-spray management includes retreatment of escapes and new growth in subsequent years, while saving desirable plants, protecting animal life, enhancing wildlife habitat and protecting water quality in riparian, estuarine and terrestrial areas.

The most desirable weed management in native habitat restoration projects may utilize a combination of chemical, mechanical, biological and competitive methods. Long-term, healthy competition from the desired species, coupled with chemical control of any re-invading exotic plants may be the optimal program. In any given project, the best combination of tools should be selected and molded into a viable weed management program.

Always read and follow the label directions for each herbicide.

Roundup® and Rodeo® are trademarks of Monsanto Company
Arsenal® is a trademark of American Cyanamid Company
Garlon® and Pathfinder® are trademarks of Dow Agroscienes

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RISKS AND EFFECTS OF VARIOUS CONTROL METHODS

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Biological control, burning, cutting, spraying, which is the best? Which is the most benign on the environment? Which is the most likely to be approved by your agency? Which is the most cost effective? Which is the safest for your volunteers? These and a host of other questions arise whenever you are developing a plan to get rid of a non-native invader. Is there a right answer? What factors should you consider when making decisions about the tactics to incorporate into your exotic pest plant management strategy? The purpose of this paper is to stimulate thinking on developing a strategy for control of an invasive plant. Major factors that need to be considered are effectiveness, cost, environmental impacts, and safety to people, along with a healthy dose of political reality.

Effectiveness

Weed control tactics need to be effective. Biological control, for example, has been very successful for control of Klamath weed (Hypericum perforatum), but less successful in the case of yellow star thistle (Centaurea solstitialis) and puncture vine (Tribulus terrestris). Even in the best of situations, biological control is not expected to be 100% effective. In fact, long term biological control fails if it too good. If all the plants in a local are killed, the biological control agent dies because it lacks the host required for food and/or shelter. Then, the weed can recover, or dormant seed will germinate, or it will reinvade from another location, and the biological control agent will not be present to attack the pest.

Other control tactics, such as mechanical control or herbicides, can be very effective in the short term, but may not have much influence on the long term infestation of the particular weedy non-native. It often looks good to see a site after the bulldozer has been through, but a return visit the next summer can be disappointing. In other cases, the simple removal of existing non-natives can be enough to allow the native flora to re-establish themselves in the area and keep the invaders at bay.

Cost

The cost of a particular weed control tactic is not just the retail price of the chain saw, but is also the cost of protective gear, training, storage, transportation, maintenance, etc. Some methods of control, such as biological control, can have a large upfront cost to find, test, and introduce the insect, but has little cost once the agent is released and established. Other practices, such as taking a group of volunteers out to a site with weed wrenches, seem relatively inexpensive, but when all of the staff time is considered for recruitment, training, transportation, liability insurance, donuts, and so on, the total cost can be high. This is especially true if their productivity, i.e. the number of weeds killed per acre per hour, is low relative to other methods. When productivity is factored into the decision making process, the value of each tactic can be assessed relative to cost per unit area per person-hour. In other words, it may be more valuable to have your volunteers hold 500 bake sales over the next five years to raise the funds necessary to get a biological control agent.

Environmental Impacts

When the environment is the topic of conversation with regard to control of exotic pest plants, the attention is most often focused on herbicides. The action of intentionally introducing a poison into an area, especially a natural habitat, is troubling to many people. The fact that the need to kill the invading plant is clear does not make the perceived negative nature of a pesticide any easier to accept. But, two things should be kept in mind when deciding which tactics to include in your exotic pest plant management strategy. One is that all weed control methods have environmental impacts. Herbicides can leach into groundwater, kill non-target plants, and persist in the soil long enough to prevent germination of desirable plants. Mechanical control often involves some disturbance to soil, which can lead to erosion or the germination of buried weed seed. Fire changes the nutrient levels in the soil and creates air pollution. Thirty people with weed wrenches and chain saws that have driven 10 to 20 miles in their own cars to gather for a cleanup day on part of the Santa Ana River likely has more overall environmental impact than 3 people with backpack sprayers. By the same token, the release of a properly selected successful biological control agent may prevent hundreds of person hours ten years in the future.

The other is that the negative environmental impacts of any method can be minimized. A cut-stump or basal bark application of a herbicide will reduce the total amount of chemical used compared to a foliar spray generally without losing any effectiveness. Herbicides should be used with caution and consideration of environmental factors. If rain is imminent, application should be delayed, especially in a watershed site where the chemical is likely to run off down hill into a stream. Fires can be timed to coincide with optimal weather so as to reduce air pollution effects. And, volunteers can be transported in buses, carpools, or vans from a central location instead of using their own vehicles.

Safety to people

As in the above section, all methods of weed control have safety concerns, but they can all be used carefully to avoid injury. The herbicides that are commonly used for control of exotic pest plants, such as Roundup and Garlon, have low acute toxicity. Neither has been shown to cause cancer or reproductive harm in tests on laboratory animals. Anyone that is contemplating the use of a herbicide must thoroughly read the label that comes with the chemical. This label is the best source of information on the safe use of the herbicide, including environmental precautions along with human safety guidelines. When used according to label directions, people and the environment should be well protected. It is also vital that everyone in the group, not just the person with the pesticide license, understands basic safe handling of herbicides. This means that training is a must for any weed control operation involving herbicides.

Safety is also an issue with any other type of weed control tactic. In the case of chain saws, brush cutters, and pulaskis, the safety issue is obvious. But, weed control warriors are out in wild country, going up and down hills, often carrying the equipment mentioned above through thick brush. Preparation and training are just as important when using mechanical control methods as they are with herbicides. The risk of injury, in general, is probably greater in a mechanical approach than it is with herbicides.

