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Campaign Against Invasive Species: A Call for Action

William Y. Brown and A. Gordon Brown
Dept. of the Interior and the ad hoc Federal Invasive Species Task Force

The Problem

Invasive species are transforming America's landscape. Foreign animal and plant species are replacing native wildlife and plant species are replacing native wildlife and wreaking enormous financial and ecological damage. Alien species invasions are second only to habitat destruction in causing species to be endangered, and estimates of economic harm from these biological invaders run as high as $123 billion annually. Among other things, invasive species crowd out nutritious native forage, create fire hazards, limit recreations, clog lakes and waterways, undermine fisheries, and corrupt water pipes. Alien species causing harm include weeds like thistles and leafy spurge, which cattle cannot eat; purple loosestrife, which chokes wetlands; miconia, which may destroy the Hawaiian rainforest; and melaleuca trees now expanding across the-Everglades. Animals are also problems, such as the zebra mussel, corrupting water supply facilities; the brown tree snake, which has extirpated forests birds on Guam; and the Asian tiger mosquito.

Diverse stakeholders such as the Cattlemen's Beef Association and The Wilderness Society are united in the need to address this problem. Those affected recognize that the problem is bad and getting worse. Global pathways for invasion are multiplying rapidly. Federal authorities and programs are and incomplete patchwork. Action is needed.

Administration Initiative

On June 17, 1997, Vice president Gore directed preparation of an Administration strategy to combat introduction and spread of plants and animals that are not native to ecosystems in the United Sates and which are now causing or could potentially cause great economic and ecological harm to out nation. The Vice President asked the Departments of Interior, Agriculture and Commerce to prepare the strategy in consultation with the Council on environmental quality and Office of Science and Technology policy in the executive Office the President. An ad hoc

dent's request and prepared a Draft Action Plan. The Plan briefly describes the problems caused by alien species and reviews needs, shortcomings and key issues. It sets forth goals, objectives, and principles for actions followed by recommendations on institutional arrangements and specific actions including

1 listings,
2. preventing entry,
3. detection,
4. rapid assessment and eradication,
5. control, restoration, and monitoring,
6. cross-cutting research and technology.
7. national information needs,
8. partnerships, education and outreach,
9. international cooperation, and
10. fund raising and financial responsibility.

Invasive Species Executive Order

In the course of its work, the Task Force reached a consensus on the need for an executive order on invasive species to create a framework for planing and coordination involving all stakeholders. The Administration is developing an executive order to prevent the introduction of invasive species and provide for their control, and to minimize the economic, ecological. and human health impacts which invasive species cause. The Invasive Species Executive order outlines Federal agency duties, creates a new Invasive Species Council and defines its duties, and directs creation of an Invasive Species Management Plan.

Federal Agency Duties

Each agency whose actions may affect the status of invasive species will identify such action. To the extent practicable and permitted by law and subject to budgetary limits, each Federal agency will use programs and authorities to prevent the introduction of invasive species; to detect and respond rapidly and to control populations of such species in a cost-effective and environmentally sound manner; to monitor invasive species populations accurately and reliably; to provide for restoration of native species and habitat conditions in ecosystems that have been invaded; to conduct research on invasive species and develop technologies to prevent introduction and provide for environmentally sound control of invasive species; and to promote public education on invasive species and the means to address them. To the extent practicable and permitted by law, each Federal agency will not authorize, fund or carry out any action it believes is likely to cause or promote the introduction or spread of invasive species in the United States or elsewhere unless the agency has made public its determination that the benefits outweigh the potential harm and that all prudent measures to minimize harm will be taken concurrently.

Federal agencies will pursue the duties in consultation with the Invasive Species Council and consistent with the Invasive Species Management Plan and in cooperation with stakeholders.

Invasive Species Council

An Invasive Species Council will be established and co-chaired by the Secretary of the Interior, the Secretary of Agriculture, and the Secretary of Commerce. The Council will include the Secretaries of State, Treasury, Transportation, and the Administrator of the Environmental Protection Agency. The Secretary of the Interior will establish an advisory committee to provide information and advice for consideration by the Council including recommended plans and actions at local, state, regional, and ecosystem-based levels to achieve the goals of the Management Plan. The Committee will act in cooperation with stakeholders and existing organizations.

Duties of the Council

The Council will provide national leadership and:

1. oversee implementation of the Order and see that Federal agency activities concerning invasive species are coordinated, complementary, cost-efficient, and effective, relying to the extent feasible and appropriate on existing organizations such as the Aquatic Nuisance Species Task Force, and Federal Interagency Committee for the management of Noxious and Exotic Weeds, and the Committee on Environment and Natural Resources;
2. encourage planning and action in cooperation with stakeholders;
4. develop recommendations for international cooperation in addressing invasive species;
4, develop, in consultation with the Council on Environmental Quality, guidance to Federal agencies under NEPA on prevention and control of invasive species, including the procurement, use. and maintenance of native species;
5. facilitate development of a coordinated network among agencies to document, evaluate, and monitor impacts from invasive species on the economy, the environment, and human health:
6. facilitate establishment or a coordinated, up-to-date Internet-based network facilitating access to and exchange of invasive species information:
7. prepare and issue a national Invasive Species Management Plan.

Invasive Species Management Plan

The Invasive Species Management Plan will be developed through a public process and issued in eighteen months and will include:

I. a review of existing and prospective approaches and authorities for preventing introductions including those for identifying pathways,
2. research needs, and
3. recommended measures to minimize the risk that introductions will occur utilizing a science-based process to evaluate risks.

If recommended measures are not authorized by current law, the Council will develop and recommend to the agencies legislative proposals for necessary changes. The Council will update the Management Plan biennially and concurrently evaluate and report on success in achieving its goals and objectives. The Management Plan will identify the personnel and other resources and additional levels of coordination needed and be submitted to OMB for consideration in the budget process. Within eighteen months after measures have been recommended in any edition of the Management Plan, each Federal agency will either take the actions recommended or provide the Council with an explanation of why the action is not feasible. No less than once every 5 years, the Council will report io OMB on the effectiveness of the order and whether and order should be revised.

Executive Order 1 1987 on Exotic Species (May 24, 1977) is revoked.

Invasive Exotics in California: a Perspective from Inland Southern California

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Introduction

One may wonder: How is the perspective of someone from inland southern California any different from that of someone from any other part of the state? I'm not sure I entirely know the answer, but it must have something to do with having a somewhat more apocalyptic view of the weed problem than other folks seem to have.

In southern California the level of habitat disturbance is so high, and the amount of undisturbed habitat for native species is declining so rapidly that, it's difficult not to despair a bit at times.

What's particularly galling to someone familiar with the flora of the area is the fact that even the pieces of open space that have been preserved on the coastal slope, frequently after long and difficult fights, are rapidly being degraded by a massive weed invasion. Weed species that have been here a long time are continuing to increase in numbers and range, while numerous new weed species are invading the area every year. This is particularly noticeable in the inland areas because this is a major interface between urbanized zones and wildlands. Farther west the landscape is much more solidly urbanized and the amount of wildland is much less.

My own peculiar perspective is colored by the fact that I'm a museum curator who has long worked with the native flora of California and who does much of identification of plant material of sorts for the public, consultants, government agencies, etc. This frequently involves weeds of one sort or another and so my interest in, and knowledge of, the weed flora of southern California has continued to grow over the past 20 years. I've also been very concerned, as a long-time conservationist, seeing the massive invasion of the landscape particularly of preserved areas by these alien plants. When things are moving so fast that I can ob serve changes within the course of a couple of decades, it seems clear to me that the situation may he a bit out of hand. I've also spent a lot of time working on the floristics of southern California and am, for example, trying to finish a flora of the San Bernardino Mtns., along with Bob Thorne and Tim Krantz. This has further focused my attention on weeds because of all the new weeds we found doing the fieldwork for that project. Because I am an active collector, I have naturally tended to come upon a lot of weeds, many of them new to the state or region.

As a result of this constant contact with weeds of various sorts, my interest grew to a point where a couple of years ago I decided that there is really a need to start getting these ongoing invasions into the public record. I noticed that virtually no one was writing notes reporting new weeds in California, but I knew that there were lots of them arriving. I decided that someone needed to call this invasion to public attention. So, I began writing notes for Madrono on new weeds and range extensions for known weeds, as well as a certain amount of commentary on native plants. I also began encouraging all the botanists I know to do likewise.

One day I was looking for some information on some weed and had heard that CaIEPPC maintained a website on weeds, so I went looking for that and found the various lists. After reading those over, my original quest forgotten, I wrote a set of comments about the status of some of the weeds on the lists in southern California, and about some species that I thought should be on the lists, but which were not. I sent my notes to the e-mail address provided and apparently they attracted some interest. As a result of that, I was invited to come to this meeting and present my views weeds in inland southern California.

The Problem of Lack of Attention

The Inadequacy of the Response to New Invasions

Invasion by new species of weeds is a major problem that is not being addressed adequately,especially in the incipient stages of an invasion by a new species. New species are not being found and reported, and they're not being aggressively attacked when they are found.

There is apparently little funding for control of incipient populations and consequently it appears not to be a priority to find and eradicate populations of new weeds. It's one of the peculiarities of our society that we won't spend a relatively small amount of public money to eradicate weeds when they first appear, but will voluntarily spend hundreds of times more in private money later. Once a weed is everywhere, there is apparently a sense of resigned inevitability. At that point, the various affected landowners just do what has to be done and get out their checkbooks.

I'm aware of several invasions that were reported, but subsequently largely ignored by the relevant agencies, for one reason or another. These include *Sisymbrium erysimoides* in California, because it is an annual; *Centaurea solstitialis* near Oak Glen, for reasons I don't know; and *Aegilops cylinclrica*, where a brief control effort was made (population mowed), but the plants are still there 4 years later in numbers at least as great as when first found. There appears to have been no follow up in subsequent years.

I've noticed a distinct tendency among botanists and others to ignore incipient invasions and to write off first records, especially if of just one or a few individuals as "waifs", as though one could know that except in hindsight. Some species that were reported as waifs by Parish in 1920 are now well-established *members of the California weed flora. Among these are Dactylis glomerata*, *Bromus sterilis* (known to in CA Parish from a single collection) and *Asphodelus fistulosus*. There seems to be a tendency to forget that species evolve and adapt to their conditions. This fact suggests that even a marginally successful invasion by a weed species, one where the species is just barely able to hang on and reproduce in one area, has the potential to later be more successful, after the species has experienced a few generations of selection under Californian conditions. I know of no well-documented examples of such local adaptation after establishment followed by later spread by the "new and improved" populations, but it seems to me that it would be remarkable if this didn't happen. I don't follow that literature, so it may be that there are well-documented examples of which I'm unaware.

It is also the case that species sometimes just take a while to build from the small number of their initial invasion to the large number that become a problem. As an observer of the local flora, I've seen a number of cases of the phenomenon of a species appearing as a rare weed, hanging around for a while in small numbers, and then later exploding and becoming immensely more common than it was initially. The weed *Brassica tournefortii*, Sahara mustard, is a species in this category. It first appeared in California in the 1920s, but then went undetected until the 1950s. Plants spread explosively in the 1960s-1980s, and the plant is now among the dominant weeds on low sandy soils on the Sonoran Desert.

Another area of concern is the establishment of weeds in disturbed or cultivated-areas, which can subsequently spread into wildlands. There have been several conspicuous examples of this phenomenon. Prominent local examples include *Sisymbrium ervsimoides*, Nile rocket, which was first found in North America as an urban weed in Highgrove in 1970. bus which as since spread widely, including into coastal sage scrub and perhaps other lowland communities. *Ehrharta erecta*, Stebbins grass, is another example of an initially urban weed which spread widely in disturbed cultivated areas, but which is now beginning to appear in native habitats. Extreme cases in this category, though I didn't see these happen, are those of *Bromus rubens* and *B. diandrus*, both of which made their first appearances in southern California as grain field weeds, near San Bernardino in 1886 and 1888 respectively (Parish 1920). As we all know, they have subsequently spread to vast areas of wild land. I don't at all think that it is safe for those concerned about protection of wildlands to dismiss as insignificant those weeds that are established only as weeds of cultivated or disturbed ground. After they build up sufficient populations in these habitats, the seed rain into wildlands may become sufficient that they'll become established there, or they may evolve local races better adapted to Californian conditions.

New invasions are not documented quickly and sometimes not at all by specimens. It is all too common to have weeds spread widely before anyone notices that they're even here. As best we can determine.

there are currently less that a dozen active plant collectors working in southern California. The major reason that more new weeds aren't being detected and reported here, and elsewhere, is simply that we have entirely too few people out looking and documenting what they see. Please pay attention to weeds and document your observations with specimens! If you find a weed you don't know, please make a point of collecting it. There is a distinct chance that it will prove to be a new invader. Don't write things off as insignificant just because you don't know what they are.

The problem with ignoring weeds until they become common is that by then it may be too late to effectively do anything. It would be desirable to track every introduced species in California. I think the CaIEPPC lists would be both more useful and more widely used if they attempted to do this. There is a real need to document all exotic plants growing spontaneously in California, regardless of the fact that someone may think them to be merely a waif, of only limited ecological concern, too well-established to do anything about, or whatever. A species which is not inventoried because it is a "waif" may in fact be turning up in multiple places and well on its way to becoming a widespread. But if its status has not been reviewed, an observer *is* likely to conclude that his additional observations add nothing to our knowledge, when it fact these observations are important.

The Influence of Exotic plants Coastal Sage Scrub and Chaparral in the Riverside Area

I'm always surprised to hear comments that imply that exotics may not be all that serious, or that the threat by some of the commoner species has not been established. A case in point is the influence of the annual grasses, particularly *Broinus diandrus, B. rubens* and *Avena barbata* on the vegetation and flora of southern California. None of there three abundant weeds is included on the CaIEPPC weed lists, yet all are among the most severe pest species in southern California and are plants that we need to draw the most attention to and for which control measures most need to be found.

A Partial Solution to the Problem of Insufficient Attention to New Invaders

The California Exotic Pest Plant Council (CaIEPPC) list of Exotic Plant Pests point the way toward a solution of the problem of inattention to invading weeds. It strikes me that the CaIEPPC lists are something like a mirror image of the California Native Plant Society (CNPS) Inventory of Rare and Endangered Plants. On that list there is a seven level hierarchy of lists of native plant status in California. The CaIEPPC Inventory could perhaps be viewed as the evil twin of the CNPS list. Both are lists where we would like to see all the species on them removed, but in one case it's by building up all their populations, whereas in the other it's by killing every last individual.

The CNPS classifies the native flora into seven levels, though two of these are informal. The levels are: A (Believed Extinct); I B (Rare and Endangered in CA and elsewhere); 2 (Rare in California, more common elsewhere); 3 (Species about which more information is needed [distribution, taxonomic, etc.l): 4 (Not rare but of limited distribution); Considered but rejected (not rare enough); The rest of the flora (never considered for listing, whether rare or not). The system is clear and logical with each terminal taxon included in exactly one of the categories.

Some suggested modifications to the CaIEPPC **Inventory of Pest Plants of Ecological Concern: A Modest Proposal**

First, I would suggest that ALL weeds that are at all. or have ever been, established in California be included in the overall list, at some level. They are all of ecological concern, and it's just a matter of degree. By including all taxa, the value of the lists is not diluted by the ambiguities that result from incompleteness and the necessarily somewhat arbitrary decision to include or exclude some particular species.

Perhaps the lists could be reorganized in a format something like the following:

A-I Most Invasive Wildland Pest Plants. Widespread (apparently uncontrollable)

A-2 Most Invasive Wildland Pest Plants, Widespread (but controllable)

A-3 Most Invasive Wildland Pest Plants, Regional (controllable)

A-4 Most Invasive Wildlancl Pest Plants. Incipient invasion (control!) [--= Red Alert]

B Wildland Plants of Lesser Invasiveness (moderate populations over limited areas. or small populations over wide areas)

C Well established (uncommon to abundant) but primarily or entirely in disturbed or cultivated lands

D Introduced, but apparently not well established and apparently not aggressive

E Need More Information (use sparingly: if the CNPS **list** is a guide, you won't get much)

F Formerly established, but eradicated or did not persist (believed extirpated)

G Considered but not listed (deemed native, or report based on misidentification)

Now this modest proposal may strike some as rather radical, but it seems to me that it's right in line with the goals of this organization. A complete weed inventory would provide a focus for everyone by presenting a summary of all that is known about the abundance and distribution of the weeds of California. By putting what we think we know about each weed in one document, there would be the possibility of finding out that there are some important things we don't know. As ii is, species not on the list are simply liable not to receive any attention. Really bad weeds are not likely to receive any more attention in an incomplete list of "highlights" than they would in a comprehensive and rigorous work that strives to present a complete summary.

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Licenses, Certification and Permits for Herbicide Applications

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The California Department of Fish and Game (DFG) uses herbicides on state-managed wildlife areas, fish hatcheries and ecological reserves throughout California. While much of this vegetation management involves routine maintenance for parking lots, roadways and other infrastructure, over the last several years an increasing amount of this work has been devoted to the management of exotic invasive plant species. These exotic species pose a significant threat to native wildlife and plant populations on DFG lands.

Like other pesticide uses in California, DFG herbicide usage falls under the regulatory purview of the California Department of Pesticide Regulation (DPR) and the offices of local county agricultural commissioners (CACs). California's pesticide regulatory program is among the most rigorous in the nation. A few of the requirements administered by DPR and the CACs are pesticide applicator certification and licensing, and the issuance of restricted use pesticide permits. Other important requirements involve pesticide use recommendations, applicator training, and use reporting and record keeping.

Applicator Certification

The Regulatory Standard — Certifying pesticide applicators provides DPR and the CACs regulatory control over the use of pesticides that are deemed "restricted use" due to their potential hazard to people and the environment. Both the U.S. Environmental Protection Agency and DPR maintain regulatory lists of restricted-use pesticides.

Pesticide applicator certification is granted to individuals by the DPR after successful completion of a written examination and is valid for two years. Certified applicators must recertify after the initial two year period by paying a fee and showing proof of meeting a 20-unit continuing education requirement. Only DPR accredited continuing education units are applicable. Retesting is not required for recertification.

Certification vs. Licensing — DPR's regulatory program makes a significant distinction between pesticide applications that are done by commercial applicators ("for hire") and those that are non-commercial ("not for hire"). Examples of "not for hire" applicators that would qualify for certification would be government agency employees and employees or volunteers of private organizations such as The Nature Conservancy or the Audubon Society. In the case of commercial applicators who use pesticides "for hire," obtaining applicator certification does not satisfy the regulatory requirement. In these cases, the applicator- must obtain an applicator license, rather than a certificate. The primary differences between the certificate and license processes are the length and difficulty of the examination and the number of continuing education units required.

Permits for Restricted Use Pesticides

As stated previously, certifying pesticide applicators provides DPR and the CACs regulatory control over the use of pesticides that are deemed "restricted use-. due to their potential hazard to people and the environment. The most common reason for the restricted status for all pesticides is mammalian toxicity. The underlying reason for using the mammalian acute toxicity standard is human (applicator) exposure hazard. However, some herbicides that are of relatively low mammalian toxicity may be restricted due to other environmental risks, including hazard to non-target vegetation. One of the best examples of this is the use of volatile agricultural herbicides, such as the use of certain high-volatility ester formulations of 2,4-D on small grains near grapes or tree fruit. Another example of an environmental hazard that may lead to a restricted-use status is the groundwater contamination potential of certain pre-emergent herbicides such as atrazine or simazine. Restricted-use pesticides can only be possessed and used by certified (or licensed) applicators. The possession of an applicator certificate allows the applicator to obtain an annual restricted-use pesticide permit from the local county agricultural commissioner. With few exceptions, certification alone does not satisfy the regulatory requirement. Prospective restricted-use herbicide users must obtain both certification and the annual permit.

Practical Application of the Regulatory Standard

The majority of herbicide applications made for the control of exotic invasive weed species in wildland settings do not involve the use of restricted-use herbicides. This being the case, neither pesticide applicator certification nor a restricted-use pesticide permit is required. Some examples of these non-restricted herbicides include Garion® products, Pathfinder®, Rodeo®, Roundup®, Telar® and Transline®.

In practice, however, many government agencies and private organizations that use herbicides still require their applicators to obtain certification prior to the use of non-restricted herbicides. There are several excellent reasons for this, including improved applicator training and increased applicator professionalism.

Other Regulatory Requirements

There are several other important DPR requirements besides the certification, licensing and permit issues discussed previously. These include pesticide use recommendations, operator identification numbers, pesticide safety training and pesticide use reporting and record keeping.

Pesticide Use Recommendations — With few exceptions, herbicide uses to control invasive weeds in wildland settings must be recommended, in writing, by a DPR-licensed pest control adviser. Recommendations must include specific information and must be provided to the applicator prior to the application. Individuals may become licensed pest control advisers by successfully completing a DPR-administered exam. Licenses are valid for two years. Recertification requires 40 units of DPR-accredited continuing education.

Operator Identification Numbers -- The applicator must obtain this number from the local county agricultural commissioner prior to the purchase and use of most herbicides. This requirement applies to both restricted and non-restricted use pesticides.

Pesticide Safety Training -- Employers must pmvide annual pesticide safety training to their employees that handle pesticides. The training must follow a specific format and must be well-documented. Potential herbicide users should contact their CAC for more information on this important requirement.

Pesticide Use Reporting and Record keeping — DPR regulations require pesticide use reporting and record keeping for most herbicide uses made in wildland settings. The regulations require that specific types of information be maintained as use records. although these records need not be submitted to either the CAC or to DPR. In contrast, summary pesticide use reports must be submitted to the local CAC each month when pesticides are used. Use reporting forms can be obtained from your local CAC.

The DFG Example

The DFG Pesticide Investigations Unit (PIU) has general oversight responsibility for all DFG herbicide use projects. The PIU provides herbicide use consultation, licensed pest control adviser recommendations and a comprehensive pesticide applicator training program for DFG employees.

DFG maintains approximately 80 certified applicators and numerous non-certified applicators at wildlife areas, ecological reserves and fish hatcheries throughout California. These certified applicators receive annual pesticide safety training and the required DPR-accredited continuing education by attending the annual DFG Pesticide Applicators Seminar. Further, the PIU-produced DFG Pesticide Applicator Manual satisfies DPR's requirement for written safety training and hazard communication programs. This manual is provided to each DFG facility or project that uses pesticides.

Reference

California Department of Fish and Game (DFG). 1992. California Department of Fish and Game Pesticide Applicators Manual. 20 pages plus attachments.