The strategic plan

The goals of an exotic pest plant management strategy have to fit within the overall mission of the project. The mission can be to merely get rid of undesirable species for safety or security reasons, to stop an invasion before it becomes too serious, or to remove existing exotics as part of a habitat restoration. The goals have to be designed to achieve the mission. This is where the four topics discussed above; effectiveness, cost, environmental impact, and safety, have to be determined and evaluated. A scorched earth methodology is inappropriate for areas with an existing stand of natives that can be capable of reestablishing themselves after selective removal of exotics. Large area infestations, such as the current population of saltcedar on the lower Colorado River, may require large scale intervention programs like biological control.

In general, the most valuable approach will combine a variety of methods into one strategy. In the case of saltcedar, for example, a fire, whether naturally occurring or started deliberately, can afford an excellent opportunity to follow up with relatively light applications of a herbicide to resprouting stems and to new emerging seedlings. Glyphosate can very effectively kill mature saltcedar in this situation, something it cannot do when sprayed on the foliage of the same plant. When a biological control agent is involved, some population of the pest has to be left alone for the survival of the agent. But, mechanical or chemical control methods can be used in certain key or sensitive sites when eradication of the pest plant is required.

Philosophical/Political Considerations

There are two basic challenges to doing something about exotic species invading ecosystems; one is to convince policy makers and land owners that something needs to be done and the other is to be able to sell these same people and the general public on the control strategy. Both of these are educational processes that require as much care and preparation as the actual implementation of the control measures. With regard to the second part of the challenge, the more thoroughly the four topics discussed above are evaluated and understood, the better the chances of convincing decision makers of the need for a particular combination of methods. Also, the more the control methods are organized into a strategy, the more likely it is that lay people will buy into an approach to deal with a problem.

The most recent issue of Wildland Weeds (Spring, 1998, volume 1, number 3), a publication of the Florida Exotic Pest Plant Council, had an editorial that is germane to this topic. In this opinion piece, the authors, (Ted Center and Ken Langeland) expressed their dismay over the "... polarization developing within the exotic pest plant management community. "over the choice of one weed control method over another. Even worse, they had observed, "... information from an expert, probably one of us, who skewed it in a self-serving way to influence public opinion." They reminded us that "we are united in a common purpose - namely, the management of invasive plants." and "Biological control research is not predicated on the failure of herbicides." The concluded their editorial by quoting from Benjamin Franklin, "We must all hang together, or most assuredly we shall all hang separately". Wise words to remember.

SANTA ANA RIVER INTERAGENCY HABITAT RECOVERY PROJECT

VAN BUREN BRIDGE PROJECT AREA SUMMARY

Paul Frandsen and Nelroy Jackson
Riverside County Parks and Open Space District and Monsanto Company

Site Description

Location:	Township 2 South, Range 6 West, Section 25, Riverside West U.S.G.S. Quadrangle, Santa Ana River directly beneath the North of the Van Buren Bridge.
City:	Riverside County and portions of the City of Riverside
Size:	50± acres

Activity Description

This project involves the testing of manual techniques for the removal of Arundo (Arundo donax), and the recovery of the site to a more natural condition. Habitat recovery activities have involved the following:

1. Broadcast application of herbicide to kill live-standing Arundo using aircraft.
2. Manual removal of dead Arundo employing trained hand-crews using chainsaws and other associated brush-cutting hand tools.
3. Spot treatment of resprouting Arundo with herbicide (either by backpack sprayer or vehicle-mounted equipment).
4. Replanting of the site with locally collected cuttings of native species.
5. Monitoring and maintenance (removal of weeds, spot application of herbicide when needed, etc.) of the site for at least five years or when the threat of reinfection by Arundo has been eliminated.

Purpose: The purpose of this project is the recovery of as many acres as possible of highly impacted willow-cottonwood forest and associated habitat.

Project History: The need for this project was great. As of the summer of 1992, Arundo almost entirely dominated this site and had burned twice in the past three years. An invasion of the Santa Ana River by Arundo and the increased threat of devastating wildfires associated with it, caused a call for action by public agencies and concerned citizens.

The pilot site provided a unique opportunity to test Arundo removal techniques at the Van Buren Bridge, a location visible to the public and easily accessed by hand crews. Work on the adjacent acres continues.

Project Time Line:

March 1993:	Initial aerial broadcast treatment of Arundo with herbicide.
May 1993:	Begin removal of "standing dead" Arundo using hand crews.
July 1993:	Second aerial broadcast application herbicide.
September 1993:	Follow-up "spot treatment" application of herbicide.
November 1993:	Burn piles and/or slash subunits.
December 1993:	Conduct site analysis in preparation for revegetation.
January 1993:	Revegetate unit using locally collected cottonwood and willow cuttings.
May 1994: (and annually afterwards)	Follow-up application of herbicide to giant reed resprouts.

Methods of Treatment:

Two aerial applications of herbicide and two follow-up applications controlled giant reed using vehicle-mounted spray equipment. Dead stalks were hand-removed and placed in burn piles for disposal. Continued "spot" applications of herbicide and planting will encourage the recovery of the native plant communities, 2,000 willow and mulefat cuttings during the winter of 1993 and 1994. Current plans include the planting of 1,000 trees at the latest site in the winter of 1998/99.

Herbicide Use and Applications:

Name of Pestcide(s)	*Rate Per Acre*	*Volume Per Acre*
Rodeo	7-1/2 pt./acre	10 Gallons/acre $H2^0$
Non-Ionic Surfactant	1 qt./acre	10 Gallons/acre $H2^0$

A COMPARISON OF TWO METHODS FOR CONTROLLING ARUNDO DONAX

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Angeles National Forest

The importance of riparian habitats for maintaining biological diversity is well known. Since perhaps 95% of the original riparian habitat in southern California has been destroyed or severely degraded, maintaining the habitat we have left is crucial if we are to preserve the native plants and animals that depend on this ecosystem.