Handling Herbicides Safely: Protecting Yourself, Others, and tile Environment

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Introduction

Various type of pests have plagued people since the beginning of civilization thousands of years ago. Weeds, certain insects and nematodes, rodents and other vertebrates, and plant diseases are troublesome pests that cart drastically impact humans. During the past half-century, scientific advances have provided new and powerful pest management tools. Most important among these tools are chemical pesticides. To protect crops, landscapes, structures, pets and livestock, human health, and many human belongings, people sometimes must use pesticides. While pesticides have saved lives, added to agricultural productivity, and protected structures and landscapes, they have also created serious new environmental and health concerns for society.

All pesticides are toxic. They must be toxic to kill the pests you are trying to control. However, some pesticides are more toxic than others. The hazard to you and others when you use pesticides is a combination of this toxicity and the amount of exposure. Exposure can take place through several routes — your skin, eyes, mouth, and lungs — and the route of exposure may influence the degree of hazard.

Nearly a century ago, state and federal governments recognized that pesticides, although necessary for many types of pest management programs, had the potential to cause serious injury to people and cause environmental disasters. At that time, government agencies .began regulating pesticide production and use. The State of California is a pioneer in pesticide regulation and today has the most stringent pesticide regulatory program in the nation.

The Pesticide Label

When you use pesticides, you are required to know, understand, and follow the federal, state, and local pesticide regulations. Pesticide labels are your most important source of information when you use pesticides. The information on • pesticide labels is put there for your protection. If you read, understand, and follow this information, your likelihood of injury or accident is reduced. Pesticide labels are legal documents and you are required to follow the directions on these labels. Any violation of the label instructions is a violation of the law. The most important few minutes in chemical pest control is the time you spend reading these labels.

Regulations establish the format for pesticide labels and prescribe what information they must contain. Some packages are too small, however, to have all this information printed on them, so manufacturers are required to attach supplemental labels. Labels may also refer you to other documents, such as endangered species range maps, that must be considered part of the libeling. Pesticide labels provide information to help von legally and economically use those products. Obtain. read, and understand all the information on a label, supplemental labeling, and referenced documents before making a pesticide application. If you have doubts about how, when, or where to use a pesticide. check with your local county agricultural commissioner.

You can incur serious legal penalties for violating label instructions. In addition, personal injury, environmental pollution, or waste of time and pesticides arc some other costly consequences re 1 su.ting from your not following the instructions on pesticide labels.

Read the pesticide label at the following times:

I. Before purchasing the pesticide: Make sure the pesticide is registered for your intended use. Confirm that there are no endangered species restrictions or other conditions that prohibit the use of this pesticide at the application site. Be certain it can be used under current weather conditions and against the weed life stage you are trying to control. Find out what protective equipment and special application equipment you need. Do not buy the pesticide on the basis of reading only the brand name. Keep in mind that manufacturers change products, formulations, and methods of application without changing brand names.

2. Before mixing and applying the pesticide: The complete label (including the label and supplemental labeling) must be at your pesticide mixing site. Read the label to understand how to mix and safely apply the material. Learn what precautions are needed to prevent exposure to people and non-target organisms. Find out what first aid or medical treatment is necessary should an accident occur.
3. When storing pesticides: Find out how to properly store the pesticide to prevent breakdown or contamination. Understand the special precautions to prevent fire hazards. Be sure storage areas are properly posted.
4. Before disposing of unused pesticide and empty containers: Learn how to prevent environmental contamination and hazards to people. Before disposal, check with the county agricultural commissioner in your area for local restrictions and requirements.

Pesticide Hazards

Several types of potential hazards are associated with pesticide use. If you are personally exposed to some types of pesticides you could suffer short-term or long-term health problems. If you are careless and allow residues to drift or otherwise get into the environment, nearby workers, residents, or passersby may be injured. Environmental contamination by pesticides may lead to loss of water quality or injury to non-target vegetation, honey bees, birds, or other wildlife. Improperly applied pesticides may cause damage to treated surfaces or, through drift, surfaces near the treatment area. In addition, indiscriminate or overuse of pesticides may result in pest resistance to certain compounds or disruption of biological control through the destruction of natural enemies.

Correct mixing, loading, and application techniques are only part of your responsibilities when using pesticides. You need to understand how pesticides can injure others or cause environmental contamination. Then you must take all the necessary precautions to keep this from happening. Responsible use of pesticides means protecting people as well as the air, land, surface water, groundwater, and plants and animals in your surroundings.

There are several ways people come in contact with pesticides. The greatest risk of exposure occurs during mixing and application and when entering or working in treated areas soon after application. Following the pesticide label instructions, wearing proper protective clothing, practicing good hygiene, and using other pm-tective measures will reduce these types of exposures. To protect workers and consumers, adhere to label guidelines for restricted-entry and harvest intervals.

As you work with pesticides, accidental spills may result in serious exposure. Protective clothing and prompt emergency response reduce the chances of serious injury if you have an accident.

It is also possible for people to be exposed to small amounts of pesticide if they live near areas where pesticides are sprayed. Anyone who eats treated produce from fields before the harvest interval expires will risk exposure. People will also risk exposure if they touch recently treated plant foliage.

One of the most tragic types of pesticide injury is caused by storing pesticides in food or drink containers. Many cases have been reported of children drinking pesticides from soft drink containers. Never store pesticides in anything other than the containers in which they were purchased. Unless you have control over the containers, keep pesticides locked up in a storage area that is inaccessible to children or untrained adults.

Poisoning or injury sometimes result from a single exposure to a large quantity of pesticide. In other cases, injury will not occur until you have been exposed repeatedly over a period of time. It is quite common for individuals to vary- in their sensitivity to the level of pesticide exposure. Some people may show no reaction to a dose that causes severe illness in others. Your age and body size often influence your response to a given dose. Thus infants and young children are normally affected by smaller doses than adults. Also. adult females are more often affected by lower doses than are adult males.

Effects of Exposure

The type and severity of injury or poisoning depend on the toxicity and mode of action of the pesticide you are using, the amount absorbed into your body. how fast it is absorbed, and how fast your body is able to break it down and excrete it.

You can lessen the severity of pesticide-related injury through prompt first aid and medical treatment. Very small doses usually produce no injury or poisoning symptoms. Depending on the toxicity of the pesticide, larger doses may cause severe illness. Effects of exposure may be localized — such as irritation of your eyes, skin, or throat — generalized when pesticides are absorbed through your skin, membranes, or intestines, and carried to your internal organs. Certain pesticides may affect several different internal systems at the same time. The extent of involvement and damage is related to the characteristics of the pesticide and to the dose.

Ways to Prevent Exposure

People who handle pesticides or contaminated equipment are best protected if they are properly trained to avoid hazards and if they use appropriate personal protective equipment (PPE) and practice good personal hygiene. People who work in areas where pesticides have been applied can reduce exposure by being aware of the hazards, observing restricted-entry intervals, wearing appropriate clothing, and practicing good hygiene.

Pesticide handler training: California regulations require that all pesticide handlers receive yearly training from their employers. This training must be specific to the class of pesticides they handle. Employers must document the training and the training record must be signed by the employee. Training must be updated before each new class of pesticide is handled. Employers are required to maintain the records of training along with the training plan and training resources for a period of two years.

Personal hygiene: Bathing helps to remove pesticide residues from your skin and hair. Always shower after applying pesticides, and then change into clean clothing. You should wash your hands with soap and water before eating, drinking, using the bathroom, and using tobacco products, if you have been involved in handling pesticides or working in areas where pesticides were applied.

Environmental Contamination

Environmental contamination from pesticides can occur in a number of ways. It may be the result of drift, when wind and air currents carry pesticides you are applying out of the target area. It can also result when pesticides you have applied run off into surface water sources or leach into groundwater.

Groundwater Contamination

Pesticide residues have been detected in many wells throughout California. Many of the detected pesticides are herbicides. In some cases the levels of pesticides found in these wells have been high enough to make the water unsafe for drinking. Since groundwater is California's most important freshwater source, hazardous levels of toxic chemicals in the groundwater are a serious concern. Therefore, stringent laws have been put into effect to protect this resource. The ways you use pesticides and dispose of them are affected by these laws.

Factors influencing groundwater contamination: The downward movement of pesticides through the soil is known as leaching. It is important for you to learn how to keep pesticides from leaching into the groundwater. Pesticide leaching into groundwater generally occurs through either point or non-point pollution sources. Small amounts of pesticides entering the groundwater from normal applications over a large area is a form of non-point pollution. When larger amounts of pesticides leach through soil at small. defined locations, such as pesticide spill sites, disposal or storage sites, and mixing and loading areas, this is called point pollution.

How to prevent pesticide contamination of groundwater: To keep pesticides from entering the groundwater, take the following precautions:

Storage: Store pesticides on an impermeable tiff-face in enclosed areas protected from rain.

Mixing and Loading: Mix only the amount of pesticide needed for the job. Carefully mix and load pesticides in ways that avoid spills. Do not overfill your spray tank. Use a check valve or air gap on filling pipes to prevent backflow of contaminated water into water supplies. Never leave your sprayer unattended while it is being filled with water.

Avoid performing pesticide handling activities near water wells. Pesticides spills from mixing and loading activities, residues from cleaning equipment. and improper disposal of surplus pesticides in these areas can result in pesticide contaminants entering the groundwater around well casings.

If a spill occurs, clean up and dispose of the waste quickly and safely in accordance with regulations. Follow cleanup guidelines on the material safety data sheet. You must remove contaminated soil.

When mixing pesticides, triple rinse empty liquid containers and pour the rinsate into the spray tank for application to the target site. Store rinsed containers in a locked area until they can be recycled or taken to a designated disposal site.

Application: Reduce drift of pesticides off the target site by lowering your equipment's spray pressure, using nozzles that produce large droplets, leaving buffer areas, and practicing other safe application techniques. Make applications during optimum weather conditions, whenever possible, to reduce off-site movement of pesticides through drift and runoff.

Disposal: Never dump pesticides or pesticide mixtures onto the soil or into sewers, drains, septic systems, or water sources. Store unused pesticide waste for eventual transport to approved disposal sites.

Surface Water Contamination

Surface waters, such as irrigation canals, rivers, streams, and lakes, are sensitive to pesticide contamination. Drift from nearby applications, as well as runoff from rain or irrigation, can carry pesticides into the surface waters. This creates a serious problem because of our dependence on surface water for irrigation, drinking, and human recreation. Effects on aquatic life and other animals can impact the entire ecosystem.

Pesticide Impact on Non-target Organisms

Non-target organisms include all plants and animals other than the pest being controlled by a pesticide application. As much as 55% of an applied pesticide may leave the treatment area due to spray drift, volatilization, leaching, runoff, and soil erosion. Pesticides that drift or move onto adjacent areas may cause damage to crops, livestock, or wildlife, and may contaminate lakes, rivers, and streams. Some herbicides in concentrations as low as 1/1000 of a pound (0.454 gram) per acre may reduce yields. Under certain weather conditions, and if large acreage is being treated, pesticide concentrations in this range can drift out of the treatment area and move for several miles before settling to the ground.

Non-target plants: If you improperly apply herbicides you may unintentionally kill non-target plants, including nearby crops. Many species of plants are important in natural and undeveloped areas because they protect the watershed, reduce erosion, provide food and shelter to beneficials and wildlife, and are part of the natural flora. When the ecological balance of an area is disrupted, such as the unintentional destruction of natural flora by herbicides, undesirable plant species are likely to take over. These undesirable species usually fail to provide the natural food and shelter needed by beneficials and wildlife.

Handling Pesticide Containers

Undiluted pesticides are a greater risk to people and the environment than are diluted spray mixtures. Your safe handling and transporting of undiluted pesticides can prevent many accidents. If you should spill pesticides on public roads, they can be blown, splashed. or scattered by passing vehicles. Spilled chemicals may wash into ditches, streams, and rivers during rainstorms, creating the potential for serious damage. including groundwater contamination. Spilled pesticides may also contaminate your vehicle and its cargo: it may be impossible to remove completely all residue from the vehicle.

If you have an accident involving spilled pesticides. alert the highway patrol, county sheriff, city police, or local fire department at once. Keep people and vehicles away. Stay at the scene of a spill until responsible help arrives. You or the responding emergency team can get advice on cleaning up spills from CHEMTREC at 1-800-424-9300.

Post-application Cleanup

Effects on human and environmental health are greatest when the exposure comes from undiluted pesticides. But diluted pesticides and their residues are also dangerous. There is a legal difference between hazardous materials, such as pesticides that will be applied, and hazardous wastes, such as leftover or unusable pesticide mixtures, You can avoid the prohibitive expenses of disposing of pesticide waste by following the procedures listed below:

Disposing of leftover pesticides: Even when your equipment is properly calibrated there may be pesticides left in your spray tank after completing an application. Before disposing of this material, first try to apply it to a legal application site (one listed on the pesticide label). It may be necessary to dilute the mixture and spray it evenly over a previously treated area, if this can be done without exceeding the label rate. Leftover pesticides can also be stored in service containers for future use on legal sites. This is not always possible, as some pesticides lose their effectiveness over time, or the pesticide may not be needed again that season. The last resort is to have the pesticide shipped to a Class 1 disposal site. This may be your only legal remedy, and it can be expensive.

Don't ever dump leftover pesticides: This is a potential source of environmental and groundwater contamination and is an illegal practice. Anyone convicted of illegal disposal of hazardous waste is subject to a large fine and possibly a jail term.

Cleaning contaminated application equipment: The residues that remain in or on your application equipment after pesticides have been applied can potentially cause human injury or environmental contamination. Therefore, you must clean and decontaminate your equipment immediately after finishing your application. Residues in the tank may contaminate your next pesticide mixture and possibly alter its toxicity. There is also the problem that some leftover residues may injure plants or cause other types of damage to sprayed surfaces.

Clean your equipment in areas where runoff will not drain into any waterway or other sensitive area, away from water wells, and where it will not leach into the groundwater. By cleaning your equipment at the application site, rinsate can be sprayed on that area. Wash the outside of the sprayer with water and a small amount of detergent if necessary. Fill the spray tank approximately one-third to one-half full with water and while running the agitator, flush the lines for several minutes. You can further decontaminate the tank by using commercial tank cleaning and neutralizing compounds. Follow label directions when using these materials.

When it is not possible to spray the rinsate onto an appropriate area, you must drain it into a holding container and either:

1. use it as makeup water for filling your spray tank when using the same pesticide at a later date;
2. transport it to a hazardous materials (Class I) disposal site; or
3. treat the rinsate in order to reduce the concentration of chemical in the water.

accidents and Herbicide Spins: What Should You Do?

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Herbicides are specialty chemicals used to control the growth of plants. As a general rule, herbicides are usually the least acutely toxic of the various pesticide types. One reason why this is so is that herbicides are designed to affect specific biological processes within a plant, processes that are often unique to plants.

Most of the herbicides that habitat restoration managers use to control invasive plants are low in acute toxicity relative to other chemicals our society commonly uses. Toxicology aside, the big difference between herbicides and other societal-use chemicals is that at efficacious concentrations in the environment, herbicides can kill and prevent the healthy growth of plants. For this reason and others, it is important to ensure that spills involving herbicides are properly handled. In this way we will be able to leave the site as clean as it was before the spill. Most herbicide spills are fairly easy and straightforward to deal with as long as you've thought about your response actions ah materials and equipment. Always wear the appropriate safety gear (prescribed personal protective equipment) when cleaning up spills. Refer to the product label or the material safety data sheet for this information. At the very least, this should include eye protection and the use of chemical-resistant gloves.

Basically, dealing with spills is a four-step process, as follows:

- Control the spill.

  The spilled pesticide should be controlled by stopping the source of the spill. This may be as simple as standing upright an overturned container or closing a shut-off valve on leaking equipment.

- Contain the spill

  Once the spill has been controlled, contain it with sand, soil, absorbent clay, pet litter, etc. For smaller spills this may not be necessary. For larger spills, this is critical to limit the extent of the spill. Proper containment will reduce cleanup time and costs and can be instrumental in protecting more sensitive areas, such as wetlands. streams, etc.

- Clean up the spill.

  After the spill has been stabilized and it appears the spill will not spread, clean-up can begin.

  The spill should NOT be hosed down as this will spread the spilled pesticide and result in additional contaminated liquid that will require disposal.

  The way a spill is handled depends on whether the product can be recovered and reused or the material is unusable and therefore a waste. Spills that can be easily recovered and reused may be transferred to a properly marked container and stored until the product can be used as intended. For example, both the spillage of a granular product on a cement floor or the release of a liquid product within an impermeable contained area could conceivably be recovered and reused in accordance with the product's label.

Spills that cannot be easily recovered may take longer to clean up and the material collected may not usable as was originally intended. Any spillage remaining after the material has been recovered should be covered with enough absorbent material to soak up as much of the remaining liquid as possible. Leave the absorbent in contact with the liquid spillage for at least one hour, Depending on the product spilled. the used absorbent may be considered a waste product. Waste is defined as material that cannot be used in the manner for which it is labeled. After cleaning up the absorbed material, the area should be washed with a strong detergent and water. Absorb the wash solution with absorbent, sweep up, and dispose of properly. If the spill is on soil, the area should not be washed. Just remove the contaminated soil. A good rule to follow is to *re-*

move at least three inches of soil beyond the visible extent (wet area) of the spill.

For large spills that have penetrated deeply into the soil, soil testing may be necessary to ensure that unreasonable residues do not remain following the initial soil removal. Check with the California Department of Food & Agriculture, California Department of Pesticide Regulation, or county Agricultural Commissioner's office for advice on disposal of contaminated soil.

• Report the spill.

Report the spill if required. Most of the products that are used for invasive plant control do not have spill reporting requirements. However, some pesticides may contain ingredients that require federal or state reporting, depending on the quantity spilled and whether or not the material was released into the environment (as opposed to in a contained area). For example, herbicide products containing 2,4-D would require reporting, depending on the actual amount of 2,4-D that was released into the environment. Reporting requirements are usually unique. according to the product and state regulations. An excellent information resource to check for reporting procedures on spills, leaks, or fires involving pesticides is CHEMTREC, an independent spill response center that is funded by the Chemical Manufacturers Association. The number is (800) 424-9300. For spills that contaminate water resources, occur on highways, result in injury, or will require extensive cleanup, the product's manufacturer should be contacted as soon as possible.

SWAT: Special Weed Action Teams as Ambassadors for Education and Energy

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Several weed activists in San Diego have formed a Special Weed Action Team (SWAT). The goal of the team is to improve the control of invasive exotic weeds in San Diego County's parks and wildlands. It accomplishes this through three types of activities:

- technical aid and education,
- hands-on training in control methods, and
- mobilizing volunteers to "jump-start" the control efforts of area open space land managers. SWAT aims to leave behind on-going control programs and on-going volunteer efforts.

Inspiration for forming the team came from Bill "Mr. Tamarisk" Neill's decade plus efforts throughout the southwest to stimulate tamarisk control efforts. The SWAT team includes a long-time veteran of Bill's team, who was also president of the local chapter of the California Native Plant Society.

Technical aid and education includes helping wildland managers. The emphasis is on helping a manager better understand the threats to the natural resources in his/her park and devising strategies that the manager implements. The team also helps managers to identify weeds and shares control methodologies for particular weeds. SWAT also helps survey newly acquired or soon-to-be acquired wildlands.

Technical aid and education also includes several team members acting as a clearinghouse for information. They receive many phone calls asking for information or advice on weed problems, including from the resource agencies, private contractors, other volunteers, park managers, homeowners and others. Coming back from a CaIEPPC conference, a team member made copies of a picture and slide of *Spartina alterniflora* that a speaker at the conference had thoughtfully provided. She then circulated them to personnel at estuaries along the San Diego coast, asking folks to be alert to the plant's presence. On another occasion, Ellen Bauder, our local vernal pool researcher, called with word of a new vernal pool exotic and asked that the word be spread to other vernal pool people. A biologist with the local County Dept. of Agriculture called several years back to inform the team of the presence of spotted knapweed *(Centaurea maculosa)* in several San Diego and Southern California sites, wanting someone else to know it was present and what he was doing about it. This past year the team received calls that Perennial peppergrass or tall whitetop *(Lepiclium latifolium)* had been identified in two areas. At a third site a team member was able to confirm that a suspect population was not the exotic peppergrass, but a native.

Training can include the effective use of hand tools such as loppers and handsaws; the use of power tools including chainsaws, brushsaws, gas-powered reciprocating limbing saws; and the proper use of backpack and hand herbicide sprayers. The team has helped organize specific classes in chainsaw-safety and use and herbicide-safety training for professional ranger staff. staff biologists, Americorps and volunteers from a number of parks. Training also includes field identification of native plants, exotic weeds and any native look-alikes. Such training avoids errors in the field and promotes an understanding of the purpose of weed control: releasing or restoring native plants, habitats and wildlife.

SWAT helps "jump-start"- weed control projects in area parks by bringing a team of 4-12 experienced weed warriors to the kick-off of a new project. The idea isn't to substitute the team for a local. home-grown effort, but to provide an energy boost at the beginning. Salting new volunteer groups with experienced weed volunteers helps projects get off to a fast and enthusiastic start. Working shoulder to shoulder with seasoned activists, new volunteers learn that projects that seem daunting are quite doable and that volunteers can have fun carrying them out. Working with experienced volunteers provides a non-threatening environment in which novice weed bashers can ask questions. SWAT members are free to volunteer -- and often do — on a continuing basis in any projects that interest them. The team is composed of experienced weed activists from the Friends of Los Penasquitos Canyon Preserve and the San Diego Chapter of the California Native Plant Society who enjoy visiting and working in a variety of open space parks. They have helped out in the San Dieguito River Valley Park, the Sweetwater River Revival, Goodan Ranch, Daley Ranch, Pefiasquitos Canyon Preserve, Torrey Pines State Reserve and Pefiasquitos Lagoon, Marian Bear Natural Park, Tecolote Canyon Preserve, Rose Canyon Open Space, Sabre Springs Wildlife Preserve, Black Mountain Open Space Park, and the privately owned Black Mountain Ranch (future open space). SWAT team members have indicated they enjoy working in a variety of sites.

Where professional staff in a park is too small and a volunteer group not-yet formed and the weed problem is modest, SWAT has taken on the entire eradication effort, such as the successful effort to control *ClfineffYI cardunculus* (Artichoke thistle, Cardoon), *Tamarix ramossissima* (Saltcedar), and *Olea europaea* (European olive) on the 400-acre County of San Diego owned Goodan Ranch.