Unfortunately, exotic weeds are invading and degrading the habitat that remains, including that on the Angeles National Forest (USFS 1993, Bautista 1994). Over the last 25 years southern California rivers and tributaries have become infested with *Arundo donax* (Arundo, or giant reed), and other invasive weeds (Rieger and Kreager 1989, The Nature Conservancy 1996). Arundo is a bamboo-like grass that grows more than 25 feet tall, can completely replace native vegetation, and creates dense homogenous stands that introduce a fire cycle into the riparian ecosystem, disrupting its normal dynamic processes (Bell 1993). Dense stands also destroy wildlife habitat, transpire excessive amounts of water, and block stream flow. On the Angeles National Forest Arundo is degrading essential habitat for the unarmored threespine stickleback (*Gasterosteus aculeatus williamsoni*), an endangered fish, and affecting potential or historical habitat for two endangered birds, the least Bell's vireo (*Vireo bellii pusillus*) and the southwestern willow flycatcher (*Empidonax traillii extimus*)(Bautista 1994).

Arundo control is a relatively new and evolving field with additional methods and refined techniques appearing each year. The Angeles National Forest has tried two methods for controlling Arundo in one of our project sites in San Francisquito Canyon: the cut stump method, and a cut-resprout-spray method.

The cut-stump method was tested during a pilot project in September 1993. Forest Service fire crews cut the standing Arundo to near ground level using chainsaws and pulled the cut cane away from the remaining stumps. The cut stumps were then treated with 100% glyphosate (Rodeo®) within three minutes after cutting. Backpack sprayers with a wand and a flat fan nozzle were used to apply the chemical, to which a dye was added. The dye allowed identification of treated stumps and prevented double-treating or missing areas of cut cane. Non-target vegetation was not affected by herbicide because delivery of chemical from the wand and nozzle was accurate, application was near ground level, and Arundo often excludes plant growth around its perimeter.

Initial attempts to transport cut cane to an administrative site for disposal proved difficult, and small pieces of cut cane blew out of the stakeside truck during transport, potentially spreading the infestation. Therefore, most cut canes were stacked in an open, dry portion of the riverbed to dry and later burned.

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1 Rodeo® and RoundUp-Pro® are registered trademarks of the Monsanto Company.

Approximately two acres of Arundo on a 15-acre area were treated using 30 gallons of Rodeo® and 99 person-days at an estimated cost of $9300 per acre of Arundo. Some clumps of Arundo were completely killed with one treatment, but most clumps showed some resprouting in late spring and summer of the following year. Resprouts frequently showed characteristic signs of herbicide effect, such as short internodes and white streaking. Unfortunately, due to difficulty in awarding a contract, no follow-up applications of herbicide occurred the following year and by 1995 Arundo had regrown and invaded to pre-treatment densities.

In 1995 a full-scale control project was initiated in the same area as the 1993 pilot project, but utilized a different method . This effort involved mulching the standing Arundo in place, and then applying glyphosate to the resprouts. A contractor mulched the Arundo using a Seppi Midiforst hammer flail mower attached to a Ford 9030 tractor. The tractor is articulated in the middle, which makes it very maneuverable able to avoid even small willow (*Salix* sp.) and mule fat (*Baccharis salicifolia*) shrubs. The Seppi produces small mulch as well as larger split canes. Some large canes are pushed over and become buried beneath the mulch. Resprouting of these canes was not a concern because we planned to treat resprouts. Initial mulching occurred in October and November 1995. Resprouting occurred the following spring (1996). Resprouts were treated with a 5-15% solution of glyphosate (Rodeo® or RoundUp-Pro®) in April, May, July, and August of 1996. "Hand can" sprayers, the size of a large fire extinguisher, or a sprayer mounted on a four-wheel all terrain vehicle were used to apply the herbicide. As before, a dye was added to the chemical and no native vegetation was affected. Resprouts were treated again in June and September of 1997. From October 1995 to September 1997, using the Seppi and follow-up herbicide treatment, 8.8 acres of Arundo on a 46-acre area were mulched in 10 person-days, and 45 gallons of herbicide and 13 person-days were used to treat resprouts. Mulching and the first five herbicide treatments cost approximately $8,425 per acre of Arundo. Retreatments for 1997 cost about $190 per acre. Arundo is continuing to resprout in the treatment area, but comprises only 1% of the vegetative cover, as compared to 30-80% prior to treatment. It will take a long-term commitment of follow-up treatments for the control program to succeed.

In comparison, the mechanical mulching using the Seppi cost almost $1,000 less per acre than the cut-stump method, and required only a fraction of the time to accomplish four-times the acreage. Another contract we recently awarded (to the same contractor) for Arundo control will cost approximately $4,085 per acre of Arundo for initial cutting and mulching and five years of follow-up treatments: less than half the cost of the previous contract. It should be noted that mechanical mulching always involves at least some hand-cutting of those Arundo clumps or canes growing within native vegetation, or those growing in inaccessible places. The tractor is extremely maneuverable, but is not well suited to steep terrain or areas without appropriate access.