Most team members have also participated in surveying populations of endangered species such as *Acanthomintha ilicifolia* (San Diego thorn mint). *Pugogyne ahramsii* (San Diego mesa mint), *Monardella linoides* ssp. *viminea* (Willowy mint) and *DueHever variegate* (Variegated dudleya), four species severely threatened by invasive weeds. Such surveys raise the consciousness of activists about the stakes involved in weed control.

In the future SWAT hopes to be able to respond as a 911 weed force to jump on early infestations of particularly dangerous exotics such as the recently observed *Centaurea maculosa* (spotted knapweed) or *Lepitintm latifolittm* (tall white-top, perennial pepperweed).

Recent Advances on the Tamarisk Front

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Abstract

Efforts to control deciduous tamarisk, or saltcedar *(Tamarix* spp.) in the California desert have accelerated impressively during the past 6 years. More riparian habitat has been reclaimed since 1992 than during the previous 20 years, and the future looks equally encouraging. Public agencies engaged in desert riparian restoration work include the Bureau of Land Management (BLM), the National Park Service (NPS), the Inyo County Water Dept., the U.S. Army at Fort Irwin, California Dept. of Fish and Game (DFG), and California State Department of Parks & Recreation. Total committed funding exceeds $1.8 million for the three largest projects -- Owens Valley, Afton Canyon and Anza-Borrego. Desert-wide, over 6 years, more than 4500 worker-days of labor have been invested by agency staff, contractors, conservation corps members and inmate crews.

Early History

Eagle Borax Spring on the west side of Death Valley was the site of the first successful tamarisk control project in California. NPS staff began work there in the early 1970's and optimized cut-stump application methods for herbicide formulations then available. The project was completed in late 1982. Ecological restoration of the spring area was rapid after tamarisk clearance, as shallow ponds of surface water appeared, native grasses and shrubs returned, and mesquite trees regained vitality.

As the Eagle Borax project was ending, a volunteer program sponsored by the Desert Protective Council (DPC) was initiated in cooperation with several area offices of the Desert District, Bureau of Land Management. In 1983 and the first half of 1984, weekend work parties of BLM staff and small volunteer groups achieved visible progress in removing tamarisk at Saline Valley, Fort Piute and Corn Spring, managed by the Ridgecrest, Needles and Indio offices, respectively.

At the same time, volunteer projects were also launched at Afton Canyon and Big Morongo Canyon. then under partial jurisdiction of the Barstow and Indio BLM offices, but these efforts were soon interrupted by a court decision.

In the summer of 1984, tamarisk control on BLM land was halted by an injunction issued by the U.S. 9th Circuit Court of Appeals against herbicide applications on BLM and Forest Service land in the western states. The injunction was prompted by lawsuits against aerial spraying of herbicide on forest lands in western Oregon and northern Arizona.

Although herbicide applications on tamarisk normally are limited to low-volume spot treatments and are indisputably beneficial to the environme»t, the lawsuit plaintiffs refused to grant exemptions for exotic tree removal. Therefore, tamarisk control on BLM land could not resume until an environmental impact statement was written and approved, site-specific environmental assessments were written and approved, and BLM employees gained certification as pesticide applicators. Together, these requirements delayed progress by 8 years; but on the positive side, as a result of the injunction, weed control problems gained a higher profile in the BLM which expedited the ambitious campaigns of the current decade.

After 1984, the DPC volunteer program shifted to non-BLM locations, primarily on land managed by The Nature Conservancy (TNC) and DFG. The major accomplishment of the late 1980's was the successful clearance of tamarisk from palm canyons that cross the Indio Hills -- Thousand Palms Canyon, Pushwalla Canyon, Hidden Palms -- on the Coachella Valley Preserve. Over a 6-year period, this effort required approximately 400 worker-days of labor, with about half from volunteers recruited partly by TNC newsletter. and the rest from TNC staff and juvenile offenders sent by the local court. The project's success was advanced by two days of precision bulldozing in the active flood channel at Thousand Palms, funded by the U.S. Fish Wildlife Service.

Concurrently during this period, the California State Park system became independently active on tamarisk removal, starting in 1984 at Anza-Borrego Desert State Park and 1987 at Red Rock Canyon State Park.

Recent Progress

After 1992 the pace of tamarisk control accelerated as volunteer efforts were largely supplanted by agency programs. One critical component of this increase was the resumption of BLM activity after the 1984 court injunction was lifted. Coincidently, other agencies initiated or expanded tamarisk control work during the same period, as the problems of exotic plant invasions became more widely appreciated.

This report describes currently active and recently completed agency-sponsored tamarisk control projects, in north-to-south order. Historical references are included to demonstrate that desert springs and perennial streams -- focal points for human and animal life — are some of the most ecologically important areas of the California desert.

Volunteer contributions between 1985 and 1997 are listed in the Appendix of this report. In some cases after 1992 these volunteer efforts provided initial impetus to agency projects, but overall the volunteer component has been a minor fraction of the total effort, unlike the decade from 1983 to 1992, when volunteer and staff time were more balanced.

Owens Valley

Most of Owens Valley is owned by the City of Los Angeles and serves as a groundwater storage basin for the Los Angeles Aqueduct, operated since 1913 by the Los Angeles Dept. of Water and Power (DWP).

In the northern half of Owens Valley -- over the 30-mile distance from Bishop to Tinemaha Reservoir -- the Owens River flows naturally though pastures and woodlands that contain dispersed tamarisk trees but few concentrations except around the reservoir. Two miles below Tinemaha Reservoir, the river flow is entirely diverted at the aqueduct intake, below which the original channel is normally dry, or holds stagnant water, and native trees are generally sparse and drought-stressed. Along the lower river channel, tamarisk grows densely in places between the intake and the town of Independence, and otherwise is present throughout the 35-mile distance to the dry lake bed southeast of Lone Pine.

Management of the valley's water resources has long been a contentious issue between Los Angeles and Inyo County, especially since the late 1960's, when DWP increased the aqueduct capacity and initiated large-scale groundwater pumping. Since 1980 Inyo County has been represented on water-management issues by the Inyo County Water Dept., which monitors the groundwater pumping and its impacts on the valley's natural vegetation.

Since 1994, the Inyo County Water Dept. has cleared outliers and small populations of tamarisk from northern Owens Valley, mostly near and between the towns of Bishop and Big Pine. Over 4 years. county employees, with some CDF fire crew assistance, have removed 9000. sizeable trees and uncounted saplings. The investment of labor and supplies amounts to about 250 worker-days and 45 gallon`
Garton 44 herbicide.

Currently the Inyo County program is expanding southward to the central portion of Owens Valley, with significantly increased funding -- $750,000 over three years -- provided by Los Angeles DWP. Tamarisk control is one component of an historic agreement between Inyo County and Los Angeles DWP to restore partial flow to the lower Owens River below the aqueduct intake, as mitigation for groundwater pumping. This agreement was formulated in the mid-1980's but not implemented until 1997, due to legal challenges by environmental organizations and resolution of these issues by amendments to the agreement.

Starting in September 1998, Inyo County will employ 2 full-time and 3 seasonal staff, plus occasional inmate crews, to clear tamarisk from the dry river channel near Independence, in preparation for the restoration of partial flow by year 2002. After the initial 3-year project, Los Angeles DWP will contrihute $50,000 per year for maintenance. Inyo County has also solicited federal financing for this herculean task.

Darwin Falls

Located at the north end of Panamint Valley, the riparian corridor below Darwin Falls was transferred in 1994 from BLM administration to Death Valley National Park. In February 1998, most tamarisk was removed in two days by the "Tamarisk Control Crew" of the National Park Service. This is a group of ten seasonal employees, based at Lake Mead, that works exclusively on tamarisk during the winter months at park units throughout the western states, from California to Texas. The crew has been operational for two years. and is nationally funded so can cross regional district boundaries. Other recent work locations have included Joshua Tree, Mojave Preserve, Lake Mead, Zion, Capitol Reef, Arches and Big Bend.

Previously at Darwin Falls, tamarisk removal via herbicide applications was delayed for years because stream flow is partly diverted to a pipeline for commercial use at nearby Panamint Springs. Before the area's transfer, tamarisk saplings above the intake were manually dug up by a volunteer group in 1992. The NPS crew dug up several additional trees above the intake but one large tree remains. Nonetheless, most of the work has been accomplished and the canyon's ultimate liberation from the tamarisk invasion is within sight.

Salt Creek

Located about 30 miles north of Baker near the highway to Death Valley, Salt Creek is a narrow mile-long riparian zone that joins the Amargosa Channel and then drains into the south end of Death Valley. It was heavily visited from 1830 to the 1870's by horse traders from New Mexico and Gold Rush immigrants from Utah, when it was an important water source on the Old Spanish Trail between Amargosa Canyon and the Mojave River channel.

The riparian zone is flanked by several small springs which fed ponds of water until the 1950's, but the surface water disappeared as Salt Creek became choked with tamarisk. With assistance from the privately funded Los Angeles Conservation Corps, the Barstow BLM staff cut tamarisk around the springs in early 1997, then burned the upper half of the drainage in the summer. Following the fire, in one week the combined spring flow increased from 1 to 11 gallons/minute, and after one month Salt Creek contained flowing water throughout. Wildlife visitation, by wetland birds, raptors, bats and bighorn sheep, increased significantly.

In 1998 tamarisk clearance at Salt Creek is continuing with chain-saw work in the drainage's lower portion. Overall the work is about two-thirds completed, at a cost of about $25,000 for 15 acres. Funding for Barstow BLM tamarisk projects is obtained partly as matching grants from the National Fish and Wildlife Foundation and partly from other sources such as California OHV mitigation funds.

In the central portion of Amargosa Canyon, about 10 miles north of Salt Creek, tamarisk control has been limited to occasional projects of the DPC volunteer program. From 1984 to 1994, this contribution averaged two work parties per year on private and Nature Conservancy land. Here the positive news is that the Barstow BLM office has acquired some inholdings by land exchanges and eventually will be positioned to clear tamarisk from the canyon's entire 8-mile length.

Bitter Spring

Now located within the boundary of the Army's tank warfare training center at Fort Irwin, Bitter Spring is rarely visited by the general public. But during the last century it was an essential water source on the driest portion of the Old Spanish Trail.

Using cut-stump treatments, tamarisk was removed from Bitter Spring in early 1994 by small work crews of the California Environmental Project -- a privately funded conservation corps for young adults. based in Los Angeles. The Army's National Training Center paid expenses and the Barstow BLM staff provided technical guidance. Project completion required about 250 worker-days of labor over a 6-week period.

Similar to Salt Creek, tamarisk removal at Bitter-Spring converted areas of moist ground to a flowing stream, with the accompanying rejuvenation of reed grass and mesquite trees.

Afton Canyon

Since 1991, Afton Canyon has been BLM's "showcase" tamarisk control project in California. in terms of priority, funding and project size. It is located on the Mojave River channel, about 40 miles east of Barstow and several miles south of Interstate 15.

Tamarisk largely replaced native cottonwood and willow trees after heavy flooding on the Mojave River in 1969, and comprised perhaps 85 percent of the biomass at Afton Canyon by the mid-1980's. The Barstow BLM office began clearance work in 1992, following several years of preparation to get the lead environmental assessment written and approved.

Because much of the tamarisk at Afton Canyon forms dense monocultural stands, prescribed fire has been the principle clearance method. Major burns were conducted in the summers of 1992, 1994 and 1998. and a small burn in 1995. Removal by fire has provided rapid, efficient clearance of large areas, with vastly less labor than chain-saw cutting, but it requires increased staff time to treat resprouts by frequent foliar spraying.

Coupled with the prescribed burn program has been ongoing chainsaw work to clear firebreaks around the native trees, remove tamarisk outliers, and clear areas not amenable to burning. In this effort the BLM staff has been assisted by crews from the Los Angeles Conservation Corps, California Environmental Project, and the minimum-security prison at Baker.

Over seven years, the labor investment on tamarisk removal is estimated to be 1800 worker-days, and project expenses amount to about $600,000. The work has yielded 95% control of tamarisk on 350 acres, in a riparian corridor about 1.5 miles long by 0.3 mile wide, **at** the upstream end of Afton Canyon. Average treatment costs are estimated to be $1500 to $2500 per acre, At the current rate of progress, another 5 years or so will be needed to clear the remaining 5 miles of narrow canyon floor in the downstream direction.

Concurrent with tamarisk removal at the upstream end of Afton Canyon, lesser amounts of staff time and money have been directed at planting about 7000 cottonwood and willow saplings in the cleared areas and erecting 3 miles of fencing to exclude trespassing humans, cattle, and off-road vehicles.

Because internal BLM funding has covered a fraction of project expenses, the Barstow staff has become proficient at creative financing, mainly by coupling matching grants from the National Fish & Wildlife Foundation with other sources such as OHV and flood-control mitigation fees.

Surface water persisted in Afton Canyon throughout the drought of the late 1980's, and if the recent tamarisk removal has increased water flow, the change is not casually obvious. But restoration of natural habitat is apparent by other measures: native shrubs such as arrowweed and quailbush and a few mesquite trees have gradually appeared on the dry terraces, infilling the areas between dead burned tamarisk trunks, and the active stream channel is now lush with reeds and grasses, replacing barren sand, due to the protective fencing. After another decade of growth by the planted cottonwood and willow saplings, the restoration of Afton Canyon should be complete.

Camp Cady

Located on the Mojave River channel midway between Barstow and Afton Canyon, property now designated the Camp Cady Wildlife Area was purchased in 1979 by the DFG to preserve riparian habitat. The area was named after the Civil War, in the 1860's, when it was the site of a U.S. Army outpost on the Mojave Road. A wagon road, it linked Prescott and Los Angeles via the Mojave River channel and a series of small springs between Afton Canyon and the Colorado River north of Needles.

Between 1986 and 1992, volunteer groups working at Camp Cady targeted a mile-long section of the active flood channel and adjacent terraces. During that 7-year period, a total of 12 organized groups and additional informal teams cleared out dispersed tamarisk that formed an understory beneath large cottonwood and willow trees. Until the drought of the late 1980's. this section of high-quality riparian habitat included springtime ponds of surface water that collected behind earthen dikes blocking the flood channel. By comparison, in the upstream and downstream directions the Mojave River channel, then largely barren of riparian vegetation, became progressively drier and choked with dense tamarisk.

During the El Nino winter of early 1993. the Mojave River experienced unusually heavy flooding that drastically eroded the channel through Camp Cady. On the negative side, although most large native trees survived, the flood stripped vegetation from the existing channel, erased the earthen dikes, obliterated about two-thirds of the previous restoration work, and deposited large debris piles of resprouting tamarisk trunks along newly formed channel banks. On the positive side, the flood removed perhaps a quarter square mile of dense tamarisk above and below the central area and was a factor in the sprouting of hundreds of cottonwood and willow seedlings in the active channel and the regeneration of the riparian woodland.

Volunteer control efforts after the 1993 flood \vere directed at basal-bark treatment of resprouting debris piles, removal of tamarisk saplings in the new channel. especially near young native trees, and initial clearance of a fire break around a large remnant stand of mature tamarisk on the north bank.

Long-term, the positive news at Camp Cady is that in 1996 the groundwater rights of the Mojave River basin were adjudicated, and as a result the DFG is due to receive several hundred thousand dollars from upstream water users as mitigation for groundwater pumping. These funds will be applied toward purchase of surrounding water rights and for tamarisk control. Following the natural flood clearance, professional contractors should be able to reduce tamarisk populations sufficiently to minimize the impacts on local groundwater levels and the natural riparian woodland.

Big Morongo Canyon

At the northern apex of Coachella Valley, Big Morongo Canyon is a heavily visited BLM area accessed via Highway 62 between North Palm Springs and

Yucca Valley. From Morongo Valley the canyon extends 5 miles southeast, cutting through the west end of the Little **San** Bernardino Mountains. The upper 2 miles of the canyon is heavily wooded with cottonwood and willow but free of tamarisk because dispersed saplings were cut and treated by volunteers before the court injunction of 1984.

Halfway down the canyon, the large native trees thin out and surface water flow decreases. Tamarisk was abundant before it was removed over the past several years. After **BLM's** environmental assessment was approved, on five occasions between 1994 and 1997 groups of 10-15 volunteer workers cleared tamarisk from a one-mile length of the middle canyon. At that rate of progress, completion by volunteers would have required at least 5 more years, so **in** February 1998 the BLM staff brought in a CDF fire crew based in Yucaipa.

Including BLM staff, a total of 18 workers with 5 chainsaws finished the job in 15 days, contributing 270 worker-days of labor. To expedite natural revegetation, the CDF fire crew returned in March and burned most of the large debris piles. Tamarisk resprouts were treated through the summer by BLM staff. In one season the lower canyon was transformed, with vistas of tamarisk thickets replaced by large cleared areas with scattered mesquite trees. For those who worked in Big Morongo Canyon, it will be a pleasure to watch the habitat's expected rapid recovery over the next several years.

Santa Rosa Mountains

On the south side of Coachella Valley, tamarisk has invaded numerous canyons that drain the Santa Rosa and San Jacinto Mountains. Much of the area is BLM land administered as the Santa Rosa Mountains National Scenic Area. Other land owners include the Agua Caliente Tribe,the California Department of Fish & Game, the University of California, and the U.S. Forest Service. Until 1997, tamarisk control was limited to volunteer work on non-federal land.

The principal volunteer project in this area has been in Carrizo Canyon, a steep rocky gorge adjacent to Highway 74 south of Palm Desert. Since 1990, work parties visiting once or twice a year have removed perhaps 85% of the tamarisk on land owned the by DFG and the Royal Carrizo residential community. Also in 1995-96, a large clump of A *rundo donax* was removed using a bushcutter, with Rodeo herbicide applied to the resprouts.

Other volunteer tamarisk projects have been Murray Canyon, **on** the Agua Caliente Reservation (1991-93), and Magnesia Falls Canyon (1994), on DFG land south of Rancho Mirage. For the Carrizo Canyon and Magnesia Falls Canyon projects, recruitment of local volunteers was assisted by the Coachella Valley Mountains Conservancy, which independently has cleared tamarisk from the University of California's Deep Canyon Preserve south of Palm Desert.

The positive development in Coachella Valley is that the BLM Palm Springs office and Agua Caliente Tribe are starting control work on their respective lands. The tribe began to clear tamarisk from lower Palm Canyon in late 1997, and the BLM staff plans to initiate work in upper Palm Canyon and Dead Indian Canyon in late 1998. Presumably, volunteer involvement will continue to be needed on state and private land.

Dos Palmas

Dos Palmas Preserve is a palm oasis on a broad alluvial fan between the Salton Sea and Orocopia Mountains. From the 1860's to 1880's, Dos Palmas was a stop on the Bradshaw Trail which extended from San Bernardino to gold mines near Blythe. Private parcels were purchased by The Nature Conservancy in the late 1980's, but the preserve is now under BLM management.

Tamarisk clearance was initiated in 1991 by three weekend volunteer projects at one outlying palm grove. Starting in 1993, the BLM Palm Springs office brought in 5-man crews from the minimum security prison at Eagle Mountain. The inmate crews have cleared around former commercial fish ponds that arc now managed as wildlife habitat. The BLM staff also has employed a small bulldozer and backhoe on the flat terrain. To date, approximately 80 acres have been cleared of tamarisk, two-thirds by work crews and the rest by power equipment.

Anza-Borrego

Approximately 100 miles of desert washes and stream channels have been cleared of tamarisk throughout California's largest state park. Much of this distance originally contained dispersed trees in normally dry channels, but the total includes sizable thickets in Coyote Canyon, the park's largest drainage. which, in places, carries perennial surface flow.

Cumulatively, the tamarisk control program at Anza-Borrego Desert State Park is the largest in California. The program began in 1984 and was intermittent for 8 years when funding was sporadic: in 1993 it was ramped up to a full-time effort when state financial support stabilized and was augmented by a generous private grant.

Small teams of seasonal park employees performed most of the clearance of dispersed tamarisk and outliers. With 9-month assignments, a two-person crew worked from 1993 **to** 1995 and a three-person crew from 1995 **to** 1997. These crews spent relatively minor amounts of time clearing tamarisk at Salton Sea State Recreation Area and other exotic plants at Cuyamaca State Park.

Additionally at Anza-Borrego, contractors were hired during two winter seasons of 1993-95 to cut and treat the dense tamarisk clumps in Coyote Canyon. This work was coordinated by PestMaster Services, employing crews of 3-4 workers over 3-month periods. With follow-up treatments by the seasonal park aides, more than 75% of the original infestation in Coyote Canyon has been removed, and only a portion of the Lower Willows riparian area remains untreated.

Since 1993, investment in tamarisk removal at Anza-Borrego has amounted to approximately $400,000 for equipment, herbicide and other supplies. and an estimated 2000 worker-days of labor.

Technical Recommendations

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Personal References

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Appendix

Summary of Volunteer Program, 1985-1997

Project Location	Years	Owner/Agency	Volunteer Groups
1000 Palms Cyn.	1985-90	The Nature Conservancy (TNC)	TNC; Orange County Teachers Assn.
Amargosa Canyon	1985-92	TNC	Marina High School
Camp Cady	1986-96	DFG	Soc. Conservation Bighorn Sheep: Boy Scout Troop 419
Hidden Palms	1988	TNC	TNC
Sheep Camp Spring	1988-89	Private	Soc. Conservation Bighorn Sheep
Shoshone Spring	1988-89	Private	
Ash Meadows NWR	1989-90	US Fish & Wildlife	TNC
Can-izo Canyon	1989-95	DFG	Soc. Conservation Bighorn Sheep; Royal Carrizo, Coachella V. Mins. Conservancy
Pushwalla Canyon	1990-91	TNC	TNC
Catalina Island	1990-91	Catalina Is. Conservancy	CA Native Plant Society (CNPS)
Afton Canyon	1991	BLM Barstow Area	
Garlic Spring	1991	NTC Fort Irwin	
Dos Palmas	1991-92	TNC	TNC
Zion Canyon, UT	1991-92	Zion National Park	Unocal Hiking Club
Murray Canyon	[991-93	Agua Caliente Resv.	
Sacaton Canyon, NV	1992	Lake Mead NRA Glen	
Rainbow Bridge, AZ	1992	Canyon NRA BLM	
Bonanza Spring	1992-94	Needles Area BLM El	
Cimarron Spring	1992	Centro Area BLM El	Soc. Conservation Bighorn Sheep
Jacumba Jim Spring	1993	Centro Area BLM	Soc. Conservation Bighorn Sheep
Fort Piute	1993	Needles Area	

Pahranagat NWR, NV	1993	U.S. Fish & Wildlife	
Granite Spring	1993-94	BLM Needles Area	Backroad Explorers
Bear Canyon Four	1993-94	Picacho SRA	Backroad Explorers
Frogs Spring Burro	1994	BLM El Centro Area	Soc. Conservation Bighorn Sheep
Spring, AZ Magnesia	1994	Lake Mead NRA DFG	Backroad Explorers
Falls Cyn. Owens	1994	Inyo Co. Water Dept.	Coachella V. Mins, Conservancy
River Piute	1994	BLM Bishop	CNPS
Canyon Buzzard	1994	Joshua Tree Nat. Park	
Spring Big Morongo	1995	BLM Palm Springs	Soc. Conservation Bighorn Sheep
Canyon	1995-97		Soc. Conservation Bighorn Sheep. Desert Explorers
Condor Canyon, NV	1997	TNC	Desert Explorers
Santa Cruz Island	1997	Channel Is. National Park	CNPS

Control Methods: Biological Control

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Introduction

Most weed control efforts are directed at a specific location and involve careful planning and deliberate action by work parties. These efforts may be required for several years, sometimes decades, before a pest plant is considered under control. Biological control is a different process in that it is not usually site-specific and once initiated, requires little follow-up effort by work parties. Instead, biological control is a regional control strategy wherein natural enemies of a pest plant are introduced with the goal of establishing self-sustaining populations that eventually spread throughout a region. These biological control agents maintain an enduring pressure on a pest plant which, ideally, results in a decline in its abundance over time. Thus, biological control is a slow process and requires several years before its effects may be observed in the field. However, once declines in the pest plant are observed control will usually be permanent.

When some plants are moved from their native habitats on other continents to new areas of habitation **in** North America, they may become aggressive, invasive, and weedy. One of the reasons for this is that they are no longer under the influence of their naturally controlling biological factors. Natural enemies, such as insects and diseases, are among the most important of these biological factors. The search, collection, and introduction of exotic natural enemies of an invasive pest plant is the practice of biological control. It is an ecologically based approach involving the establishment of missing biological influences in the new habitat.

Historically, biological control efforts have been directed at agricultural weeds because of their direct economic impact and strong political support for solutions to agricultural pest problems. Some wildland weeds are also agricultural weeds (e.g., yellow starthistle, diffuse and spotted knapweed, tansy ragwort, Klamath weed) and control efforts of these weeds have benefited from the research directed at them in agricultural systems. More recently, primarily wildland pests (e.g., purple loosestrife and melaleuca) have become targets of biological control programs (Hight 1990: LaRoche 1994).

The amount of control achieved by the introduction of biological control agents can be dramatic. as was illustrated by the control of Klamath weed, *Hyperienth perforatwn,* in northern California. Klamath weed is poisonous to cattle, sheep, and horses, and renders heavily infested pastures and rangeland almost worthless. Control resulted from the importation of the weed's natural enemy, *Chrysolina quadrigemina,* a leaf- and stem-feeding beetle, in 1945. Within tell years, C. *quadrigemina* reduced Klamath weed from an extremely common rangeland weed to an occasional inhabitant of roadsides (Holloway 1964). Currently, Klamath weed exists at less than *1%* of its abundance prior to 1945. Klamath weed had also invaded the Yosemite Valley and was considered a serious threat to the native floral community. *C. quadrigemina* was released in Yosemite National Park in 1950 (Randall 1996) where it quickly controlled the weed and has maintained control thereafter.

Steps in a Classical Biological Control Program

When exotic natural enemies are actually introduced in the field, it is the result of many years of research by biological control scientists. This effort involves searching the weed's native habitat for natural enemies, testing potential natural enemies for host specificity and safety, and shipment, release and establishment in the new habitat. This effort is outlined in six steps:

1. S•lee n **•1111** •pr •te w d ar et. A biological control program requires a large amount of time and funds, and necessitates a wise choice in its target, especially at the inception of the program. The targeted weed must be a significantly important pest, either from economic losses or from

aesthetic or environmental damage, such as displacement of native vegetation. Weeds of relatively minor importance do not warrant the extensive commitment of resources required to establish a biological control program. Potential conflicts of interest should also be addressed at this point. Weeds that are considered quite troublesome for many people can be highly valued by others, such as use of yellow starthistle for honey production, the perceived erosion control properties of iceplant and aesthetic characteristics of pampas grass and water hyacinth. Potential opposition to introducing natural enemies of a weed needs to be addressed at the earliest point. Also, the potential to locate safe, host-specific, biological control agents successfully should be considered early. Many weeds have close taxonomic relatives that are either crop plants or desirable native plants. Large numbers of at-risk plants decrease the odds of locating sufficiently host-specific biological control agents. These concerns and conflicts of interest should be evaluated prior to moving to the next steps.

2. Overseas exploration and testing. Overseas exploration is the collection and identification of all natural enemies of a plant throughout **its na**tive range. Much of this work is currently being done by scientists stationed overseas, through travel with local guides to known locations of the targeted weed. Recognizing significant damage and associating it with the causal organism is a specialized skill. It may take 2 to 3 years of surveys to sample the majority of a weed's natural enemy complex. An additional activity overseas is the completion of some level of host-specificity testing. Host-specificity testing involves a systematic examination of potential biological control agents on relevant plant species. Once foreign exploration is complete, the list of natural enemies are evaluated and potential biological control agents are identified.

   When a natural enemy is identified as a potential biological control agent, host specificity is initially evaluated by examining its host records in its native habitat. If it has been recovered from only the target weed and a few closely related plants (e.g., within the same genus), this suggests that a natural enemy may be host-specific and should be considered as a potential biological control agent. Host specificity is next examined through a series of host-range tests in which the natural enemy is systematically exposed to an array of potential host plants and observed for feeding and reproduction. Host-range testing follows standard protocols that assume that potential bioagents are more likely to feed on close relatives of the target plant, less likely to feed on distant relatives, and unlikely to feed on unrelated hosts. Thus, the selection of plants for testing is based on an ever-widening circle of relatedness. Several plants within the genus of the target plant are tested, then 1-2 plants from genera within the tribe, then 1-2 plants from other tribes within the family, then a few plants outside the family. Most of the initial host testing of agricultural plants occurs in the natural enemy's native habitat in outdoor gardens or in field cages. Testing of California native plants usually occurs in quarantine facilities in the United States to avoid growing our natives in new regions where they can escape and become weeds themselves.

3. Domestic field studies. The target weed is examined in its introduced range for insects and diseases that may already attack it. Occasionally, a potential biological control agent that arrived accidentally can be found already here on the target weed. It makes little sense to continue evaluating an organism for release into an area where it is already present. Additionally, these studies help establish vulnerable life stages for the plant (e.g., there might be a shortage of root feeders but plenty of seed feeders and foreign exploration could then emphasize root feeders).

4. Domestic quarantine studies. Quarantine facilities are used to complete host range testing and other biological studies of potential biological control agents prior to their release in North America. These facilities are designed to contain the organisms during testing and protect the environment from potential damage. These facilities allow the completion of any relevant host range testing not performed overseas, including tests of North American native species, and allow production of a culture of the agent that is free of parasites or disease. In California, this function is usually performed at the United

States Department of Agriculture, Agricultural Research Service's (USDA-ARS) quarantine facility in Albany, California.

5. Release and Establishment. When appropriate host range testing is completed, the data are submitted in a written proposal to state and federal regulatory agencies. The proposal is extensively reviewed by several scientists, including an appointed panel called the Technical Advisory Group, which includes representatives from USDA-APHIS (Animal and Plant Health Inspection Service), USDA-ARS, USDA-Forest Service, U.S. Fish and Wildlife Service, state departments of agriculture, etc. Pending approval by all appropriate parties, the USDA-APHIS-PPQ (Plant Pest Quarantine) will grant a permit for field release. Releases **in** California are made in coordination with the California Department of Food and Agriculture (CDFA) and representatives of the local county's agricultural commissioner, who usually secure the release sites. Release sites are expected to be protected from disturbance for several years to let the biological control agent establish and multiply. The first releases of insects usually number from 100 to 300 per release site, with one to three sites **in** a state. Monitoring of its establishment and distribution of the biological control agent throughout California is performed by CDFA with the assistance of the county agricultural commissioners. The CDFA Biological Control Program monitors the initial release site and determines when a significant level of establishment has been achieved. Once established, workshops for biologists from agricultural commissioner's offices and other federal and state agencies are conducted, where biology and collection procedures are detailed. The biological control agents are field-collected and distributed to counties and public land managers to establish their own nursery sites. This program structure has allowed an efficient and extensive distribution of biological control agents throughout the state.

6 Evaluation and Integration. Evaluation of the success of a program is an essential, although too often ignored, step in a biological control program. Quantifying and documenting the impact of the biological control agent returns the information to the user group -- those who paid for the project. If the program is successful and can be integrated with other control methods, then overseas testing of additional natural enemies can cease. If the biological control agents are not effective, then these studies provide the data needed to ensure renewed exploration and host range testing overseas, particularly with new knowledge of what went wrong and how to correct the procedure in the future.

The Benefit and Risks of Biological Control

Biological control of weeds in wildlands can be an effective control option for many invasive exotic weeds. The advantages are many: 1) once the hioagents establish, they usually maintain control of the pest indefinitely; 2) they can spread to other infestations and bring them under control: and 3) in most cases they do not impact other species noticeably. Biological control may also be the only option capable of bringing certain widespread pests, like leafy spurge. melaleuca, and purple loosestrife, under control over large areas. In addition, many find biological control to be preferable to the use of pesticides because of the danger these compounds pose to other organisms, including humans, and from movement of pesticides offsite into ground and surface waters.

In theory, biological control agents are specific to the target plant and leave the native species alone. Biological control agents can actively search and discover individual target plants among the other plants in a community. They also attack plants that are physically inaccessible, such as on cliffs and steep hillsides. and in road less areas and sensitive environments that might suffer from activities of work parties.

Despite these advantages, there are several disadvantages and risks in a biological control program. First, control results from the addition of an exotic organism. This addition is intended to be permanent. and once released, the exotic organism will be difficult or impossible to eradicate. This permanency requires that the risks, including the direct and indirect potential impacts posed by this organism, be considered as carefully as possible before its release. If a biological control agent does attack economically important species or native host plants, then the advantages of long-term control pressure and its ability to spread throughout a region become serious liabilities. Thus, only organisms with high specificity to the target weed are considered for use as biological control agents.

Host-range testing of potential weed biological control agents began in the 1920's and initially included only agricultural plants growing in the region infested by the target weed. Later, in the 1940s, some closely-related native plants were included but it wasn't until the 1970's that the protocols described in Step 2 above were developed. Some biological control agents released before 1980 have been observed attacking some native plants. For example, C. *quadrigemina,* introduced to control Klamath weed, has been observed to attack other *Hypericum* species, including *H. calycinum,* an exotic ornamental commonly planted along highways, and *H. concinnum* (gold-wire), a native species sympatric with *H. perforatum* in northern California. Pre-release host-specificity tests had produced data suggesting that several *Hypericum* species could serve as hosts for the bioagents (Andres 1985), Approval for its release was made based on the immense benefit over the small but anticipated risk concluded from the testing data (van den Bosch, Messenger, and Gutierrez 1982). For *H. concinnum,* attack by C. *quadrigentina* has been limited to date and the plant is still common in its native habitat (Andres 1985).

Another example *is Rhinocylus conicus, a* seedhead weevil released throughout the United States for control of several *Carduus* closely related thistles. It was first released in California **in** 1971 against milk thistle *(Silybum marianum),* Italian thistle *(Carduus pycnocephalus),* and musk thistle *(Carduus nutans).* Since then, it has been observed feeding on several native *Cirsium* species. The impact of *R. conicus* on native thistles is unknown but is currently under evaluation. All native *Cirsium* species are heavily attacked by native lepidopterans (butterflies and moths) and tephritids (flies), so quantifying impact by *R. conicus* is difficult. However, current research suggests that it can be significant (Louda et al. 1997). It should be noted that, given our current high standard of host specificity, it is unlikely that *R. conicus* would be approved for release today.

Since the 1970's, increased interest in protecting native species and preserving biodiversity has resulted in more complete representation of native and economic plant taxa in host range tests. The results to date have been encouraging in that unanticipated host shifts have not been observed. Still, the potential for host shifts must be acknowledged as all organisms are subject to change through mutation and evolution. Fortunately, this is a comparatively rare event as exotic organisms have just as strong an affinity for their host plant as native species do. Ultimately, the decision to release an exotic biological control agent must result from assessing risks and benefits of the different control options, including the risk of doing nothing. Usually the damage caused by an uncontrolled aggressive weed far outweighs the potential risks of an introduced biological control agent. Gardner et al. (1995) reported that in Hawaii biological control is reserved only for those exotic species so well established that they are uncontrollable by hand removal or other mechanical approaches.

Another disadvantage of biological control is that it is not a solution for all weeds. For some species, safe and effective natural enemies simply may not exist. Some natural enemies exhibit poor survivorship or lack of reproduction in their new area of habitation and fail to establish a strong population. Other natural enemies may not be specific enough to justify their introduction. As pointed out earlier, high host specificity is a primary requirement for a successful biological control program, but it can effectively remove several potential bioagents from consideration and limit the number of natural enemies considered as potential control agents.

Other disadvantages of biological control include the high expense and length of time needed for the development of this control method and the uncertainty of success at the beginning of the project. There is always some uncertainty when working with biological systems and biological control efforts are no exception. Several unanticipated factors can limit success including the use of natural enemies that are specific to only one biotype of the target weed population when several biotypes exist. Finally, an exotic biological control agent may itself be attacked by one or more indigenous natural enemies (e.g., native parasitic hymenopterans) which can severely limit its effectiveness.

Conclusion

The major benefit of a successful weed biological control project, the long-term control of a *weed* throughout a region or watershed, is too great to be ignored. Despite the uncertainty of success and the risks associated with introducing an exotic organism, this form of weed control will likely continue to be explored and promoted. Interestingly, because biological control agents disperse and establish self-sustaining populations away from their initial release sites, all surrounding areas, irrespective of land ownership, benefit from their establishment. Thus, once established, there is no sufficient way to make a profit from selling these biological control agents. Funding for biological control has therefore been principally from public sources and research into biological control has been the activity of university, federal, and state scientists.

For all practical purposes, the development of a biological control agent (exploration, host-range testing, approval, and initial release) has been completed before land managers become involved in a biological control project. The task for the land manager, then, is to determine what biological control agents are available and incorporate them into an overall weed management strategy.

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Mechanical Control Methods: Beyond Weed Bashing

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There's a wild west flavor to the subject of "mechanical control." It brings up images of bold and decisive action that leaves villainous plants stone dead for miles around. It's reflected in the visceral satisfaction that weekend weed warriors feel when they chop, pull or otherwise lay waste to a patch of nasty invaders. This is instant vindication. It is *victory* over the aggressor.

All this is well and good for its motivational value alone. Volunteer program managers and natural resource managers everywhere benefit from the morale-boosting qualities that flow from direct and personal action out in the field that produces visible and gratifying results on the spot.

We should never lose track of this very bright side of mechanical control work, always using it to advantage when possible. But there is a downside. There is a tendency I've noticed in myself and in others to regard hand and power tools as simple devices that don't require a lot of thought about their use. You just get them out and have at it. Or do you? I'd like to get back to that shortly after giving some examples of mechanical control.

Some Examples of Mechanical Control

What scale and kind of project are we talking about?

At the small and personal level, there are examples of very successful hand-pulling. Nothing could be more basic. Pull the plant out by the roots with your own hands and it dies. Along the coast, in San Francisco and north of Santa Monica, volunteers have pulled acres of iceplant by hand, piled it to dry or carted it off site, and have been delighted to see remnant native plants on the dunes regenerate dramatically. Hand-pulling of castor bean *(Ricinus communis)* plants in the riparian corridor has likewise been successful in the canyon country behind San Diego. Oh, if it were always so simple!

One of my favorite examples is that of Torn Ness, the inventor of the Weed Wrench™ tool, who in the late 1980s personally hiked the Marin Headlands north of the Golden Gate to stop an incipient explosion of gorse *(Ulex europaeus)*. He mapped every pioneer gorse plant or population in several watersheds, removed hundreds of plants with his pulaski ax, and kept detailed notes of everything he did. If you go to the Headlands today, you will be hard pressed to find a gorse plant anywhere. Tom's initial work was so thorough, and the maps and notes he left behind were so good, that National Park Service staff and volunteers have been both inspired and guided to do the essential follow-up needed to keep the Headlands gorse-free.

On preserves all over California, preserve managers, paid staff and volunteers are using hand-held power tools such as brushcutters, chainsaws and power trimmers to help control a variety of invasive species. On the desert, chainsaws cut tamarisk *(Tamarix* spp.) trees away and the stumps are treated with an herbicide. Around San Diego, a similar treatment is being applied to other invasive trees including eucalyptus *(Eucalyptus globulus)*, Brazilian pepper *(Schinus terebinthilohits)* and catalpa *(Catalpa bignonioides)*. Brusheutters armed as rotary scythes or saws are being used in the control of mustard *(Brassica* spp., *Hirschteldia Inconel. Sisy,nbrium* spp., et al.), Italian thistle *(Carduus pycnocephalus)*, tocalote *(Centaurea melitensis)*, tamarisk seedlings, *Arundo*, fennel *(FoeniC11111111 vulgare)* and broom *(Cytisus* spp., *Genista* spp., *Spartium junceum)* — both alone and as a preliminary step to herbicide treatment of resprouts.

Still heavier equipment is beginning to be deployed successfully to control wildland weeds. Through a contractor, the Riverside-Corona Resource Conservation District (RCD) is using a four-wheel-drive, r_ib-ber-tired tractor outfitted with a flail mower to mulch acres of giant reed *(Arundo donax)* at a time. The resprouted. In the Bay Area, the Marin Municipal Water District **(MMWD) has** recently purchased its own Caterpillar[Tm] diesel excavator, a wide-tracked vehicle that can work sensitively off-road **on slopes up to 50%.** Rigged with a large rotary brushcutter it is being used to reduce heavy vegetation fuel loads and to control invasive broom.

Then there are special projects like resource manager Dave Boyd's recent broom control project on the once-grassy slopes above Muir Woods at Mt. Tamalpais State Park **in** Marin County. Dave contracted with a professional forest clearing crew to come **in** with their chainsaws and cut down a horrible tangle of dead and living broom plants on about 100 acres of hillside. After the downed broom was well cured, he cleared away the biomass through controlled burning — a dramatic and efficient landscape-level result that he has followed up with additional burns to kill broom resprouts and seedlings.

What would you nominate as the largest project ever to use mechanical control methods in a wildland setting? Mine is the "Blister Rust Wars" — an amazing chapter in the west that people don't talk much about these days. This was, in hindsight, a very ill-conceived though bold effort to save native five-needle pines from the ravages of white pine blister rust — a Eurasian forest fungus accidentally introduced here through a government-sponsored reforestation program. Since the life cycle of the fungus depends on an intermediate host plant, it was reasoned that eradication of the intermediate host would stop the spread of the pine-killing rust. The intermediate hosts, in this case, were all plants in the genus *Ribes* — the native currants and gooseberries of the forests. Thus, from 1940 through 1971 tens of millions of these native plants were regarded as de facto pests and were cleared by forest crews using hand tools and herbicides on public lands throughout the west. In Yellowstone National Park alone nearly eight million native *Ribes* plants were destroyed, but the blister rust survived. The land area covered at Yellowstone was 175,692 acres, the labor expended totaled 57,636 person-days, and the cost in 1994 dollars was over eleven million dollars. This included the cost of 437,000 gallons of the herbicides 2,4,5-T and 2,4-D that were used in the project (Kendall 1998). Thanks to wildlife biologist Katherine Kendall (pers. comm.) of the USGS Biological Resource Division at the Glacier Field Station in Glacier National Park we have these figures — and a lot to think about.

There is a lot to think about in all these examples. They lead me to my main theme today which is that controlling wildland weeds by mechanical means is a *new* technology that needs to grow and mature. Natural area management and habitat restoration are newly emerging fields — and wildland weed management within this context is even newer. Still, we have some inspiring (and sobering) examples. We have learned a great deal in a short time. We have a good deal of information about mechanical control that forms a solid base from which to grow.

Some Lessons Learned

Advantages

We know some clear advantages or best uses of mechanical control. They include:

- Patrolling for and removing pioneer invasive plants — one of the most productive and efficient of all wildland weed control activities;
- Removing scattered pest plants or small populations from a sensitive natural area; the human touch combined with precise application of hand tools or light machinery is hard to beat. Close observations made in the process by field crews are an important element of a good stewardship program.
- Containing pioneer populations of certain invasive species; getting the outliers spreading out from a patch of invaders, pushing back and holding the perimeter of an infestation, or clearing a containment zone around a virulent species like Cape-ivy *(Delairea odorata)* are all examples of mechanical intervention by field personnel that can be extremely valuable parts of an overall control strategy.
- Working in difficult terrain or in a complex plant community where access by heavy equipment or use of chemical controls would be impossible or inappropriate; access by field crews on foot with hand-held tools may be the only practical way to work.
- Using power equipment to implement a cost-effective removal phase before applying another treatment such as herbicide or fire; for example. heavy equipment can grind up an acre of thick *Arundo* canes on flat terrain rapidly, efficiently

and cost-effectively — making herbicide treatment more effective and lowering total project cost.

- Winning public acceptance; mechanical means of invasive plant removal are often more familiar, readily understood and accepted by the general public than fire or chemicals. For this reason, mechanical methods may be preferred when public acceptance is an issue.
- Building a volunteer program and community involvement; hand tools and light power equipment make a great rallying point for a well-managed volunteer program, and therefore offer a way of building a work force for wildland weed control and habitat restoration.

Disadvantages

- Mechanical control is at great disadvantage when the area of infestation to be treated is extensive. It becomes futile and cost-prohibitive, for example, as a primary means of controlling a widespread species like yellow starthistle *(Centaurea solstitialis).*
- Mechanical control by manual field crews has obvious practical limits, especially on the size of area that can be treated at a reasonable cost. If heavy equipment can't handle a larger area, another control method will be needed.
- Physical disturbance inherent in some mechanical techniques can be a distinct disadvantage. For example, fennel may be successfully controlled on a small scale by chopping the roots out with a pulaski but the ground disturbance can perpetuate weedy succession. A method to avoid ground disturbance is to .cut away top growth, let the plant resprout, then selectively use herbicide on the new growth to kill the plant. The use of any tool that uproots plants can have similar limitations.
- Heavy equipment may have unacceptable impacts on terrain or sensitive vegetation, ruling it out as a means of control. The use of heavy equipment may also be prohibitively expensive to some agencies and programs.