Results of the control program are very encouraging so far. Native willows (*S. exigua* and *S. lasiolepis*) and cottonwood (*Populus fremontii*) show increased resprouting and growth, and mule fat is now sprouting leaves along the entire length of its stems instead of just at the tip, as it did when Arundo was present (Nickerman 1997). Not surprisingly, weedy or pioneer species such as wild mustard (*Brassica nigra*) and annual bur-sage (*Ambrosia acanthicarpa*) have invaded the treatment area, but we expect them to diminish as succession proceeds. Willow and mule fat seedlings, as well as juncus (*Juncus macrandrus*), sedge (*Carex* sp.), miner's lettuce (*Claytonia parviflora* and *C. perfoliata*), and six species of lupine (*Lupinus bicolor, L. bethamii, L. concinnus, L. hirsutissimus, L. nanus, and L. succulentus*) have been found growing in the old Arundo mulch (Nickerman 1997).

Unarmored threespine sticklebacks were seen breeding in the treatment area during late spring 1996 and summer 1997 (Bautista, personal observation). Other wildlife commonly seen after Arundo was removed include mule deer (*Odocoileus hemionus*), raccoon (*Procyon lotor*), California quail (*Callipepla californica*), western toad (*Bufo boreas*), and many species of neotropical migratory birds.

In conclusion, removing Arundo can have dramatic benefits to native vegetation and wildlife and appears to be an effective method for restoring riparian ecosystems. Mechanical mulching, using a contractor, is more efficient and less costly than the cut-stump method, using Forest Service fire crews, for controlling Arundo. Costs for mechanical mulching are decreasing as competition for business increases. Some use of hand-cutting will always be required and may be the only method feasible in rough terrain.

ACKNOWLEDGMENTS

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BYLAS SPRINGS: *Tamarix pentandra* REMOVAL AND REVEGETATION PROJECT

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Tamarix pentandra Pall. (saltcedar), was introduced from Eurasia in about 1820 as an ornamental shrub (Horton 1964). The history and spread of saltcedar as well as the distribution of the species are documented by Robinson (1965). Many factors have contributed to the rapid invasion of riparian habitats by saltcedar. Reduced fire regimes, changes in streamflow patterns and land use practices have aided in the establishment of saltcedar. Saltcedar produces viable seeds for a longer season than most native species (Horton et al. 1960, Turner 1974). Sexual maturity requires several years in native woody vegetation, but flowers are often produced by saltcedar in their first year (Tomanek and Ziegler, no date). The ability of saltcedar to withstand extended periods of drought and submergence make it better adapted than native species (Horton et al. 1960).

Saltcedar has a number of characteristics which are less desirable than the native species it has replaced. It evapotranspires large quantities of water causing diurnal fluctuations in the water table (Gary and Campbell 1965). In small spring systems this fluctuation could conceivably affect surface flow. The replacement of native species by saltcedar destroys the habitat of wildlife that are dependent on native flora. Stands of pure saltcedar reduce species diversity usually found in riparian stands of native flora (Branson 1985). The long-term control of saltcedar has required mechanical and chemical treatment (Hollingsworth et al. 1979).

The Bylas Springs complex is a series of three small springs adjacent to the Gila River on the San Carlos Apache Reservation in Graham County, Arizona. The springs, referred to as S1, S2, and S3 (labeled from west to east) historically all contained populations of the endangered Gila topminnow (*Poeciliopsis o. occidentalis*). Saltcedar had invaded the spring complex from the Gila River drainage. The San Carlos Apache Elder's advisory Council recall the first appearance of saltcedar in the Bylas Springs complex in 1934 or 1935.

All of the springs are small, with base flows of a few liters to a few tens of liters per minute (Marsh and Minckley 1990). The replacement of native vegetation by saltcedar varies among the springs from moderate in S1 and S2 to almost complete in S3. The San Carlos Elder's Cultural Advisory Council described S1 (*Tusidugihalen*, "Hot Spring") in the early 30's as having much more water running than today. The riparian area was thick with grass and large mesquites (Prospois sp.) and there was no saltcedar. They described S2 (*iya bilnagoswaud*, "Mesquite Round") as historically containing large mesquites with an increased surface flow. There was little underbrush and the stream banks were lined with Yerba Mansa (*Anemopsis californica*) and no saltcedar was present at the spring or along the stream course. S3 (*Tu Macho)*, "Big Wolf's Spring" or

(*Tubahanahi Tsoose)*, "Water Coming out from a Point") was described as having much more water and no saltcedar. The consulting elders thought that the saltcedar should be removed from the Bylas springs complex , "as they drink so much water".

Specific objectives of the two projects completed included consulting with the San Carlos Apache Elder's Advisory Council to determine the historical plant assemblages in the Bylas Springs complex, the removal of introduced plant species from the system (mainly saltcedar), re-vegetating the sites with native vegetation, and the protection and reintroduction of the endangered Gila topminnow.

S2 was treated the first year as it contained no Gila topminnow and had the least extensive invasion of saltcedar. The S2 project was initiated in June of 1996. Removal of saltcedar involved mechanical and chemical treatments. The trees were cut down with chainsaws and the debris removed from the site. All stumps were treated with a 100 % solution of Rodeo® herbicide within 5 minutes of being cut to maximize effectiveness. This treatment proved to be approximately 90% effective at killing the saltcedar and only one additional treatment with Rodeo was required to kill the few resprouting stumps. Slash removed from the site was piled and burned in appropriate burn windows. During this project the culturally significant medicinal plant, Yerba Mansa, was removed from disturbed areas and transplanted back during the completion of the project. By August 1, 1996 the project was completed and Gila topminnow received from stock maintained at Arizona State University were returned to their historic home at Mesquite Round (S2).