And finally, some lessons learned:

Do it with a plan!

Regrettably, many well-intentioned efforts to control wildland weeds fail each year for lack of a plan. Of all the common mistakes, the greatest in my mind is to make no provision, or unrealistic provisions, for follow-up. As Jo Kitz (pers. comm.) says from her experience with CNPS and the Mountains Restoration Trust in the Santa Monicas: "The indispensable ingredient is persistence — and a calendar for going back." If you can't do the follow-up, don't start the project.

Another very common mistake (which of course points to the need for a plan) is failing to establish priorities, both among species to be controlled and within the populations to be treated. This is not necessarily easy to rectify when little is known about the biology of the species you're fighting. For this, you need the best biological information you can get, or at least the best-educated guesses regarding comparative threats of the weedy species. Prioritizing actions on a single species within a treatment area is easier. Start with outliers first, the "foci" of new infestations. Contain the perimeter of established infestations next, and only last remove the main stand. Depending on the species, working from windward or upstream first, then downstream can be extremely important. There is little point to removing an infestation that will be constantly replenished from an upstream source.

In general, there needs to be an overall plan that considers not only the factors just mentioned but many other factors. Start by thinking of the context. Is there something about the hydrology or the cultural conditions of the site that created the conditions for this weed? If so, changing those conditions may be more important than removing a single weed. Based on the best information available, what is the best approach to this weed? It may be that several modes of treatment are needed, and that the timing of each treatment is critical.

Select your technique(s) with great care!

This is where you have to watch the "wild west" syndrome most carefully — that tendency to think of mechanical tools as simple devices that don't require a lot of thought. Because of this, there is a tendency to underestimate the need for critical and subtle thinking. There is also a tendency to ignore the need for careful record keeping and experimentation.

My main advice is to think of a mechanical control technique as a studied intervention based on biological factors. It takes light, soil, moisture, a certain temperature regime, and a number of other factors to make a healthy, living plant. The plant, in turn, makes its living directly through its roots, bark, stems, leaves, flowers and seeds — and through its genetic adaptations. Think **in** terms of interventions that can most effectively disrupt these conditions or processes, and therefore the plant's means of survival.

A good example comes from experience **in** the Bay Area with controlling French broom *(Genista monspessulana).* This species is a re-sprouter. Cut its main stem a few inches above the ground in winter or spring and it will usually resprout. Cut it cleanly with toppers or a saw and its chances of resprouting are high. Shatter the stump with a flail or similar action and the frayed stump will hasten the plant's demise. Best of all, if you cut it right at ground level in late summer when the plant is stressed from drought and from expending its stored energy to set seed, and you cut it with a shattering action (such as from a brushcutter flail head), the plant will nearly always die. It is a matter of studied intervention that can make the difference between success and failure.

Use the best tool for the job!

And if the best tool doesn't exist, invent it. Because the field of wildland weed control is so new, many of the best tools have not even been invented. It was a piece of history in our field when Tom Ness invented the Weed Wrench™ tool and Mike Giacomini invented the Root Jack™. These, as far as I know, were the first inventions specifically brought to market for controlling wildland weeds. These specialized tools relegated to the dark ages some of the tools, such as pulaskis and toppers, that we once used to remove broom. We need more inventions like these. Assuming that you can get along without a specialized tool, there is still the challenge of selecting the best tool. It's painful to see the human frustration and wasted effort that plague field crews and volunteers because they are using the wrong tool or a poorly maintained tool, The right choice of brand, model and material can easily make the difference between success and failure. For example, Ken Moore of the Wildlands Restoration Team in the Santa Cruz Mountains once spent many long hours of shopping and experimentation before he found just the right "sharpshooter" shovel which he uses to uproot broom in one deft shot. Not any shovel will do! Nor will

landscape fabric, or chainsaw. Be picky and exacting about your tools! It will pay tremendous dividends. And keep those tools in safe, excellent condition to protect your precious investment in people and effectiveness.

Know how to use the tools correctly!

This advice almost goes without saying. Even if you have an excellent plan, and you've chosen your techniques and your tools with great care, you can still lose the game by having poorly trained field crews and volunteers. A good training regime, of course, is important not only for the success of your control strategy but also for the health, safety and morale of your field staff and volunteers.

It is good to assume that training is always necessary, even with the most simple tools, and that training must be done in the context of a good safety program, As Mike Kelly (pers. comm.) points out, people need basic instruction to use successfully and safely even something as simple as a pair of toppers. As the level of difficulty or risk increases, so should the rigor of the training. A certification program for advanced took and techniques is an excellent idea - - for the good of the program and the individual volunteer or staff person.

Never underestimate the importance of institutional support!

With the best of intentions, a program of wildland weed control and habitat restoration can flounder like the Titanic if there is inadequate institutional support for the program. I know of important work that didn't happen in the field because the contracting office couldn't get a bid package out in time, of personnel gaps that paralyzed a program for months, of excessive regulations and procedures that inhibit field staff effectiveness, and of failure by institutional management to understand the program mission, and therefore. not to give the program adequate support. And the list goes on.

Always pay attention to the issue of institutional support and do everything in your power to keep it strong and supportive.

Keep science, and hope, alive!

By now, you've heard my emphasis on the newness of our field, the advisability of making carefully-studied interventions using the best techniques and tools, and the need for growth and maturity in the technologies of mechanical control. Few things could be more helpful **at** this point to the evolution of our weed-control technologies and programs than good science.

We know so little about the biology and ecology of many wildland weeds, but we go out anyway and do the best we can, burdened by the feeling that there are so many weeds and so little time. We are often impatient with science because of the rigor involved and the time it takes. But it is rigor and time that we need to be more successful at controlling wildland weeds. When we know the biology and ecology of our target weeds, we will make more intelligent and effective interventions. We will combine methods of control more skillfully. Our timing will improve. Our tools and techniques will evolve and become more efficient.

So I say to everyone here who loves field work: Don't forget to take your scientist along. I mean that literally (if you can swing it) and metaphorically. Be a keen observer of everything you do. Keep careful notes and good records. Take photographs over time from pre-defined points. Learn how to do statistically valid monitoring of your site. Experiment intelligently. Support and involve scientific allies in your work.

And, please, share your successes and failures with your colleagues through CaIEPPC. We have come a long way in a short time. We are headed in the right direction. And we're going to get a whole lot better.

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Chemical Control

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Herbicides are newcomers to weed management. For years land managers used such methods as hand removal, fire, cultivation, chaining, and varietal manipulation in an effort to defeat the invasion of alien species. These methods continue to be a major defense in the struggle with unwanted species, however herbicides can also be useful.

First attempts at the large-scale usage of chemcials started over one hundred years ago. At first very "hard" compounds were used. Salts of arsenic were used at high rates (risking accidental poisoning and soil contamination). High concentrations of salts such as sodium chlorate were used (risking spontaneous combustion and temporary soil "sterilization" until the salts were leached out). Petroleum oils and solvents were used as foliar applications to burn back undesirable foliage (high rates of application resulted in temporary changes in soil environment). These first attempts at chemical management of unwanted vegetation were clumsy by today's standards. High rates of application were used (often several hundred pounds of chemical per acre) and environmental side effects were unacceptable. Today's herbicides are used at much lower rates of application (often in the range of grams per acre) and have been thoroughly screened for undesirable side effects before they are registered for use.

Preemergence or residual herbicides

Preemergence (residual) herbicides are used to control weeds before they emerge. Herbicides such as trifluralin (Treflan), oryzalin (Surflan), and isoxaben (Gallery) are examples of over 30 common herbicide compounds which fit this category. Herbicides like oryzalin are safe to use as a directed spray on many woody perennial species for the control of unwanted annual species. These herbicides are used in the fall or early winter prior to the emergence of weeds. They control weeds after seed germination but before seelling emergence. Most preemergence herbicides require rain or sprinkler irrigation to leach them into the soil for activation. Weeds that emerge while the herbicide is on the surface, before it is activated by rain or irrigation, will not be controlled. Each of these herbicides has a different rate of degradation, some persist in the soil for several weeks — others for several months.

Foliar Herbicides

Foliar herbicides have the advantage that they can target existing unwanted vegetation. The disadvantage of this approach is that often retreatment is required when there is a new flush of weeds. If one depends solely on foliar herbides, as many as three or four treatments may be needed for annual weed control per season.

Of the non-selective, foliar herbicides used, glyphosate (Roundup) is the most common. It is non-selective, killing almost all plants that it contacts. Therefore, one must be very careful to spray only unwanted vegetation. Glyphosate controls a broad spectrum of both annual and perennial weeds. In order to be most effective, weeds should be in good growing conditions and not under stress at the time of application. Annuals are best controlled when small, before they begin to produce seed. Most perennials, on the other hand, are best controlled when they are nearing the flowering or reproductive stage. Higher rates are used for perennials and more than one treatment is usually necessary. A few annuals are not well controlled by Roundup, these include filaree and malva.

Paraquat and glufosinate (Finale) are examples of more rapidly acting, non-selective, "contact" foliar herbicides. Paraquat is effective on small broad-leaved weeds and seedling grasses; however, it is a restricted material and a permit is required for use. Glufosinate is a newer contact herbicide which is also effective on some larger herbaceous species.

Selective foliar herbicides are also available. These herbicides will control some species while not injuring certain desirable plants. The first of these types of herbicides to be used were the phenoxy herbicides. 2.4-D is the leading example. It controls many dicotyledonous species while not injuring grasses. Later, other broad leaf herbicides were introduced. These include triclopyr (Garlon) and clopyralid (Transline). Grass herbicides like sethoxydim (Poast), fluazifop (Fusilade), and clethodim (Prism) are useful in the control of annual grasses such as barnyardgrass and crabgrass, and perennial grasses such as bermudagrass and johnsongrass. The perennial grasses generally require retreatment for control.

Foliar sprays are most often used to apply these herbicides, however, other methods have also been successful. Triclopyr, 2,4-D, and glyphosate have been used successfully as "cut stump" treatments (where the surface of freshly cut stumps of unwanted trees and brush is treated with a concentrated solution of the herbicide). Frill or injection treatments have also been successfully used (tree or shrub bark is penetrated with an ax, knife, or injection device and a concentrated herbicide solution is introduced into the penetrated cambium area). Basal treatments have also been utilized where the herbicide is mixed in a concentrated solution with an oil or solvent and the resultant mix is. painted around the base of unwanted brush species allowing the oil/herbicide to penetrate the bark.

The Down Side

There are some negative aspects of the use of herbicides, particularly their large-scale use on public lands. These include cost, public perception of pesticides, and environmental contamination.

Cost is a major concern. Many of the above herbicides can cost $25 or more per acre per application. If large-scale use is planned, one application could blow the budget. For this reason it is imperative that the right herbicide is used for the weed species present and that is applied so that its effect is maximized on the unwanted species (get the most bang for the buck).

Earned or not, pesticides have a bad reputation among a large portion of the public and herbicides are pesticides. When used improperly over a vast acreage. surface and groundwater contamination are possibilities with some herbicides. Therefore herbicide must be carefully selected (matched to the conditions of the sites where they are to be used). They must be used in accordance with product labels, safely and intelligently. A mistake with a hoe is usually a small one (unless it's your foot) — mistakes with herbicides nay be difficult to correct.

The Combined Approach

Herbicides are just another tool in our arsenal to use against unwanted vegetation. Often they may have no application at a particular site. They may be too costly or offer no long-term benefit. Sometimes. however. they can be extremely useful. When early infestations of an alien species are found in a few isolated spots. herbicide treatment can aid in eradication attempts and be extremely cost effective. Herbicides can also be effective management tools when they are used in conjunction with other management practices. Together they must reduce the competitive ability of invading species and improve the environment for desirable species. Herbicide use only makes sense where long-term benefits can be achieved.

Restoring Habitats to Prevent Exotics

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Abstract

Restoration is practiced increasingly in rural and urban California for conservation and aesthetic purposes. An additional goal of restoration, or revegetation with desirable species, is to control exotic plant species. A stable revegetated site depends on the principle of preemptive competition, where species that already occupy a site prevent other species from colonizing naturally. Exotic pests often colonize a site after disturbance, and then "preempt" the resources of that site and prevent native or desirable species from recolonizing. The goal of the restorationist is to remove or manage the offending vegetation and replace it with desirable vegetation. In principle, competition from the newly established vegetation should reduce the recolonization of exotics. I will present several examples from restoration sites in southern California with varying degrees of successful restoration. For instance, native coastal sage scrub and chaparral shrubs planted on roadsides in California have become stabilized for over 20 years and have resisted weed invasion. However, weedy sites dominated by Mediterranean annual grasses and forbs also remain stable (become type-converted), if they are not restored to native shrubland. Examples will be given of sites where even restoration efforts may prove difficult to minimize weed reinvasion. Restoration sites must be managed to reduce weed reinvasion, just as for natural vegetation.

Introduction

Ecological restoration is practiced increasingly to increase the conservation and biodiversity value of disturbed landscapes, but it can also be viewed as a tool to reduce the incursion of undesirable exotic species. Restoration using native species is done increasingly because exotics have invaded a site and reduced the conservation value or utilitarian value of the site. For instance, the invasion of tamarisk or arundo in riparian sites, and increased the fire hazards and decreased the water table (Jones 1997, Bell 1997). Many efforts are underway to remove both of these invasive species, and allow the natives to recolonize or to replant them. Replacement of exotic species by native species depends upon the principle of preemptive competition, where one vegetation type occupies a site and preempts the resources. The resources include soil nutrients and moisture, light, and space for a seed to land and germinate. Both native and exotic type-converted vegetation may preempt these resources, depending on which occupies the site. Restorationists hope that restored vegetation can also preempt the site, after the offending exotic vegetation has been removed. Whether native, exotic, or restored vegetation have the capacity for preemptive competition depends upon the stability of each of the vegetation types, especially with regard to invasion by other species. Thus we need to explore the concept of ecological stability. Examples of stability will be given primarily for California vegetation types, but especially for coastal sage scrub (CSS). This may be an inherently unstable vegetation type in some areas, that may be more difficult than others to maintain as a native vegetation.

Stability, Resistance and Resilience

Ecological stability is commonly divided into two components, resilience stability, the ability of a disturbed site to return to a pre-disturbance state, and resistance stability or inertia, the ability of a site to resist change in response to a disturbance (Westman 1986). Resistance to invasion by exotics is one measure of stability, and is a function of the vegetation type and the disturbance regime. Resilience is usually measured as the ability of a site to recover naturally, but restoration to a previous condition is another measure of resilience (Westman 1985). Natural vegetation may be able to recover from natural disturbance such as a natural fire regime, but is less able to recover from anthropogenic disturbance that destroys the topsoil and seed bank. This is when restoration must often be done, as the ecosystem has surpassed the ecological amplitude for natural recovery. Mediterranean shrublands have high resilience to fire, as they recover very well after a natural fire cycle (Westman 1986, Westman and O'Leary 1986). However, as discussed below, anthropogenic disturbance is making some of the shrublands less resilient and resistant. The goal of the land manager is to maintain a system that is resistant to invasion by exotics, while the goal of the restorationist is to recreate a system that is also resistant to invasion. Various California vegetation types have different degrees of resistance and resilience, which characterize the intact vegetation.

Chaparral appears to resist weed invasion more than other associated vegetation types including coastal sage scrub, grassland, and oak savanna, so chaparral may be considered relatively stable. In a study on weeds colonizing a pipeline through the Santa Margarita Ecological Reserve in western Riverside County, chaparral adjacent to the pipeline had virtually no weed invasion, while CSS, perennial grassland, and oak savanna had up to 25% cover of Mediterranean annual grasses and forbs (Zink et al. 1995). The difference between chaparral and these other vegetation types is the closed sclerophyllous canopy that is maintained during the summer dry season. Where chaparral has natural openings, it too is subject to invasion. This occurs, for instance, in vernal pool areas of southern California as in lands at the Miramar Naval Air Station, where patches of chaparral shrubland occur on the rises between pools. The edges of the pools themselves are subject to invasion (Zedler 1987), and the annuals occur to the edges of chaparral shrub patches (Stylinski and Allen 1999). Other places where Mediterranean annuals occur in chaparral are in maintained fire breaks, but I am not otherwise aware of weed invasion in closed canopies of chaparral, and consider this a vegetation that is relatively resistant to invasion.

Conversely, California grasslands and savannas have been invaded by exotic annuals since the first European settlers arrived over two hundred years ago (Heady 1977). The native caespitose grasslands were not resilient to intense domestic grazing as are rhizomatous grasslands, such as shortgrass or tallgrass prairie of the Great Plains (Milchunas et al. 1998, Collins et al. 1998). The removal of biomass by grazers is hypothesized to have promoted colonization by Mediterranean annual grasses and forbs (e.g., Heady 1977). Land managers are attempting to restore grasslands and savannas in reserves where grazing has been removed, as discussed in the next section.

Coastal sage scrub is also highly susceptible to weed invasion, as has been especially apparent in the last few decades (Stylinksi and Allen 1999). Previously CSS seemed to be a stable vegetation type that could recover from minor disturbance (Minnich and Dezzani 1998, Allen et al. in press). Most of the historic disturbance was agriculture and grazing. Ranchers have been known to burn CSS to convert it to exotic annual grassland to improve grazing (Burcham 1957). Extensive grazing ended in the 1930's in southern California, but there is no evidence past grazing management caused a permanent type conversion to grassland. Areas that were grazing lands in the 1930's were also still CSS (Minnich and Dezzani 1998). Alternatively, other more severe disturbances to CSS that altered the topsoil and seed bank such as construction, landfills, and tillage caused permanent type conversions to exotic annual grassland (Stylinski and Allen 1999). Sites that were abandoned as early as 1922 still remain in annual grassland, and restoration will be needed to return them to CSS.

A more alarming change in the past few decades is the large scale loss of CSS to annual grassland in the Los Angeles Basin and the Riverside-Perris Plain in areas where there has been no soil disturbance. A re-survey of CSS in the Riverside-Perris Plain using plots from the 1930's Forest Service Vegetation Type Map showed that many CSS areas have converted to annual grassland (Minnich and Dezzani 1998). More shrubland loss has occurred in the urbanized north. Some exotic grasslands in the Los Angeles Basin have been recolonized by native shrubs, but the exotic understory remains (Freudenberger et al. 1987). The reasons for shrub loss and lack of vegetation recovery are multiple (Minnich and Dezzani 1998). Invasion and spread of new exotics since the I 890's may he one reason, as the now-abundant *Bromus marlritensis* and *Brassica geniculata* were not introduced until that time. Fragmentation has increased greatly in the past several decades with increased development, in the urbanized areas, and possibly accompanied by increased invasion into adjacent CSS. Fire has become more frequent in some areas, such as in the Box Springs Mountains and Mt. Rubidoux in Riverside (Minnich unpublished), and has been the major cause of conversion to grassland over 20 years.

However, even CSS sites that have not experienced fire in the past few decades are also losing shrub cover.

Air pollution that brings anthropogenic nitrogen deposition may also be a cause of vegetation change. The major source of N is automobile exhaust that is a source of plant-available nitrate. Up to 45 kg/ha/yr of N are deposited in southern California (Bytnerowicz and Fenn 1996, Padgett et al. [999). Fast growing exotic grasses and forbs may be better situated to take up the N than native shrubs (Allen et al. 1997). Nitrogen is accumulating in soils near urban areas, and may make this vegetation change permanent, or may promote grass dominance as long as N deposition continues. Thus CSS is highly threatened by N deposition, although N deposition is probably greatest in in land areas (Padgett et al 1999). Further work on regional N deposition patterns are needed.

Restoration and Preemptive Competition

Restoration may be viewed as a way to reduce the exotic species that have already invaded native California vegetation types. But restoration will only be a permanent "cure" for weeds if the resultant communities are stable and capable of resisting new invasions. The vegetation types that were discussed above are discussed in a restoration context.

Because there has been so little restoration of chaparral, there is little evidence for stability of restored chaparral. Since undisturbed chaparral is highly resistant to invasion, we might infer that a stable stand of restored chaparral would be so also. However, for any vegetation type during the establishment phase, there is a high probability of weed invasion while planted seedlings are young. Thus while mature chaparral is stable, a recently seeded or planted open community might not be able to resist weed invasion. The best example I know of is highway plantings along 1-15 in San Diego County by the California Department of Transportation that include chaparral species (although not the flammable *Adenostolna fascieulatum!)*. Most of these have some degree of weed invasion (Allen et al. in press). However, as the shrubs mature, older sites up to 18 years have closed in over the understory exotics.

The Nature Conservancy has undertaken restoration of native caespitose grasslands and oak savannas with some success at the Santa Rosa Plateau. This has been accomplished by spring fires to destroy the current year seed bank of exotic grasses (Carol Bell, Robin Wills, TNC, pers. comm.). The native *Nassella* species responded and grew back in dense stands within 1-2 growing seasons. The degree of success of this technique to control exotics varies with the degree of exotic invasion and the amount of remnant native species left, and management must be continued with fire at intervals of every few years. Although spring burning to control exotics in perennial grassland is not a widespread practice, it appears to have promise. Some exotic species will always remain a part of the vegetation, especially the widespread *Erodiuin* species.

The stability of CSS after restoration is questionable in areas that have continued N deposition and frequent fire. CSS is a naturally invasible vegetation type, and will continue to be so even in restored stands. Experimental restorations of CSS were done using continual weed removal during two year studies to assure the success of establishing seedlings (Eliason and Allen 1997, Allen et al. in press). Thus CSS reestablishment on a large scale will require considerable weed management to be successful.

Bowler (1990) has stated that we cannot declare success in CSS revegetation until it has withstood the test of fire. To date that has not occurred: no restored stands of CSS have been burned and then recovered. However, Nancy Storms, a M.S. student from my laboratory has done a CSS restoration study on Mt. Rubidoux that has some exciting prospects for success and future stability of restored stands. Mt. Rubidoux is a city park in Riverside that has been converted from CSS to annual grassland, and is a cause of concern to the neighbors because of the yearly grassfires. During May 1998 a fire passed over her plots burning the surrounding grassland, but leaving her planted shrub plots intact. This indicates that the native shrubs are not nearly as flammable as the exotic grasses. In fact, historically CSS burned on a 25-30 year cycle, while annual grasslands now burn on a 5 year cycle (Minnich, unpublished data). The restoration of critical parklands like Mt. Rubidoux could proceed, but we already know that the grasses will continue to invade. Land managers must take a positive and proactive approach, and use more clever methods to manage the vegetation to reduce exotic reinvasion. For instance, sheep grazed the local CSS until the 1960's in some areas of Riverside, and could be reintroduced as a selective "mowing machine" to keep grass invasion down. Thus replanted CSS alone will not act sufficiently to preempt resources and prevent reinvasion of weeds, but coupled with a program of weed control the local city parks may be able to control fires and increase the conservation value of local parks and other wildlands. Whether such a program will work depends upon the willingness of land managers and citizens to accept a sheep grazing program. This idea is admittedly still experimental, but should be tested to decrease the severe fire hazard associated with exotic grasses.

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Saltcedar Invasion in Desert Wetlands of the Southwestern United States: Ecological and Political Implications

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Introduction

One of the most significant threats to global biodiversity is the invasion of exotic species into natural areas due to human activities and commerce (Clout 1995). Effects of invasive exotic species (weeds) often include the inexorable displacement, or replacement, of native plant and animal species, disruptions in nutrient and fire cycles, and changes in the pattern of plant succession (Randall 1996). Rapid and massive translocation of species around the world through "ecological imperialism" ultimately leads to decreased regionally distinctive biotas and impoverished biodiversity (Soule 1990).

Saltcedar or tamarisk is native to Eurasia and is considered to be a major weed throughout the southwestern United States (Kerpez and Smith 1987; Kunzmann et al. 1989). Several species including *Tamarix aphylla, T chinensis, T parviflora, T ramosissima,* and others (Baum 1967; Crins 1989), were introduced into the United States in the early 1800s for ornamental use, bank stabilization and as windbreaks. Since then, several species have successfully invaded nearly every riparian and wetland system in the Southwest, occupying over 607,050 hectares (Brotherson and Field 1987), including approximately 18,211 ha of pure saltcedar and 20,235 ha of mixed saltcedar along the lower Colorado River below Davis Dam (Younker and Andersen 1986). However, saltcedar is not restricted to the floodplains of southwestern rivers but occupies suitable habitat west of the Great Plains, north into Montana and south into northwestern Mexico (Robinson 1965; DeLoach 1989). The rate of spread has been phenomenal in some areas. Examination of historical photographs led Graf (1978) to conclude that, following its introduction into the southwestern portion of the Colorado River basin, saltcedar spread upstream at the rate of 20 km/year.

There is wide recognition that saltcedar is undesirable from the standpoint of maintaining vigorous native ecosystems (Kerpez and Smith 1987), and the species has the dubious distinction of being included on the California Exotic Pest Plant Council (1996) list of exotic pest plants of greatest ecological concern. The purpose of this chapter is to review the ecological causes of saltcedar's success, the consequences of its success on native ecosystems, and finally to examine some of the political implications of its proliferation. This paper is a contribution to the ongoing debate (Anderson 1996) regarding the control of saltcedar in the context of wetland policies and wildlife conservation.

Saltcedar: invader or opportunist?

The rapid spread of saltcedar throughout the southwestern United States has been facilitated by large-scale modifications of environmental conditions associated with human activity. One such major disturbance was the damming of rivers in the Southwest for flood control, energy generation, and irrigation projects. Natural flooding regimes were changed and floodplain ecosystem characteristics were altered to the degree that **an** exotic species like saltcedar, better adapted to these new abiotic characteristics than were the native species, proliferated (Everitt 1980; Kerpez and Smith 1987; Busch and Smith 1995; Anderson 1996). Another major disturbance was the systematic and widespread removal of the original river floodplain woodlands (which were dominated by cottonwood *(Populus* spp.) and willows *(Salix* spp.) by early pioneers for conversion to farming (Horton 1977; Everitt 1980). Saltcedar is now found in a wide variety of climates and soils where human disturbances have created favorable conditions for its establishment (Brotherson and Field 1987; DeLoach 1989).

Models of weedy plant behavior have been suggested which describe an opportunistic response to disturbance. Baker (1965) proposed that weedy species are characterized by a "general purpose" genotype which does not permit an important role in undisturbed communities, where native plants are more finely adapted, but which allows it to grow and build large populations quickly in habitats that have been disturbed. Grime (1973) suggests that increases in level of stress (e.g., disturbance, management, etc,) in a particular environment yields a corresponding shift in species composition, with species that are more competitive in stressed environments (e.g., saltcedar) replacing those that were more competitive **in** non-stressed conditions (e.g., the original native species). Because it has been successful at exploiting habitats with a wide variety of abiotic characteristics, saltcedar has been described as having a near perfect fit with Baker's (1965) model (Brotherson and Von Winkel 1986).

However, saltcedar is not restricted to areas disturbed by past human activities. In the Colorado Desert, it has now established itself in remote mountain springs, streams and washes, such as Buzzard Spring in the Eagle Mountains of the Riverside County, where no signs of human disturbance are apparent, many miles away from the Colorado River, and sometimes thousands of feet above grazed or cultivated areas (Neill 1985; Neill, pers. comm.). Hobbs and Humphries (1995) suggest that not all weedy species invasions can be attributed to modifications of the ecosystem being invaded. Some cases may represent the exploitation of a new environment by an "aggressive exotic," a term also used by Soule (1990), who acknowledges the same possibility. Under that model saltcedar is thus not only an opportunistic but an aggressive species as well. In parts of Buzzard Spring for instance, saltcedar did not merely become an integrated component of the original plant community of arrowweed *(Pluchea)* and cattail *(Typha* spp.). It became overwhelmingly dominant, altering completely the species composition and yielding nearly monotypic stands of saltcedar (pers. obs.). **In** these cases both alpha and beta diversities are reduced, as suggested by Angermeier (1994). The vegetation of each spring loses its own bi °diversity by becoming more monotypic, and all springs become more similar in their species composition by harboring dense groves of saltcedar.

A series of physiological traits make saltcedar an "aggressive exotic" in an environment where its native pests are absent. First, because of saltcedar's large water uptake and evapotranspiration rates (Kerpez and Smith 1987), the longer a plant community is occupied by saltcedar, the more xeric the area becomes (Brotherson et al. 1984). Saltcedar has thus been found to lower local water tables in Big Bend National Park. drying up springs (OTA 1993). During periods of drought, when the water table may drop below the reach of its roots, saltcedar can continue to thrive by extracting not only free groundwater but moisture from unsaturated soils as well, giving it a competitive advantage over native desert riparian species such as cottonwood and willow (Van Hylckama 1970; Busch et al. 1992). On a regional scale, water use by saltcedar may greatly exceed that of other native plant species (Sala et al. 1996), although evapotranspiration rates vary widely under different environmental conditions (Davenport et al. 1982; Weeks et al. 1987; Ball et al. 1994 and references therein).

Second, saltcedar is very prolific. A single large plant is capable of producing 500,000 seeds per year (Neill 1983). The seeds are produced from April to October,' remain viable for several weeks, are small and easily dispersed by wind, and germinate within 24 hours on moist soils (Kerpez and Smith 1987).

Third, saltcedar is capable of reproducing vegetatively, even when severely damaged. Plants that are cut off above the roots or partially burned are capable of resprouting vigorously (Lovich et al. 1994).

Fourth, saltcedar is resilient to a wide variety of disturbance factors including fire, drought, flood, and high salinity. One study in Utah demonstrated that saltcedar was capable of growing in soils containing soluble salt concentrations of 700-15,000 ppm (Garman and Brotherson 1982). In fact, saltcedar exudes salt from special leaf glands (Hagenmeyer and Waise 1

1988), increasing soil salinity over time, and suppressing the germination of native vegetation (Thomson et al. 1969).

Collectively, the traits outlined above predispose saltcedar to be a vigorous invader of the wetlands of the Southwest (Table I), It is capable of tolerating wide variations in environmental conditions (Brotherson and Von Winkel 1986) unlike many native species. Once established, dense saltcedar groves shade out many native species, thereby affecting their reproductive potential and further contributing to the loss of native biodiversity.

Table 1.

Selected list of potential causes and consequences of saltcedar invasion in desert riparian systems of the southwestern United States. The order of placement in each column is random and individual causes may lead to multiple consequences.

Causes	Consequences
diminished riparian flow rates	stream channel modification
increased soil salinity	diminished value of wildlife habitat
lowered water tables	increased fire frequency
physical soil disturbance	loss of biodiversity
irrigation	increased evapotranspiration
destruction of native vegetation	decreased growing potential for native plants
deliberate planting	elimination of salt-intolerant plants

Consequences of Saltcedar Invasion

Impacts on physical processes and features

Saltcedar infestation often has profound effects on the geomorphology and hydrology of riparian systems. One of the most thorough studies of the impact of saltcedar on the structure and dynamics of streams was that of Graf (1978). He noted that saltcedar trapped and stabilized alluvial sediments causing an average reduction in channel width of 27% (with a range of 13-55%) since the late 1800's on the Green River in Utah. The expansion of stabilized deposits along stream channels decreases the ability of the channel to adjust during high flow events. As a result overbank flooding is more frequent following heavy colonization by saltcedar, even during modest discharges. Sandbars that once developed along sweeping bends of rivers during low water, and were eliminated by floods, are now permanent due to stabilization by saltcedar. Another result of saltcedar invasion has been the development of enlarged and stabilized islands in southwestern rivers.

It is important to note that Graf s conclusions were challenged by Everitt (1979) who concluded that increased sediment inputs into the Green-Colorado River system from natural erosion, dam building, and watershed management were responsible for the observed changes in channel morphology during the period of interest. In addition, Hereford (L984) concluded that changes in the channel morphology of the Little Colorado River in the twentieth century were due more to decreases in average annual precipitation and the frequency of large floods than they were to saltcedar invasion. In response to Everitt (1979), Graf (1979) defended his assertion that saltcedar spread had dramatic impacts on channel morphology but recognized that the impact of other factors should be evaluated in future studies.

Impact of saltcedar on native plant communities

Saltcedar invasion has serious consequences on the structure and stability of native plant communities. The decline of riparian stands of cottonwood *(Populus fremontii)* along the Rio Grande in New Mexico is partially attributable to the invasion of saltcedar. The thick stands of exotic plants along the floodplain have severely limited the number of germination sites that are suitable to cottonwood (Howe and Knopf 1991). Similarly, in the desert region of Australia T *aphylla* is capable of displacing native plant species, resulting in the dominance of native vegetation by a relatively few species of introduced and salt-tolerant plants (Griffin et al. 1989).

The success of saltcedar in riparian ecosystems of the southwest is due largely to its ability to successfully compete with native vegetation. Shafroth et al, (1995) examined the effects of various river salinities on germination and first-year survival on T *ramosissima* and P *frem.ontii* under controlled conditions. Germination of cottonwood declined significantly with increasing salinity but saltcedar was unaffected. The range of salinities tested did not produce significant effects on mortality or above- and below-ground growth in either species. They concluded that increased salinities along river floodplains resulting from evaporation and salt excretion from saltcedar leaves could contribute to declines of cottonwood forests.

Experimental removal of saltcedar from areas in which **it** was codominant with willows allowed increased growth, less negative water potentials and higher leaf conductance in willows (Busch and Smith, 1995). Unfortunately, removal of saltcedar does not always facilitate increased growth or recolonization by native plant species. Anderson (1996) demonstrated that many areas now occupied by saltcedar have soil electro-conductivities in excess of limits that support germination, vigorous growth and survival of native trees and shrubs. His results, and the entreaties of Westman (1990), underscore the importance of evaluating site-specific conditions prior to any revegetation efforts.

A secondary effect of saltcedar invasion is related to increased frequency of fire in impacted areas. The drought-deciduous nature of saltcedar contributes to a heavy fuel load in infested areas, promoting a fire rotation of about 10 to 20 years (Kerpez and Smith 1987; Rosenberg et al. 1991). The fire tolerance of saltcedar coupled with the fire intolerance of many native shrubs (Busch 1995) in the southwestern deserts effectively leads to saltcedar dominance in native plant communities in a relatively short time period (Busch and Smith 1993).

Impact of saltcedar invasion on native fauna

The suitability of saltcedar as wildlife habitat has been a subject of considerable debate. In its native range in the old world **it** may or may not be highly utilized by wildlife for food or cover depending on species. For example,, elephants *(Loxodonta africana)* in Namibia, Africa exhibit a definite preference for the native *Tamarix usneoides* irrespective of plant availability or size (Viljoen 1989). In contrast, seasonal rivers in South Africa dominated by the same species of native *Tamarix* are depauperate in bird species richness compared to drainages dominated by native *Acacia* woodlands (Brooke, 1982). Similarly, in Australia, riparian areas dominated by introduced T *aphylla* show a reduction in the numbers of native birds and reptiles (Griffin et al. 1989) relative to native ecosystems.

In the southwestern United States, outside of its natural range, saltcedar generally provides unsuitable habitat for most wildlife species because neither its foliage nor its flowers (including seeds) have any significant forage value in contrast to native species like mesquite (a notable exception being the fact that the exotic honeybee, *Apis mellifera*, utilizes the pollen). However. from a structural standpoint it does provide cover for some species, particularly birds. For example Mourning Doves *(Zenaida macroura)*, Mississippi Kites *(tellnia mississippiensis)*, and various passerine birds are known to nest in saltcedar-dominated habitats (Glinske and Ohmart 1983; Brown and Trosset 1989; Rosenberg et al. 1991). In fact, Black-chinned Hummingbirds *(Archilochus alexandri)* apparently nest only in saltcedar-dominated habitats along the Colorado River in the Grand Canyon (Brown 1992).

Bird abundance and diversity were compared in habitats with saltcedar or native vegetation along the Mojave River in California by Weintraub (1993). Both abundance and diversity were higher in areas dominated by native riparian plants. However, areas where saltcedar was removed from among native willows and cottonwoods did not exhibit significant differences in bird abundance and diversity in comparison with mixed stands of all three plant species. Weintraub postulated that the decrease in structural diversity caused by removing the shrub layer of saltcedar may have temporarily affected use of the removal area by birds. Rice et al. (1983) determined that saltcedar foliage height diversity was an important determinant of avian community organization, although native plant species were more important determinants.

The value of saltcedar to various species appears to vary geographically. Utilization of saltcedar by birds was high on the middle Pecos River, intermediate on the lower Rio Grande, and very low on the lower Colorado River. Avian use of saltcedar along the Pecos River may be enhanced due to the occurrence of seed producing shrubs and annuals within or adjacent to the exotic habitat (Hunter et al. 1985; 1988).

In an unpublished report, DeLoach (1991 a) summarized literature on the utilization of saltcedar by various non-avian species. Of 13 species of small rodents trapped along the lower Colorado River Valley, only the cactus mouse *(Peromyscus eremicus)* exhibited sonie preference for saltcedar-dominated vegetation types. Data based on rodent trapping on the Rio Grande River showed that of seven vegetation types sampled, saltcedar ranked sixth in density of rodents and fifth in number of species sampled. Reptile densities and diversity were found to be very low in saltcedar vegetation types in the Grand Canyon and on the Rio Grande.

It is important to note that most published studies of the value of saltcedar as wildlife habitat in North America have focused on birds. Purported benefits to selected birds do not necessarily extend to other animals. Additional research is needed on the relationship between saltcedar and other groups of species, including invertebrates, as compared to native vegetation types.

In spite of the value that saltcedar may have for wildlife cover, most authors have concluded that the exotic has little value to native wildlife (Kerpez and Smith 1987; Anderson and Miller 1990; Rosenberg et al. 1991). As saltcedar displaces native vegetation the value of the original habitat is progressively diminished for many native animal species.

Saltcedar and Politics

Water here, water there: mitigating the proposed Coachella Canal lining

Background — In the Dos Palmas Basin, at the northeastern edge of the Salton Sea, conditions for the establishment and proliferation of saltcedar were considerably enhanced when the Coachella Canal was built in 1948. The unlined, earthen canal brought two major landscape changes to the Basin: it created a physical barrier to flash floods, and it created moist soils, surface trickles and pools downslope by leaking nearly 14,000 acre-feet of water per year (USDI 1990; USDI 1993).

The original native perennial plant species of the desert scrub communities, which were adapted to the ephemeral moisture regime of periodic flash floods, lost their competitive advantage in the new environment., as expected under Grime's (1973) model of species composition changes under shifting environmental conditions. Saltcedar, itself much better adapted to perennially wet soils, proliferated. Some of the native species, naturally growing in the wet environment of palm oases, also took advantage of the newly available water. The California fan palm (Washingtonia *filifera)* and salt grass *(Distichlis spicata)* were the two major beneficiaries. More than 800 ha of alluvial fan and alkali sink landscape in the Dos Palmas Basin, originally punctuated with isolated palm oases and previously occupied by native desert shrubs, were replaced by phreatophitic communities dominated by saltcedar (USDI 1990; USDI 1993). The additional water percolating into the basin also made the historically ephemeral Salt Creek a perennial stream, with two thirds of its flow estimated to be from canal seepage (USDI 1990).

Environmental impact determinations and mitigation — In 1988, Congress authorized the Metropolitan Water District (MWD) and the Bureau of Reclamation (BOR) to line 33 miles of the Coachella Canal in Riverside County to prevent the loss of water to seepage each year (USDI 1993). The lining would have two major environmental effects: it would greatly reduce the amount of water seeping from the canal into the Dos Palmas Basin and it would reduce the flow of Salt Creek, most likely returning the stream to natural winter/spring discharges (USDI 1990; USDI 1993).

In the Draft Environmental Impact Statement/Environmental Impact Review (EIS/EIR) prepared by the BOR (USDI 1993) and in supporting documents (USDI 1989) a series of determinations were made. First, nearly 1093 ha of canal seepage-induced phreatophitic vegetation, 890 ha of which are almost exclusively composed of saltcedar, and 162 of which are composed of a mixed saltcedar-palm or saltcedar-mesquite vegetation, were classified alternatively as "wetland community types" and "desert riparian" vegetation. Second, because marsh communities are known to support the Yuma Clapper Rail *(Rallus longirostris yumanensis),* an endangered wetland bird species, a general criterion was adopted by the BOR that the loss of all "wetlands" would be avoided/mitigated. This included pure saltcedar and saltcedar-dominated communities, which account for 78% of all communities designated as wetlands and contain no marsh habitat characteristics. Third, reduction of stream flow in Salt Creek to winter months was determined to have potentially significant impacts to the desert pupfish *(Cyprinodon macularius),* an endangered fish species. The intent of the U.S. Fish and Wildlife Service (USFWS) was well-meaning in that the mitigation measures were intended to protect endangered species and maintain wildlife habitat value at a level similar to prelining conditions (Ray Bransfield, in Litt.). Their intentions were strengthened when Solicitors for the U.S. Department of the Interior decreed that mitigation was necessary (Jim Rorabaugh, pers. comm.).

These determinations set the stage for a series of mitigation measures designed to redress what was perceived and described as negative impacts on wetland habitats and biological resources resulting from the lining of the canal (USDI 1993). Specifically, mitigation measures would ensure that;

1 approximately 279 ha of private lands would be acquired and transferred to a resource agency to

mitigate for the loss and degradation of 840 ha of pure saltcedar and saltcedar-dominated communities with a combined "Habitat Unit" value of 10,358 to be mitigated at a rate of one ha per 6.07 Habitat Units,

2 as much as 7,125 acre-feet of water per year would be appropriated, from existing artesian wells, canal diversion, and new wells drilled on public lands, to maintain existing marshes, create new marshes near Dos Palmas and ensure a perennial water flow through Salt Creek.

Another ecological scenario — From an ecosystem viewpoint, the two "impacts" of the canal lining (demise of saltcedar communities and yearly drying out of Salt Creek) might be considered beneficial to the Dos Palmas Basin for the following reasons. First, an artificial water input would be taken out of a desert environment, returning soil water regimes to more naturally low and restricted levels, and potentially allowing native plant species, in time, to re-occupy the alluvial fan slopes, desert washes and streams now choked with saltcedar. It is important to note, however, that locally high soil salinities (Anderson and Miller 1992) would likely persist, and surficial flow would still be limited by the canal and associated flood diversion structures (Schlesinger et al. 1989) following canal lining. These impediments to restoration of a more natural system need to be addressed. Second, a noxious exotic plant would be denied its life support, thereby reducing the cumulative input of its seeds into a region already affected by its widespread establishment (Lovich et al. 1994). Third, an ephemeral desert stream would be returned to a more naturally intermittent hydrology. The endangered desert pupfish, whose life-cycle is adapted to life under stressful conditions (Schoenherr 1988) would experience more natural flow regimes in its habitat. Fourth, since the artesian wells on which the native oases depend are hydrologically isolated from canal leakage waters, these oases would not be greatly affected (USDI 1993) by the lining. The California fan palm, now occupying large expanses of contiguous artificial "wetlands" alongside the canal, would be confined, once again, to discrete palm oases, as it is naturally (Vogl and McHargue 1966), perhaps with beneficial long-term genetic diversity consequences.

The politics of wetland restoration vs. the politics of weed control —The determination that the canal lining would have overwhelmingly negative impacts on resources and the water-intensive approach to mitigate these impacts is not supported by a thorough ecological analysis. Long-term ecosystem functions and sustainability were not assessed. Instead, immediate and indiscriminate replacement of ecosystem parts are proposed, in a mechanistic rather than holistic approach, and with a political, rather than ecological, underpinning. Much confusion is created by the indiscriminate use of the terms "wetland" and "riparian" to describe any plant community that grows in wet soils, regardless of its exotic character, its ecosystem dynamics, its biodiversity, its own impact on surrounding native communities or its long-term sustainability.