The S3 system encompasses 720 meters of riparian habitat adjacent to the Gila river bottom. Prior to treatment, the riparian area was a near-monotypic stand of saltcedar. Restoration of S3 began in June of 1997 with the removal of the saltcedar. Due to the cultural significance of the spring and associated plants the cut-stump method was selected and chainsaws and backpack sprayers were used for the treatment. A crew of 10 people worked full-time for 30 days to cut, treat and pile the slash off site. The initial chemical treatment was a 100% solution of Rodeo herbicide, applied within 5 min. of cutting to maximize effectiveness, a dye was added to help keep track of the treated stumps. The trees were not completely killed by the initial treatment and most resprouted from the remaining trunk soon after they were cut. A second chemical treatment was used in the fall of 1997, a foliar application of 6½ oz. of Rodeo, 1½ oz. of Arsenal and 3 oz. of surfactant to 5 gal. of water. This treatment was successful in top-killing the resprouts; however, additional resprouts occurred during the spring of 1998. Additional treatments will be required to completely remove saltcedar from the system. After the saltcedar was removed, the stream section was re-vegetated using cottonwood (*Populus fremontii*) and willow (*Salix gooddingii*) poles.

The main features of the 1997 restoration of S3 were: removing exotic plant and fish species from the spring; re-vegetation with native flora; construction of a cement fish barrier; and reintroduction of the Gila topminnow. Gila top minnow were reintroduced into the spring in April 1998.

These projects focused on restoring the native flora and fauna to the Bylas

Springs system.

Bylas Springs is unique in that it is a riparian oasis situated in the desert. It provides habitat to aquatic species including the Gila topminnow, two endemic spring snails (*Tryonia gilae* and *Pyrgulopsis sancarlosensis*), Sonoran mud turtle and a variety of aquatic macro invertebrates. It also supports many species of riparian obligate neotropical birds such as Bell's vireo, yellow-breasted chat, vermilion flycatcher, summer tanager and wintering birds as well as non-migratory resident species. This restoration provided habitat for a broad suite of species, including many sensitive ones.

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SPRING LAKE- A NEW MEXICO CASE STUDY IN SALTCEDAR MANAGEMENT

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Saltcedar growing in two 13 acre dry lakes near Artesia, New Mexico was aerially sprayed by a fixed-wing aircraft on August 8, 1989. Imazapyr was applied at 1.0lb a.i./ac in a total volume of 10 g/ac with 0.25%v/v Activator surfactant and 0.25% v/v NalCotrol. The two dry lakes are approximately 100 yards apart and were permanent spring-fed lakes prior to saltcedar invasion in the 1960's.

A 2 in. diameter hole was hand augured into the bottom of the deeper of the two lakes on August 15, 1989. The hole was bored to a depth of 19 ft. and a 20 ft. joint of 2 in. PVC pipe inserted into the hole. A removable cap was placed over the end of the pipe to prevent moisture or debris from entering the hole from above ground. A soil sample was removed from the hole and soil moisture determined gravi-metrically. Soil samples were collected and soil moisture determined at approximately 60 day intervals for 12 months.

An attempt to collect a soil sample in October 1990, 14 months after application, was aborted when water was discovered in the bottom of the hole. Beginning in October 1990, the depth of the water table was monitored at 30 day intervals.

Water table monitoring data indicate that the water table at Spring Lake rose approximately 6 to 8 in. each month from October 1990 to July 1991. From July 1991 to August 1991 the water table rose 6 ft. following a large rainfall. Thereafter, the water table continued to rise 6 to 12 in. each month until June 1992 when 1 ft. of water was recorded on the surface of Spring Lake. This was the first record of surface water in Spring Lake since 1969. In September 1992, saltcedar canopy reduction was visually estimated to be 99%, while stem counts determined saltcedar mortality at 95%.

Water was recorded on the surface of Spring Lake for 26 months before receding below ground in July 1994 where it remained for 12 months. In July 1995 the water table returned to surface and stayed until receding below ground from March-July 1996. Water has been recorded on the surface of Spring Lake continuously since August 1996 and reached a level of 4 ft. deep in March 1998. In June 1998 the water level in Spring Lake was approximately 2 ft. deep.

For more detailed information on Spring Lake see:

Duncan, K.W. 1997. A Case Study in *Tamarix ramosissima* Control: Spring Lake, New Mexico. In: Plant Invasions: Studies from North America and Europe. Edited by J.H. Brock, M. Wade, P. Pysek and D. Green. Backhuys Publishers, Leiden, The Netherlands. pp. 115-121.

Reprints are available.

For more information on Bosque del Apache NWR saltcedar management program see:

Taylor, J.P. and McDaniel, K.C. 1998. Restoration of Saltcedar Infested Flood Plains on the Bosque del Apache National Wildlife Refuge. Weed technology, April-June 1998, Volume 12, Number 2.

TAMARISK ERADICATION AT RED ROCK CANYON STATE PARK MOJAVE DESERT, CALIFORNIA

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At the southern tip of the Sierra Nevada Mountains as these ranges blend into the Mojave Desert, erosion has revealed a canyon of great aesthetics. Here in the northwestern Mojave Desert the El Paso Mountains have been carved by water to reveal bright sandstone and volcanic layers etched into a badlands topography. Red Rock Canyon, located in eastern Kern County, California, is a landscape of great majesty that has attracted diverse human use. The same cliffs which have been the backdrop for over 130 motion pictures attract over forty collegiate geologic field trips annually (using Red Rock Canyon as an outdoor textbook) as well as paleontological research on one of the best fossil terrains in California.

A public effort to protect the canyon was begun in 1915, with magazine articles proclaiming the need for preservation, which culminated in 1968 in a successful citizen's effort to establish Red Rock Canyon State Park. In 1968 the California legislature appropriated moneys toward the purchase of Red Rock Canyon. Since 1970, when the first ranger was assigned to Red Rock Canyon, it has been the quest of California State Parks to document, understand, interpret and preserve the vast heritage of this landscape.