Under the current official definitions of "wetland" and "riparian areas" this confusion is unfortunately possible. Executive Order 11990 of May 1977 (the "Protection of Wetlands Act") defines "wetlands" as "those areas that are inundated by surface or ground water with a frequency sufficient to support and under normal circumstances does or would support a prevalence of vegetative or aquatic life that requires saturated or seasonally saturated soil conditions for growth and reproduction" and the Bureau of Land Management defines a riparian area as "an area of land directly influenced by permanent water . . [and which contains] vegetation dependent upon free water in the soil" (USDI 1991). The Order directs all federal agencies to "take action to minimize the destruction, loss or degradation of wetlands and to ... avoid undertaking or providing assistance for new construction located in wetlands unless the head of the agency finds . . . that the proposed action includes all practicable measures to minimize harm to wetlands which may result from such use." However, Executive Order 11990 also directs that "In making this finding [to minimize harm to wetlands] the head of the agency may take into account economic, environmental (emphasis added) and other pertinent factors." Analysis of naturalness, ecosystem function and long-term wildlife species habitat value could be addressed under this latter section of the order, and could impart some ecological reasoning into an otherwise very political and administrative requirement. Executive Order 11987 of 1977 on exotic organisms also instructs government agencies to restrict introduction of "exotic" species into U.S. ecosystems. Unfortunately this directive has seldom encouraged a comprehensive analysis of resource management projects by affected agencies (OTA 1993).

In the case of the proposed Coachella Canal lining a decision was made to restore artificially created and maintained wetlands dominated by an exotic pest plant. But does it make sense ecologically or politically? Short of systematically asking that question, noxious species like saltcedar may benefit from ill-conceived wetland restoration projects.

The Southwestern Willow Flycatcher Story and Efforts to Initiate Saltcedar Biocontrol: pitting an endangered species against ecosystem restoration.

Background — The Southwestern Willow Flycatcher *(Empidonax traillii extimus)* was listed as a federally endangered species on February 27, 1995 (USFWS 1995). The subspecies is widely distributed in scattered remnant breeding populations in southern California, Arizona, New Mexico, western Texas, and portions of Nevada, Utah and northwestern Mexico; a range that is largely coincident with the southern range of saltcedar. As its name implies, the breeding and foraging habitat of the bird is associated with riparian woodland communities supporting dense stands of willows, arrowweed, *Baccharis,* and saltcedar. Historically, the species nested in willows, *Baccharis* and other riparian shrubs situated in dense plant communities that were typically even aged and structurally homogeneous. Although the Southwestern Willow Flycatcher continues to nest in native plant communities, they are known to nest in areas dominated by saltcedar (USFWS 1995) and therein lies the problem.

The biological control controversy — The procedure for release of biocontrol agents is a rigorous and highly scientific process. Efforts are made to identify control agents that 1) will damage the target species sufficiently to reduce growth, survival or reproduction, 2) whose host range is narrowly restricted to target species and its close relatives, and thus are unable to complete their life cycle on other critical test plants (Huffaker 1957; Zwolfer and Harris 1971; DeLoach 1991b). After nearly ten years of testing the United States Department of Agriculture, Agricultural Research Service (ARS) has identified two insects (manna *mealybug-Trabutina mannipara* and saltcedar leaf *beetle-Diorhabda elongata)* for release that would add a valuable tool to the arsenal of integrated weed management aimed at saltcedar (DeLoach 1989; DeLoach et al. 1996a).

Recent efforts by the ARS to release insects for the biocontrol of saltcedar have been questioned by those concerned that such a release would be injurious to the continued survival of the endangered Flycatcher and other birds that occupy saltcedar-dominated riparian areas (DeLoach et al. 1996a, b). In our opinion, these concerns, while well-meaning, deserve additional discussion for the following reasons.

First, it is extremely unlikely that a small number of biocontrol agents would eliminate saltcedar as there is no historical precedent for a control agent eliminating its target host in attempts to control 50 weed species in North America and Hawaii over the past 94 years (Goeden 1978; Harris 1988; DeLoach 1991b; Julien 1992). Many species of insects and pathogens affect saltcedar negatively within its native range and yet it manages to survive there. Introduction of a small fraction of its natural enemies is intended to assist in control by limiting rates of expansion. As host densities decrease, so will the density and efficiency of the biocontrol agent. This is not to say that the release of biocontrol agents is not without risk. However, in light of the known negative impacts of saltcedar on native ecosystems, the risk of not releasing biocontrol agents is potentially much greater than the risk of release.

Second, concern for the Southwestern Willow Flycatcher ignores the plight of numerous other legally protected and sensitive species that are negatively affected by saltcedar. We, like others, believe that the key to conservation of biodiversity rests with the preservation of natural habitat (Lovich and Gibbons, in press). To this end, Murphy et al. (1994) noted that "Conservation strategies that try to restore and maintain natural habitats offer greater promise than strategies that attempt to conserve species apart from their habitats. Habitat-based strategies also increase the chances that other species occupying the same areas will not become endangered." A debate on the shortcomings of the Endangered Species Act is beyond the scope of this paper, but it is worth noting that others have criticized the Act for protecting high-profile individual species rather than overall biodiversity (Rohlf, 1991). The predicaments of several native species inhabiting saltcedar-dominated habitats are highlighted below, but the impacts of saltcedar on other species are poorly known, if at all.

Known and suspected impacts of saltcedar on sensitive animal species — Some wildlife managers consider saltcedar to be a threat to populations of desert bighorn sheep (pers. comm.). The "Peninsular Ranges" metapopulation of bighorn sheep (Ovis *cana-*

densis cremnobates) is proposed for listing as an endangered species under the Endangered Species Act (USFWS, 1992) and is protected as threatened by the state of California. Bands of these animals are totally dependent on a steady supply of water from a limited number of small and isolated water sources. Many of the natural springs are infested with saltcedar and the high rate of associated evapotranspiration can reduce or eliminate the flow required to maintain a band of sheep (Bill Neill, pers. comm.). In addition, the unnaturally thick saltcedar groves that form around desert water sources can conceal large predators such as coyotes *(Canis latrans)* and mountain lions *(Fells concolor)*. Literature reviewed by McCarty and Bailey (1994) suggests that bighorn sheep prefer habitat providing the least visual obstruction of vegetation since they cannot effectively detect or evade potential predators in dense plant growth.

Another animal associated with desert springs is the desert slender salamander *(Batrachoseps aridus)* a federally endangered species. Discovered in 1969 (Brame 1970), the salamander is known from only two small springs in the upper Colorado Desert ecosystem near Palm Springs, California. It is the only salamander in the world whose entire range is completely surrounded by a hot desert environment. As such, it is totally dependent on the maintenance of a steady supply of water from its spring habitat. On a recent visit to the type-locality for the species, it was noted that saltcedar had not yet invaded the site. However, the prospects for invasion are excellent as saltcedar is well-established nearby. If saltcedar does infest the site the continued survival of an entire species may be at risk. In this case an exotic pest plant has the potential to cause the extinction of a vertebrate species.

The western pond turtle *(Clemmys marmorata)* is also affected by saltcedar and an isolated population in the Mojave River of California (Ernst et al. 1994) is at particular risk. As a semi-aquatic species living in an ephemeral desert river this population faces severe challenges when flows are reduced. The Mojave River is heavily infested with saltcedar (Lovich et al. 1994) which alters stream morphology by contributing to sediment accumulation (Graf 1978). The impact effectively limits the pool habitat utilized by pond turtles (pers. obs.). The pond turtle is a former Category 2 species under the Endangered Species Act (USFWS 1994) and is protected by the state of California, Similarly, the desert pupfish and its allies have been negatively affected by saltcedar invasion in desert wetlands (Schoenherr 1988).

Does the Southwestern Willow Flycatcher need saltcedar to survive? It is logical to ask the question of whether or not saltcedar control efforts will have a significant impact on the survival of the Southwestern Willow Flycatcher? The ARS is currently preparing an Environmental Assessment for evaluation by the USFWS. If the ARS determines that biocontrol "may affect" endangered species like the Flycatcher, then the USFWS must render a biological opinion on whether, or not, biocontrol would jeopardize the continued survival of those species. If a jeopardy opinion is rendered by the USFWS, then reasonable and prudent alternatives may be developed that would be mandatory and could include major changes to the program. An additional concern is the fact that the plant Frankenia johnstonii, an endangered plant in Texas and Mexico that is closely related to the genus *Tamarix*, may be negatively affected by the release of biocontrol agents. However, data collected by ARS suggests that F. johnstonii occurs south of the climatic range, and certainly the preference, of *Diorhabcla* (Jack DeLoach, pers. comm. and in litt.).

When viewed in the broadest context, it is obvious that the bird did not evolve in association with saltcedar and thus would be best adapted to native plant communities. However, in the modern desert southwest landscape, where native plant communities are increasingly rare, proponents of the Southwestern Willow Flycatcher and other birds suggest that saltcedar-dominated landscapes are necessary for bird survival (Anderson 1996). It may be that the Flycatcher and other bird species are effectively utilizing saltcedar woodlands, and that saltcedar control efforts would cause some temporary avian population declines. But, what are the ecological costs of not controlling the saltcedar invasion, particularly to native plant communities supporting many other species? We maintain that the costs of ignoring the continued expansion and dominance of saltcedar are very high, particularly to other species and the habitats on which they depend.

We are not advocating pitting the survival of one species against that of another. Value-laden anthropocentric constructs of species importance that ignore broader ecological issues are driven largely by emotions and politics. But we note that it is more than a little ironic that saltcedar infestation is considered to be one of the factors that contributed to the "loss and modification of Southwestern Willow Flycatcher habitat" (USFWS, 1995) and the need to list the species as endangered in the first place. The expansion of saltcedar corresponds with the decline of the Flycatcher and the bird is generally absent where saltcedar has replaced native vegetation (USFWS, 1995). Given the track record of saltcedar, efforts to control its spread should be given high priority.

Conclusion

Central to recent discussions of the effects of saltcedar on biodiversity is the question of whether it is a cause or a consequence of deteriorating habitats. Available evidence suggests that saltcedar can be both a cause and a consequence (Horton 1977; Anderson 1996) of habitat degradation, with the relationship varying from one site to another. Irrespective of the answer, the presence of saltcedar in riparian habitats of the southwestern United States is a warning sign that something is wrong with the ecosystem. Replacement of saltcedar by native plant species will require identification and correction of the environmental factors that favored the invasion of saltcedar in the first place (Anderson and Miller 1990; Anderson and Miller 1992; Anderson 1996). Unfortunately, an area dominated by saltcedar is likely to remain so unless altered by natural cataclysms or man (Kerpez and Smith 1987). Recent experimental release of water from Glen Canyon Dam on the Colorado River by the federal government demonstrates a heightened awareness of the need to address riparian restoration at large scales.

The contention of some (Anderson 1996) that present environmental conditions render restoration of saltcedar-dominated habitats impossible is not always correct. Even badly disturbed areas along the lower Colorado River show the promising effects of revegetation efforts. Andersen (1994) studied the demographics of small rodent populations five years after saltcedar was cleared and replaced with cottonwoods and willows. The high biomass of rodents suggests that such sites may be important in ecosystem functioning by providing source habitat, material processing capabilities of associated fauna, and high prey abundance supporting higher trophic levels. The success of others in controlling or eliminating saltcedar in sensitive natural areas other than the lower Colorado River is discussed by Barrows (1993), Sudbrock (1993), and DiTomaso and Bell (1996).

Invasive phreatophytes such as saltcedar have serious impacts on community structure and dynamics, and on ecosystem functions. While it may be difficult, given current trends in trade and travel worldwide, to defend and protect the ecological status quo (SoulE 1990) the characterization of artificial wetlands dominated by invasive phreatophytes as "desert riparian" and "wetland" communities is ecologically flawed.

To systematically implement the "Protection of wetlands" policy of Executive Order 11990 without engaging in an ecological cost-benefit analysis of the community dynamics and ecosystem functions involved may, in the long run, contribute to a loss of community and landscape biodiversity by protecting loci of exotic, weedy species well adapted to establish themselves in artificially created wetlands and prone to invade natural desert riparian areas from those loci under the right environmental conditions. Ecological restoration, if applied without a long-term goal of restoring native communities and landscapes, or protection of exotic plant species as habitat for endangered or charismatic native animals, may become instruments of ecological degradation for achieving political rather than ecological objectives.

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Perspectives on Disturbance, Invasion, and Management

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In light of recent events such as the 1997-98 El Nino, there is great interest in the role of large scale and 'catastrophic' disturbance in promoting invasion by exotic plant species. However, disturbances at all scales are a natural feature of our landscape and both small and large scale disturbances can promote invasion by exotic species. It is therefore important to understand what aspects of the disturbance regime are important in influencing both native and introduced species and which types of disturbance do or do not promote invasion in the California landscape. In order to manage for native species and against exotic species we must know a great deal about the regeneration responses and availability of propagules of both native and introduced species over time after disturbance and the necessity for immediate management action after a disturbance event. In this talk I will present examples of how disturbance can promote invasion at all scales and discuss research questions that might help us to manage the response of ecosystems to disturbance in this ever changing world.

Protecting Volunteers and Yourself; Issues of Safety and Liability

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Since the late 1980s agricultural work has been regarded as the most hazardous in the nation, with an occupational death rate surpassing even that for mining by 1980. Agricultural work involves exposure to a wide variety of hazards. Emergent national priorities reported by the National Institute for Occupational Safety and Health (CDC, NIOSH, 1991) include: lung diseases, musculoskeletal disorders, cancer. traumatic injuries, cardiovascular diseases. reproductive disorders, neurotoxic disorders, hearing loss, dermatological conditions, psychological disorders, and infectious diseases. When numbers and types of injuries and illnesses are tabulated it is clear that by far the most severe non-fatality problem involves injuries. California agricultural workers experience some 20,000 work-related injuries each year. Of these the most numerous and most costly are back injuries. Agricultural work also involves exposure to higher risk of fatal injury than most other occupations. Primary among reported causes are motor vehicles, tractors and equipment.

Because of the high risks and high fatal and non-fatal injury rates involved in agricultural work in California, California OSHA has designated it a high hazard industry subject to special regulatory and educational attention. Nonetheless, there is reason to believe that most persons working in agricultural jobs underestimate the risks of injury involved. The high rate of injury is largely accepted as normal. Supervisors and workers need to recognize that standing CA-LOSHA regulations apply in agricultural workplaces and that both supervisors will be held liable for both unsafe conditions and unsafe work practices reported or discovered in their operations. Most common agricultural work-related injuries and illnesses can be readily prevented by informed and responsible supervisors and workers.

Distribution and Effects of Exotic Species in Tropical Island Environments in Sri Lanka

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The distribution and effects of exotic plant species in the tropics have some similarities to the situation in temperate zone California but there also exist important differences. Sri Lank, approximately 1/6 the size of California, is a tropical island with very diverse environments. The Sri Lank flora contains 26.4% endemic species, but over 25% of the flora is exotic species. Some invasive species have broad distributions and occur in tropical Sri Lanka and also temperate California. Others (like *Arundo donax)* due to their evolutionary history do not behave invasively in both.

There is great variation among habitats in the degree of impact of exotic species in Sri Lanka. Physical conditions are changed by invasive plant species particularly in aquatic environments. Exotic species im pact Sri Lankan environments in several ways. I multispecies stand of exotics often displace native species; 2. native forage species are heavily impacted which decreases native fauna; 3. decreases in native forage species results in human-faunal conflicts; 4. biodiversity changes in some environments are subtle but farreaching. Solutions are few and economically rarely feasible. What should the industrialized world be doing to help mitigate these problems?

Poster Titles and Abstracts

Reproductive Biology of Yellow Starthistle *(Centaurea solstitialis):* Maximizing Late Season Control

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Field and growth chamber experiments were conducted to determine the reproductive potential and phenology, seed viability and germination, and overall seedbank longevity of yellow starthistle in the Central Valley of California. Seedheads contained an average of 79 achenes and a mean ratio of eight pappus-bearing achenes for every non-pappus-bearing achene. Viable seeds did not initially develop until the late corolla senescence stage, eight days after flower initiation. From a field perspective, initial viable seed production corresponded to approximately 2% flower initiation of total spiny heads. Over 90% of the developed seeds germinated under growth chamber conditions one week after seedheads reached the dispersal stage. This suggests that most yellow starthistle seeds have no significant after-ripening requirements. Under field soil conditions, yellow starthistle seed germinated from January (planted) to early June, and germination closely corresponded to rainfall events. A total of 92% and 88% of the pappus-bearing and non-pappus-bearing achenes, respectively, either germinated or degraded after one growing season. In the second season, an additional 7% of pappus-bearing and 9% of non-pappus bearing seeds germinated. After two years, 99% and 97% of the pappus-bearing and non-pappus-bearing achenes, respectively, were accounted for. This suggests that the longevity of viable seeds may be relatively short under normal Central Valley field conditions in California. These results will be important to the proper timing for late season yellow starthistle control methods and to the development of long-term sustainable management strategies in California grassland ecosystems.

The Use of Molecular Systematics to Enhance the Biological Control of an Invasive Plant Complex *(Tamarix* or Salt Cedar)

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Successful biological control of invasive species depends on accurate taxonomy and information on population origins. Biological control research faces the following problems associated with invasive *Tamarix*.

Problem #1. Uncertain taxonomic status of invasives can reduce effectiveness of searches for biocontrol agents in the plant's native habitat. Tamarix is considered a very difficult genus taxonomically due to its lack of distinctive macroscopic features. Most of the 54 currently recognized tamarisk species are virtually unidentifiable in the vegetative state. Even fertile specimens are often confused and debated over by *Tamarix* specialists. We need to know how many taxonomic entities currently exist in the U.S. and Eurasia. and their invasive status.

Solution: The use of molecular markers is a powerful tool to test hypotheses of taxonomy based on morphological characters. Vouchered DNA samples are currently being collected for nucleotide sequence analysis. Candidate genes include the internal transcribed spacer (ITS) between the nuclear ribosomal genes 18S and 26S, and the trn region of the ehloroplast genome. Molecular variation within U.S. and native Eurasian populations of invasive entities (such as T *lamas's-sima)* and geographically overlapping, morphologically similar Eurasian species will be analyzed. Species consistently falling within the lineage formed by T *ramosissima* will be suggested as potential sources of biological control agents. (The invasive entities T *parviflora* and T *canarieusis* will also be investigated in a similar manner.)

Problem #2. Invasive *Tamarix* entities may be hybrids of previously disjunct Eurasian species.

Solution: Initial morphological observations show

no evidence of this event, but since hybrids retain molecular characters representing elements of both parental genomes, hybridization may be detected by molecular methods. The incongruence between phylogenies (family trees) reconstructed from independent data sets (the nuclear and chloroplast genomes), or incongruence between taxonomic status and phylogenetic status (when a taxon shows sequence variation that gives it multiple positions in the phylogeny) can suggest hybridization. A hypothesis of hybridization may be further supported by geographical data, if suspected hybrids are geographically intermediate to their parents.

Problem #3. Initial common plot tests show that biological control agents have differential effects on geographically distinct T *ramosissima* populations in the U.S., suggesting that *T ramosissima* may represent a collection of genetically diverse populations from Eurasia.

Solution: DNA collections from populations across Eurasia and the U.S. are being gathered for candidate T *ramosissima* taxa. Geographic origins of invasive populations may be determined with molecular methods by comparing gene sequence data for native and invasive populations. This investigation uses phylogenetically informative, ordered data from the nuclear gene gpd (as opposed to RAPDs or restriction site data) which have the added bonus of estimating relationships, not just similarities, between populations. Information on evolutionary relationships can provide additional insight, as biological control agents may have co-evolved with plant host populations, and increased relatedness of plant populations may enhance the odds of sharing a common effective biological control agent.

Phylogeographic analysis (structure of the geographic information plotted on a haplotype tree) will be able to discern between the following four scenarios:

I) Invasive entity has one Eurasian origin.

2) Invasive entity contains populations originating from different Eurasian locations with no gene flow between U.S. populations after invasion .

3) Invasive entity contains populations originating from different Eurasian locations with gene flow between U.S. populations after invasion.

4) Eurasian populations representing invasives were subject to gene flow (or lineage sorting) before invasion.

In the case of scenarios 1 or 2, studies of population structure will be able to geographically focus biological control searches. In the case of scenario 3, origins of the parental types of the invasive may be discernible, but the biological control agent may be less effective on the new invasive genotype. In the case of scenario 4, population specific biological control agents may not be discernible via this study.

Fire Effects on First-Year Scotch Broom in Redwood National and State Parks

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Restoration of native species to the parks' grasslands is a goal outlined by Redwood National and State Parks. Scotch broom *(Cytisus scoparius),* a nonnative shrub, has become a serious pest on the northern California coast. It becomes established initially along the roadsides before invading the adjacent grasslands which it can quickly convert into brushfields. At an age of two or three years, the plant produces flowers and abundant, hard-coated seed which can remain viable for decades. Since 1993, Scotch broom has become systematically pulled from the Bald Hills prairies of Redwood National Park. In an effort to speed germination and deplete Scotch broom seed from the soil the seed beds have been burned in conjunction with prescribed burns. In dense patches that burned poorly. we piled brush on seed beds to increase fuel loading and bum temperatures. Douglas-fir limbs cut from nearby trees that had invaded prairie areas was used as fuel. This approach has reduced broom densities in some location, however, dense patches of seedlings continue to emerge in areas that burned cooler. Scotch broom removal has proved to be costly and difficult. Park staff have noted that when some plants are cut at the base or burned, they quickly resprout, flowering and producing seed the same year. Optimization of burn protocols is needed to properly examine the effects of fire on first-year Scotch broom. It was hypothesized that the fuel type, soil moisture, and plant size might influence whether or not plants survive.

In the summer of 1997, prior to burning, 20 transects were established to evaluate the burn effects on first-year Scotch broom. Treatments included 6 drygrass transects, 6 brush-pile transects to increase fire intensity, 6 water-soaked transects to simulate 7.5 cm of rain, and 2 foamed transects to protect from direct flame. Six hundred individual Scotch broom plants were tagged with nails and numbered brass tags. Results of April 1998 monitoring showed that brush-pile plots produced the greatest Scotch broom burn response (there was no evidence of growth/resprouting in 98% of tagged individuals). The only tagged individuals that survived in brush-plots were where the brush failed to burn. Evidence so far suggests that the brushing provided a total kill of existing plants. In dry-grass plots 82% of the tagged individuals exhibited no growth/resprouting. Mortality in dry-grass plots was greatest with backing fires. The soaked plots were saturated 3-5 days prior to burning. Even with the presence of subsurface moisture there was no evidence of growth/resprouting in 87% of tagged individuals. The foam treatment was intended to serve as a "no-burn control." Although survival in foamed plots was higher than in other treatments, some individuals were scorched and apparently killed by radiation or hot gases from surrounding flames (53% no growth/resprout) even though no grass or Scotch broom was consumed.

The data suggest that use of prescribed grass fire with low surface moisture, low to moderate humidity, warm air temperature, and long duration (generally associated with a backing fire) is 100 percent lethal to young Scotch broom.