As part of the department's effort to preserve the natural heritage of Red Rock Canyon, which includes several sensitive to rare plants, a variety of management programs have been initiated, especially since the mid-1980s. Non-native tamarisk eradication has been one such program spanning over a decade of field effort.

In 1985 recognition of tamarisk infestations fostered a mapping of these non-native populations (Faull 1985). The mapping at first occurred within the original 4,000 acre park, but expanded when the park extended its managed properties to 10,000 acres in the late 1980s.

The documentation of tamarisk infestation achieved funding to begin eradication efforts in January of 1987. The initial treatment centered around a thick population of tamarisk within the main Red Rock Wash channel near the State Highway 14 bridge crossing. These tamarisk were entrenched along a washside bench at this location and were occasional in the wash proper. Some of these tamarisk were observed in direct competition with populations of the state listed "rare" plant *Hemizonia arida*, the Red Rock Tarplant.

Two species of invasive deciduous tamarisk were identified, *Tamarix parviflora* (the four petaled tamarisk) and in lesser numbers *Tamarix ramosisima*.

Initial Treatment Techniques

Treatment initiated utilizing the "cut stump" method, where by tamarisk trunks were cleared of debris to ground level and the tamarisk were cut with chain saws (or if small enough with pruning shears) as close to ground level as possible. In early 1987 an application of Garlon 3A at full strength was sprayed on the freshly cut stump, normally within one minute after the cut was effected. The herbicide was applied utilizing a four gallon "Hudson" sprayer. This technique produced a 75% kill ratio. Therefore, retreatment was required for 25% of the initial tamarisk treated (Faull 1987).

In March of 1987, following a meeting with Dow Chemical Corporation representatives, the cut stump method continued in an experimental capacity, utilizing Garlon 4 in a two part diesel to one part Garlon 4 mixture. The Garlon 4 treatments registered nearly an 85% kill ratio. Resprouting was not observed for three to six months following the date of treatment (Faull 1987).

In addition, a basal bark Garlon 4 treatment was applied to a very limited number of standing tamarisk, pursuant to an agreement with Dow Chemical. Per this agreement the basal bark solution consisted of a mixture of 3.4 ounces of Garlon 4 to one gallon of diesel and was applied to the lower 15 inches of the tamarisk trunk, around the entire circumference. In 1987 only a 50% kill ratio was obtained for the limited basal bark treatment (Faull 1987). In other studies Dow Chemical had registered a 96% kill ratio (Howard, et al. n.d.). It remains uncertain why the Red Rock results varied widely from other basal bark applications.

Tamarisk control efforts continued to harvest and treat parental tamarisk stock at the original site until late 1988 when the last of approximately 10 acres of parental tamarisk received application. Re-treatment of resprouts were needed on an annual basis until control was achieved.

Re-emergence of Sodium Springs

The original treatment of tamarisks within Red Rock Canyon resulted in an increased surface expression of one local spring (Faull 1987). This spring had a historic place name of Sodium Springs (on a 1920 map by Rudolf Hagen), but displayed a surface expression of less than 100 feet at the height of the tamarisk infestation. As tamarisk removal proceeded the surface expression of the spring slowly increased until it reached a maximum exposure of nearly six tenths of one mile within the Red Rock Wash channel.

This new surface moisture initiated an immense germination of local tamarisk seeds which resulted in a carpet of tens of thousands of tamarisk seedlings (Faull 1988). Five Boy Scout troops and other park volunteers assisted the park staff in uprooting the young tamarisk seedlings before they became established. Large tamarisk seed germinations and subsequent removal programs occurred in the autumn of 1987 and 1988 and the spring of 1988, before the maintenance was reduced to annual forays to pull small numbers of new seedlings. These annual tamarisk seedling removal campaigns still occur, to protect the investment made toward eradication.

Resurgence of Native Riparian Values

By the late summer of 1987, less than six months after the initial treatment, native sedges (*Scirpus americanus* and *S. maritimus*), rushes (*Juncus balticus* and *J. bufonius*) and cattails (*Typha domingensis*) began to germinate in the newly enlarged expression of Sodium Springs. These populations initiated from native local seed without intervention from park managers. Relatively rapidly these riparian species began to form islands of habitat within the new surface expression of Sodium Springs. Nine willow seedlings (*Salix laevigata*) and four cottonwood seedling (*Populus fremontii*) also emerged by the fall of 1987 (Faull 1987).

In 1988 the wetlands began to evolve and the expansion of the native riparian growth became both a source of inspiration and a source of conflict. Prior to tamarisk removal and the restoration of a surface flow to Sodium Springs vehicle use of the main Red Rock Wash was permitted. After the wetlands began to form conflicts with continuing unrestricted vehicle use became apparent.

An attempt was undertaken to protect the emerging riparian vegetation from vehicular degradation by defining an acceptable vehicle route through the wash corridor with moderate to large boulders. While the rock barrier did allow some expansion of riparian values, it was not effective in eliminating conflicts. Vehicular intrusions into the new vegetation mats were common despite a well defined barrier. Still the vegetation had expanded sufficiently for documentation of riparian values to occur and to determine that resolution of vehicular conflict was needed (Faull 1988, 1989a).

In November of 1989 construction began on a by-pass road that would remove traffic from a one fourth mile segment of the new wetlands by diverting the traffic to a washside bench (Faull 1989a, Faull 1989b). The route was in place one month later with over 20 signs directing vehicle use. This by-pass protected the thickest emerging riparian vegetation, but could not eliminate conflicts on the whole riparian corridor.

The protected segment now began to display classic signs of repair. The stream bed morphology changed from a continuously flat bottomed wash profile to a differentiated channel with a lower central flow channel banked by slightly raised flood plains on both sides. The central low channel was typically vegetated by expanding sedge colonies. On the flood plains colonies of rushes typically would blend into "mesic meadows" predominated by salt grass (*Distichlis spicata*). Closer to the fringes of the riparian zone willows, mule fat (*Baccharis salicifolia*) and cottonwoods were emerging (Faull 1994). The willows in particular began to mature and flower contributing more seed to the local restoration. The stream bed morphology had evolved into a mid-seral stage (Prichard, et al. 1993).

Wildlife values surged within the wetlands corridor. The spring waters became a soupy mixture of various bluegreen bacteria species which in turn attracted significant insect activity (both below the water and on the waters surface). Larger wildlife were increasingly drawn to the wetlands for available water and emerging food resources (Faull 1994). Documentation of increasing wildlife values, the development of a differentiated stream channel, the expansion of the native riparian vegetation, continued vehicle intrusions into the closed area and the inability of new riparian communities to develop on the segments of Sodium Springs outside the closure area all led to a 1996 decision to close the entire riparian corridor to vehicle access. The closure order (# 915-96-001) became effective on March 1, 1996.

A two year study period in the absence of vehicle intrusion began. The natural restoration of the riparian community progressed rapidly as documented in photographic records and within certain locations where expansion was quantified. Sedges were measured expanding into new habitat at five feet or more a month during the summer of 1997. Over a dozen mature shrubs and trees fringed the riparian community with tens of new willow seedlings documented emerging in 1997.

All of the riparian values were expanding exponentially until ... on September 3, 1997 an immense thunderstorm cell unleashed ten to fifteen inches of rain on Red Rock Canyon in a one to two hour period. Collected flashflood waters crested over the twenty five foot high Highway 14 bridge at the riparian zone. When the flood waters receded the lush riparian vegetation was absent, having been scoured by nature's fury. This immense flood was conservatively calibrated to be at a minimum a one in two hundred year event (through damaged to archaeological sites and other canyon features). Others individuals would argue for a longer interval between reoccurring events (Dr. David Whistler, personal communication 1997).

The wetlands and the associated riparian community represent a dynamic system which will rebound promptly to recolonize the denuded spring habitat. The past success of this communities expansion foretells the potential re-emergence which a few years of protective maintenance will yield.

Recent Tamarisk Control Efforts

In 1994 Congress passed the California Desert Protection Act. Pursuant to this act 17,000 acres of Bureau of Land Management property was designated for transfer to California State Parks as an addition to Red Rock Canyon State Park. This increased the total acreage managed as Red Rock Canyon State Park to approximately 27,000 acres.

The new acreage contains spectacular scenic and scientific values. Along with the valuable new natural and cultural heritage the park inherited approximately fourteen acres infested with untreated tamarisk. A renewed program of tamarisk control was initiated. The majority of the new tamarisk problem centered around three prominent springs within Last Chance Canyon.

A partially intact native species riparian zone is present within Last Chance Canyon, however, tamarisk invasion dominates most of the local springs. Funding was acquired which allowed treatment to begin on limited populations in April of 1996. A grant from the United States Fish and Wildlife Service to enhance habitat for the Red Rock Tarplant (Hemizonia arida) was supplemented by California State Park funds to begin the removal process.

Present Treatment Techniques

The tamarisk treatment was performed under contract with a private company. Approximately eight acres of tamarisk were treated with a basal bark technique utilizing a one part Garlon 4 solution mixed with three parts of diesel. The weather during the treatment in April of 1996 turned unseasonably hot which appeared to reduce the effectiveness of this application. A kill ratio of approximately 60% was obtained (John Crossman, personal communication 1998).

The resprouts were trimmed with shears in the absence of sufficient funding, in an effort to starve the surviving damaged tamarisk root stock. Retreatment with herbicide is now scheduled for the autumn of 1998.

In 1998 additional tamarisk control moneys were secured and during the spring approximately two additional acres of tamarisk were treated. Once again the application of the herbicide was contracted to a private company. The recent tamarisk treatment involved a basal bark application which encircled the trunk to a height of eighteen inches. The herbicide solution contained one part Garlon 4 to three parts diesel. A foliar spray was applied to a limited quantity of tamarisk to measured the success of this alternative treatment. The foliar spray contained a mixture of two percent Garlon 4 and two percent Roundup in an aqueous solution. The results of these recent applications are not available at the time of publication.

Conclusion

Red Rock Canyon State Park is one of the most outstanding landscapes in California. A diverse, and sometimes unique, flora is preserved for posterity within this painted desert canyonland. As would be expected, the local flora supports a diverse faunal assemblage, involving both resident and migratory wildlife populations.

Within Red Rock Canyon State Park documentation of tamarisk infestations combined with the results of tamarisk control efforts effectively and dramatically demonstrate the impact these non-native colonizers can inflict upon desert wetland communities. The resurrection of Sodium Springs, which resulted from tamarisk control efforts, attests to the positive environmental reward possible when an active tamarisk removal program is implemented.

Tamarisk control efforts at Red Rock Canyon State Park have experienced higher eradication percentages utilizing the "cut stump" method of control and herbicide application when contrasted with the success ratios of the "basal bark" exterior herbicide spray technique. The cut stump method, however, is far more labor intensive. Although tamarisk resprout treatments have proven more extensive in fieldwork conducted at Red Rock Canyon State Park, basal bark applications are, nevertheless, less labor intensive and likely less expensive when faced with large dense stands of tamarisk slated for removal.

The importance of Mojave Desert wetlands and their associated riparian communities needs increased documentation in the published literature. However, anecdotal observations attest to the increased and focused biological activity centered on these mesic islands which exist surrounded by expanses of less hospitable xeric terrain.

At Red Rock Canyon we had no prior warning of the significant potential for the increased surface expression of Sodium Springs which was hidden by the water consumptive infestation of non-native tamarisk. The restoration of a thriving green oasis of native vegetation supporting accentuated wildlife activity, centered around a rejuvenated desert spring, is the potential behind the removal of all arid lands tamarisk colonies.

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THE POLITICAL SIDE OF EXOTIC PEST PLANTS

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While most of us deal with exotic pest plants as a biological or maintenance problem, I suggest another important aspect—Politics! For most of us that word is not a good one as politics can deter us from obtaining our objectives and beyond our normal roles. Dealing with exotic pest plants is a people problem. For example, how did the plant get here in the first place? Approvals have to be obtained for its removal and a place found to store the biomass, besides getting the help of other agencies and fending off requests to remove the plant from private property. All these things come into play and bump into politics.

Nevertheless, the issue of politics is very real when dealing with removing exotic pest plants. Too many people have a say in what goes on in our waterways, wetlands, and flood channels for conflict not to arise. Politics to me means dealing with competing and, sometimes, conflicting agendas, motives and needs.

When I began removing *Arundo donax* from the Santa Ana River in southern California, I learned that other people had concerns and hopes. Sometimes these concerns went to local political leaders or were from the local media. While always trying to put a best *face* on our project, soon competition for funding between agencies occurred. We submitted a large grant application (six month's work), which was killed at the last minute by a new state senator.

Bringing together 20 agencies or more, some having a long history of conflict among them, is very difficult to overcome. Boards, commissions, elected officials, resource agency staff and leaders are learning about all the negative impacts from exotic plants. New pressure on the land managers forces them to do something about it.

Over the last five years, I have seen agencies gain a much better understanding of all the *how-to's* related to the removal of Arundo and why it is bad for our rivers. Community leaders and political leaders also are much more aware of the role the plants play in our rivers: fires, transportation and damage to flood control structures, denial of public access to our rivers, high rate of water uptake over native plant species, and reduction of habitat quality. In today's environment, any of these will cause conflict and thus move your project into the political realm.

The following step may help now that you are aware of where your project may end, and that you may not always have control of events.

- Know your subject better than anyone else. This can get you into the room where they make major decisions so you can give your ideas. Also, be clear and up front about the problem. State how long it will take, and the cost to solve it.

- Educate the local press of the problems. State its benefits and the actions that your agency or group is taking. Political leaders read their local papers and hear from their constituents, which may bring quite a bit of support your way.
- Local political leaders are very important to both state and federal agencies. Take a local political leader or his/her aide on a tour of your site, do the same for state and federal leaders. Be a host to a media event with local school classes working in your river, invite the press and stand back and watch magic occur. When citizens better understand how much exotic plants in *their* river are really costing the community, political leaders listen.

I attended a meeting with a dozen local political leaders and a congressional representative that ended in a $15,000,000 proposal for our watershed. While I hope we can obtain full funding, the long-term benefit is that top political leaders will better understand that the problem is growing (pardon the pun) and that they will benefit by applying leadership to solve this very complicated problem.

In almost every step to remove exotics, you may find politics at play between divisions in your organization, local community groups, the media, other city or county agencies, environmental groups, politicians and agency heads. Each may require a different approach to gain their support.

Politics is not a bad word, however, be aware that when dealing with people and their conflicting needs, there will be influence and jockeying for position. Try and keep a positive attitude where others may win, and through cooperation and mutual support we will all win, eventually. Winning is having our rivers and wetlands healthy and functioning to meet all human and natural needs.

ROOTING BY STEM FRAGMENTS FROM HANGING AND UPRIGHT STEMS OF GIANT REED (*Arundo donax*).

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The rooting ability of *Arundo donax* stem meristems during different times in the growing season was examined. Stem fragments from upright and hanging stalks were allowed to root in soil, plain water, and nutrient solution. Speed and percentages of root emergence were calculated. Both upright and hanging stalk stem fragments rooted throughout the growing season. However, the speed of root emergence was affected by the original orientation of the stalk and the time in the growing season. In early spring, the t^{50}Õs (in days) for root emergence for stem fragments of both types were equal for stem fragments kept in plain water, but stem fragments from hanging stalks rooted significantly faster in nutrient solution than those from upright stalks. In August 1997 the t^{50}Õs for root emergence were equal for stem fragments from both stalk types and faster than early spring rooting of the upright stem fragments in the nutrient solution, and both stalk types in plain water. However, these differences diminish as the growing season progresses. The initial difference between rooting abilities of both stalk types may result from changes in the localized concentrations of plant hormones, e.g. IAA, GA, and ethylene.

HYDROPONIC GROWTH CHARACTERISTICS OF *Arundo donax* L. UNDER SALT STRESS

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The exotic weed, *Arundo donax*, has invaded many riparian ecosystems in California. *A. donax* dramatically changes the habitats it invades, because it has an aggressive growth habit that allows it to become the dominant plant in wetlands. In an experiment that examined the salt tolerance of *A. donax*, stem fragments from three populations were grown hydroponically at three salinity concentrations (0, 15, and 30 g $NaCl \cdot l^{-1}$). Cumulative root emergence, new shoot mass, root mass were measured.

All three populations grew well in the 0g $NaCl \cdot l^{-1}$ treatment, and all three populations showed some growth in the 15g $NaCl \cdot l^{-1}$ treatment. All three populations showed shoot growth, but no root growth in the 30g $NaCl \cdot l^{-1}$ treatment.

This study provides evidence of *A. donax*'s ability to grow in saline conditions. Thus, it may be able to invade saltwater marshes if given the chance.