Mapping and Control of Weeds in the American River Parkway

Eva Butler, and Sue Britting

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Introduction

In 1997 a group of four independent scientists formed a team to develop a management plan for invasive exotic plant species (invasive exotics) in the American River Parkway. With the California Native Plant Society acting as the grant administrator, we submitted an application to the U.S. Bureau of Reclamation (the Bureau) for funds to undertake this effort. The Bureau provided one half of the project budget, with matching funds to be obtained by the team from other sources. These funds were ultimately secured from the Sacramento Area Flood Control Agency, due to their concern with the potential impact of exotics on flood conveyance and levee integrity.

Objectives

The objectives of the project are:

- To collect baseline data on the distribution and abundance of invasive exotic plant species in the American River Parkway (the Parkway) and to map those populations in a geographical information system (GIS);
- To prioritize species for management and select target species for testing pilot-level management strategies;
- To summarize the available literature on control methods for the targeted species;
- To establish research and demonstration areas for pilot-level management of the target species and native plant community restoration;
- To develop partnerships with the multiple management agencies and community groups of the Parkway, to identify mechanisms for implementing Phase I of the Management Plan in the Year 2000.

Location

The American River Parkway is located in Sacramento County along a 32 mile segment of the American River that extends from Folsom Dam to its confluence with the Sacramento River at Discovery Park. Levees generally restrict the riparian vegetation to a fairly narrow band along the river although small areas of the historic floodplain remain connected to the river. Many of these areas are dominated by dredger tailings from historic gold mining and by more recent gravel mining operations. Outside of these levees. commercial and residential landuses dominate.

Despite the fact that flood control and water supply objectives dominate management strategies for this river corridor, the scenic, recreational and habitat values of the American River are widely recognized. Although many agencies exercise jurisdiction over Parkway management decisions (for flood control, water supply, fish, etc.) the local County Parks Department (the Parks Department) shoulders most of the responsibility for maintaining the habitat and parkland values of the Parkway. With this responsibility the Parks Department also inherits the burgeoning problem of invasive exotics that threaten to rob the Parkway of much of its recreational and habitat value. The Parks Department has neither the staff, funds, nor expertise to tackle this problem in a comprehensive way. Thus, this project was born out of an evident need and the desire of local scientists to address it.

Project Approach

Field Surveys

In the fall of 1997 and the spring of 1998 we collected baseline data on the invasive exotics growing within 2,300 acres of the Parkway. The surveys were conducted by foot, bicycle, and canoe. We delimited approximately 367 vegetation polygons based on ground features that were easily identifiable on recently flown aerial photographs. We then determined the percent cover in the polygon for each weedy species. Approximately 125 species of exotics which exhibited or were known to exhibit invasive tendencies (in other locales) were included in the survey. Several of these were not widely known to be invasive in the Sacramento Valley, including the Chinese tallow tree (Sapium sebiferum) and the scarlet wisteria tree (Sesbania punicea). In addition to presence/absence and percent cover data on invasive exotics, we noted the dominant native vegetation in each polygon. We plan to compare our data on dominant community types to a vegetation classification being completed by another local consultant for the Sacramento Area Flood Control Agency.

GIS Mapping

Field data were incorporated into a spatial database in Arclnfo/ArcView, a geographical information system (GIS) software product produced by Environmental Systems Research Institute, Inc. Each polygon in the GIS is connected to a data table identifying the invasive exotic species present there, the percent cover of each species and the dominant native vegetation. The polygons were plotted on rectified aerial photos with contour intervals of 2 feet. The mapped information was used to evaluate the distribution and density of populations of each species, forming the basis for selecting target weeds for our pilot-level management strategies.

Pilot Studies

We selected four target species for the research/demonstration plots: giant reed *(Arundo donax)*, tree of heaven *(Ailanthus altissima)*, Spanish broom *(Spartiuni junceutn)* and yellow starthistle *(Centaurea solstitialis)*. Our experimental designs include tests of different herbicides with various application rates, times and methods, as well as mowing, cutting and controlled burning. We set up our plots in the spring of 1998 and began evaluating their success in the spring of 1999. Contingent on availability of supplemental funds, we plan to extend the treatment/monitoring period of some plots beyond the initial two years, especially for the evaluation of yellow star thistle control and grasslands restoration. Baseline vegetation data was collected from the plots for comparison against the final vegetation community at the end of the control project.

Giant Reed *(Arundo donax)*

We are testing five different control techniques for Arundo at each of two sites, including:

Broadcast spray with Round-upTm

Cut-and-paint with Round-up-rm

Line-drawing with Round-up[Tm] (spraying horizontal lines at intervals along the clumps)

Broadcast spray with Poast[Im] (a grass herbicide) Line-drawing with PoastTM

Cut and paint is the only method which provided excellent control (90-100%). The only other method which afforded any control was line-drawing with Round-up[Tm]. Line-drawing provides excellent control on small stands and controls the perimeter of larger stands.

Yellow Starthistle *(Centaurea solstitialis)*

The test area is located in the Folsom State Recreation Area in Folsom, California in a previously cultivated field that now supports a predominantly non-native, annual grassland and an impressive yellow starthistle population. Long-term biological control plots for starthistle located adjacent to this field are routinely monitored by the U.S. Department of Food and Agriculture.

Two plot studies are underway. In the first experiment, 9 treatments for yellow starthistle are to be applied each spring from 1998 until the Year 2000 to 10' x 10' plots, with four replicates each. The tested methods include:

Garton [TM] in broadcast spray and wick application

Round-up-rm in broadcast spray and wick application
Transline™ in broadcast spray and wick application
Burning
Flaming
Mowing

Given that any one treatment method, if used exclusively, could be expected to select for certain species and against others, it is reasonable to assume that application of the same treatment to a grassland year after year could result in a mix of species which is tolerant of that particular treatment. That selection pressure would not necessarily encourage native species, as those species would not have evolved under similar conditions, e.g. being burned or heavily grazed (mowed) every spring. In order to mimic a system that more closely resembles a more diverse set of selective pressures (that might promote natives), we undertook a treatment sequencing experiment that included annual rotations of burning, mowing and spraying with Transline. Transline was chosen due to its selectivity to a relatively narrow range of plants that includes yellow starthistle (and other composites) and legumes.

In the second study area (adjacent to the first), the entire 2 acre field was burned in June of 1999 and subsequently marked off into 54, 10m x 1.0m plots, including 6 replicates of each of 9 serial treatments. However, the sequence **in** which the plots receive the three treatments will vary. The different treatments are represented below with the letter "B" for burn, "M" for Mow, and "T" for Transline. The Year 1 treatment for all plots appears as the initial "B" to represent the 1999 burn:

BBB	**B M B**	**B T B**
BBM	**B M M**	B T M
BBT	BMT	

The purpose of this experiment is to compare the efficacy of these treatments against yellow star thistle, as well as to monitor the effect of the selective pressures of the treatments on other species. Ultimately we would like to shift the system toward native plants and away from non-natives. We anticipate a need to seed the area **in** Year 3 with native grassland species after achieving control of the yellow starthistle and non-native annual grasses, as few native species have persisted **in** this field.

Spanish Broom *(Spartittm junceum)*

The pilot project for Spanish broom was the largest scale exotics removal conducted under this project. lii 1997 (prior to this project) two of the project scientists began to conduct research as CNPS volunteers to evaluate methods of killing Spanish broom on a 15 acre site, the decades-old "motherload" of Spanish broom in the Parkway. Pathfinder (a formulation of Garlon 4 in vegetable oil) was applied as a basal bark spray to:

3 size ranges of broom – <1 m, 1 to 2 m, and >2 in
3 phenological stages of broom – flowering, green pod, brown pod
3 different levels of bark coverage – 1%, 10% and 20%

The most efficient and effective kill rate appeared to be achieved by spraying later in the season, when broom was in the "brown pod" stage, presumably moving nutrients (and Garlon) into its roots. However. the kill rate was not statistically better than spraying at the other phenological stages. For plants under I meter tall, increasing the amount of spray applied (measured by percent of bark covered) did not increase the kill rate. However, for plants over 2 meter tall, the highest application rate was more effective in achieving complete kill than were the lower rates.

We discovered that, if the entire stem was not circumscribed by the spray, a portion of the plant was more likely to survive. We also observed that Garlon may volatilize into the air after spraying on hot days, causing damage to native grapevines (Vitis cal ifornica) growing up to 15 feet away from the sprayed broom plants. Therefore, it is recommended that Garlon treatment of target plants growing near grapes be conducted after the grapes have dropped their leaves.

Based on these experiments the remaining acres of Spanish broom were sprayed in the summer of 1999. Removal of the dead broom on 3 acres was accomplished with chain saws with labor from the California Conservation Corps. Volunteers dragged and stacked the cut material into long narrow piles (100' by 12') on the cobbled floodplain. This slash was burned on site in November of 1999 by arrangement with the local fire district to keep flood waters from transporting the biomass (and its seeds) downstream.

Tree of Heaven *(Ailanthus altissima)*

Two research/demonstration sites were selected in the Parkway for control of Ailanthus. Site I consisted of mature tree of Heaven. The other site was comprised primarily of re-sprouts from the roots of trees cut (but not herbicide treated) by volunteers in a previous control attempt. All treatments were conducted during the fall to facilitate herbicide movement to the root system. The control techniques tested at each of the tree of Heaven sites were:

Site I

Paint Garlon™ on cut stumps

Paint Round-up™ on cut stumps

Site 2

Spray Garlon™ on intact re-sprouts

Paint Round-up™ on cut re-sprouts

All of the treatments were equally effective. Each provided excellent control and few resprouts. Future tests will determine the most economical dilution of herbicide.

Future Plans

Reporting

An Exotic Plant Management Plan for the American River Parkway will be prepared by the project team by November of 1999. This plan will summarize the results of the pilot studies and a process for implementing the first phase of the plan implementation.

Implementation

We continue to work with Parkway management agencies to inform them about our project and to offer assistance in developing effective invasive exotic management techniques for their areas of interest.

Through the County Parks Department, volunteers are directed toward exotics management projects with the guidance of project scientists.

A slide show, display and information sheets about local invasive exotic plants are under development for public outreach and education purposes.

An agreement has been developed between project managers and a local flood control district to provide scientific assistance with their plans to remove Arundo donax.

Funding is being sought for coordination of Parkway-wide management of exotics for the Fall of the Year 2000 based on the Exotic Plant Management Plan.

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Prescribed Burning for Control of Yellow Starthistle (Centaurea solstitialis) and Enhanced Native Plant Diversity

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Two separate open grassland areas within Sugarloaf Ridge State Park, Sonoma County, California, were burned for three consecutive years (1993-95 [Site A] and 1995-97 [Site B]) for control of yellow starthistle. Burns were conducted in late June to early July following seed dispersal and senescence of desirable grasses and forbs, but prior to viable seed production in yellow starthistle. After the first year of burning, there was no significant reduction in yellow starthistle cover the following spring and summer. Despite the lack of control, the first year burn reduced the yellow starthistle soil seedbank by 74%, and the number of seedlings the following spring by 83%. However, total plant diversity and species richness increased dramatically in the burned areas. This was due primarily to an increase in the number of native broadleaf species. A second burn the next summer (1995-1997 site) reduced seedbank, seedling density, and summer vegetative cover the following year by 94, 92, and 85%, respectively, while maintaining significantly higher native plant cover and richness. A third consecutive summer burn decreased yellow starthistle seedbank and seedling density by 96, 98, and 85%, respectively, in the 1995-97 burn site. Three consecutive years of burning in the 1993-1995 site reduced seedbank and seedling density by over 99%, and summer vegetative cover by 9 1 %. These results indicate that prescribed burning can be an effective tool for the management of yellow starthistle, and can have a long-term benefit on native broadleaf diversity and richness.

The CalWeed Database

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The CalWeed Database, a project of the California Interagency Noxious Weed Coordinating Committee (CINWCC), provides information on weed control projects occurring throughout California. CINWCC was formed **in** 1995 when 14 federal, state, and county agencies came together under a Memorandum of Understanding to coordinate the management of noxious weeds. Formed as a subcommittee effort of CINWCC, CalWeed serves as a tool to agency staff, researchers, biologists, and the public by facilitating the exchange of weed control information.

The project is led by staff of the California Department of Food and Agriculture, and has received additional funding from the California office of the Bureau of Land Management. This Internet-based database is hosted by the Information Center for the Environment at the University of California, Davis.

CalWeed provides viewers with short reports on more than 700 weed control projects within California. Information available for a specific project includes: project title, purpose, and abstract; weed targeted for control; project contact; cooperators, funders, and landowners; location and habitat information; and control method. A visitor to the CalWeed website can view a complete list of projects, or can refine a search by county, targeted weed, or control method. In the future, CalWeed will also contain an on-line encyclopedia of noxious weeds including life history and control information.

Anyone affiliated with a noxious weed control project in California can add their project to CalWeed by completing the project entry form. Forms can be accessed from the CalWeed home page or by contacting the California Department of Food and Agriculture. CalWeed's Internet address is: http://endeavor.des.ucdavis.edu/weeds/

Environmental Effects on Asexual Reproduction in *Arundo donax,* Giant Reed

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Arundo donax (giant reed) is an invasive perennial plant that has spread widely in riparian areas in California, where it has altered wildlife habitats, created a fire hazard, compromised water conservation efforts, and affected flood control. Currently physical removal is the primary means of controlling this weed, which *is* ineffective due to prolific asexual reproduction from an extensive rhizome system. We conducted controlled experiments on the sprouting potential of vegetative propagules, effects of storage duration and conditions on sprouting, and survival and growth of propagules in various soil types and moisture regimes. Sprouting and regrowth varied greatly with propagule type and size and with treatment and duration of storage following removal from the plant. Over 90% of stem and rhizome pieces with at least one node sprouted. Stern sprouting was affected by prior storage duration, temperature, and moisture, while only storage duration and moisture affected rhizome sprouting. Sprouting was reduced by drying propagules at 30 degrees C for one week and by storage in a soil slurry. After 16 weeks, even propagules maintained optimally in moist soil showed reduced sprouting. Rhizome pieces sprouted readily from a soil depth of 25 cm, while stem pieces sprouted from less than 10 cm. Responsiveness of asexual reproduction in A. *donax* to environmental cues suggests that mechanical control can be achieved by careful timing and treatment of cut biomass pieces to minimize or inhibit resprouting.

Nitrate Immobilization and the Mycorrhizal Network for Control of Exotic Ruderals.

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Healthy native ecosystems resist invasion by ruderal plant species, and successfully restored sites acquire resistance to invasion as they develop. Several mechanisms have been proposed for resistance to invasion, but an argument is made here for rapid removal of soluble nutrient ions by a network of roots and mycorrhizal hyphae in the soil. Although the experimental evidence is as incomplete for this mechanism as it is for the alternative hypotheses, it has better predictive value relative to habitat restoration.

Development of the soil network requires time, during which ruderals can potentially preempt the site and cause project failure. This can be prevented by temporary removal of soluble nutrients through "anti-fertilization": introduction of organic carbon to cause microbial immobilization of nutrient ions. Photographic documentation is provided for one large commercial project and three small test projects, all of which resulted in excellent control of exotic annuals while establishing ecosystem function. A full version of this and related reports may be found in pdf format at http://www.mycorrhiza.com/downloads.htm.

Introduction

Natural systems resist invasion by exotic or ruderal (weedy) species. In spite of a few well-known exceptions, healthy native ecosystems tend to contain only a few relatively stunted ruderal species. Ewe] (L987) included resistance to invasion as one of the fundamental properties of a functional ecosystem. If we can understand resistance to invasion, we can use it to establish native ecosystems without serious weed problems.

The mechanism

Zone without weed invasion

Resistance to invasion is exemplified by Figure 1 (not shown—ed. *See* web site cited later). Such scenes are very common at the boundary between native and ruderal (weedy) vegetation. Native perennial grassland seems to have the least resistance to invasion of our native vegetation types, and chaparral may have the most.

In this example, a rather weedy stand of native *Nessella pulchra* meets a stand of chamise chaparral. The weeds (mostly annual grasses, including *Avow* spp.) drop out in a band around the brush. The native bunchgrass grows right up to the brush.

Previous explanations

Allelopathy

Chemical forms of interference competition appear throughout biology, and undoubtedly take place among higher plants (Rice 1984). The concept has been criticized because allelopathy is often invoked indirectly, by rejecting alternative explanations. There are many potential alternative explanations that are rarely or never addressed in allelopathy experiments (Harper 1977, Williamson 1990).

Without trying to resolve the allelopathy question in general, I would propose that the situation shown in Figure l is not adequately explained by allelopathy. There would have to be some means for allelopathy to select between ruderals (weeds) and natives, since the natives shown here have no problem entering the "exclusion zone." The other native shrubs likewise are not excluded from this vegetation.

A microbe-based toxicity, as proposed by Kaminsky (1981) could explain the bare zone, but would not predict the selective exclusion of ruderals.

Animal activity

Herbivory is known to be a potent force in California native vegetation (Mills 1986), and has been proposed as an alternative explanation of some effects previously attributed to allelopathy (Bartholomew 1970; Halligan 1973; Christensen and Muller 1975). lf rabbits or other herbivores are responsible for the situation shown in Figure 1, they have developed an unlikely preference for dry weeds over green native grasses.

The mycorrhizal network

Natural plant communities usually develop an extensive network of mycorrhizal fungi that interconnects the root systems of most plant species. This network performs and mediates numerous important ecosystem functions, and its destruction is the most far-reaching effect of soil disturbance (Brundrett 1991). Among the effects attributed to the network is the suppression of ruderal species (Francis & Read 1994), an effect that depends upon close proximity of active hyphae to the roots of ruderal seedlings.

The scene shown in Figure 1 could be readily explained by a network of mycorrhizal mycelium associated with the root systems of the shrubs.

A nutrient-based explanation

An alternative to these explanations (but compatible with an association with the mycorrhizal network) is based on soil nutrient availability. While a rather unexciting mechanism, it stands up to the criticisms leveled at the mechanisms listed above. It depends upon two well-established generalizations: that mechanical disturbance of the soil is in effect a "fertilization," and that ruderals are highly responsive to soluble nutrients, especially ionic forms of nitrogen.

There is no claim that this discussion presents an experimental test of these alternative mechanisms for resistance to invasion. However, the view proposed here has a great deal of predictive value. That is, it successfully predicts a way to suppress ruderals while encouraging natives. I present it for its practical utility, recognizing that the underlying mechanisms may be disputed or refined by future research.

Mechanical disturbance liberates soluble nutrients

A key reason that disturbed soils have a higher concentration of available nutrients is that while decomposition continues vegetation is no longer continuously removing nutrients. St. John (1988) reviewed other factors contributing to this fertilization effect.

Ruderals respond more strongly than natives to soluble nutrients

Perennial native plant species tend to require a lower rate of nutrient uptake than ruderals for a range of reasons: slow growth, evergreen leaves, and greater relative root growth are among these (St. John 1988).

When we install a restoration project on disturbed ground, we have already set the stage for disaster by creating the best possible conditions for ruderals and the worst conditions (lack of mycorrhizal fungi) for natives. Unless we intentionally inoculate the site with mycorrhizal fungi, the natives do not have the advantage of their natural means of absorbing nutrients. If we should double the insult by fertilizing (the usual way to compensate for a lack of mycorrhizal fungi) the odds against the natives are often insurmountable.

The Procedure

This mechanism of resistance to invasion is of use in restoration and weed control if we understand how it works and how to reduce the availability of nutrients at the restoration site. For the short term, soluble nutrients may be immobilized in microbial biomass through the addition of organic material on the surface of the soil. For the long-term, a healthy native ecosystem. with its network of roots and mycorrhizal hyphae. removes soluble nutrients through plant and microbial uptake, followed by their storage in live biomass and recalcitrant organic fractions.

Short-term immobilization with organic additions

A decade ago (St. John 1988), I made what I believe to be the first suggestion of intentionally immobilizing nutrients as a part of habitat restoration ("anti-fertilization"). At that time, the restoration field in California was dominated by a landscaping approach that included fertilization, and the idea of intentionally making nutrients unavailable was unpalatable to all but the few restorationists at that time who were trained in plant ecology. Since that time the field has become populated with talented ecologists, and the topic has been the subject of experimental study (McLendon and Redente 1992, Morgan 1994, Zink and Allen 1998) and practical application (Claasen and Marler 1998). Questions that have not yet been fully resolved include the circumstances in which the procedure may be appropriate, the relative advantages of "hard" and "soft" organic materials, and alternatives that minimize the cost and labor required to carry out "anti-fertilization" on large areas.

Long-term immobilization by the establishment of nutrient cycling

Since organically bound nutrients are re-released as the organic matter decomposes, any immobilization with organic matter is temporary. To maintain resistance to invasion over the long term, a network of roots and mycorrhizal hyphae, along with a growing vegetation. must be established by the time the organic matter begins to release soluble nutrients. This requires rapid and effective establishment of a densely-rooted vegetative cover. The decomposition rate of the organic material must be rapid enough to allow fast microbial growth. but not so rapid that nutrients are released before the native vegetation is ready to absorb the nutrients. The *veg-*

etation must include rapidly growing native species to serve as a sink for soluble nutrients, and good mycorrhizal hosts to rapidly build a network of mycelium in the soil. Clearly, timing is critical, but the case studies reviewed in the next section provide evidence that these requirements can be met.

Case Studies

This method was described in the trade literature by Riefner et al (1988), who successfully used it at San Onofre State Beach. A series of photos summarizing the method used in that project can be found in the online version of this manuscript (http://www.mycorrhiza.coin/downloads.htm). This large and low-cost project made use of land imprinting and mycorrhizal inoculation on about 33 acres of weedy annuals (mostly *Brassica nigra)*. Between 70 and 90% of the area has now become coastal sage scrub or a native grass-dominated intermediate vegetation of a type that has been steadily turning into coastal sage scrub. The organic material at San Onofre State Beach was the dry stalks of *B. nigra*. The last paragraphs of that publication summarize the sequence used at San Onofre.

Smaller trial plots are shown in figures in the online version of this paper. These have now proven quite consistent, and the method apparently can be used at will to control *B. nigra* and annual grasses. Its utility against other invasive species remains to be verified, but most will likely be amenable to the method. The smaller projects are detailed in the photo captions.

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Exotic Plant Control to Preserve and Restore Riparian Areas in Numerous National Park Units

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The primary objective is to control the exotic tamarisk (saltcedar) tree that is responsible for degrading riparian habitats throughout many park units. This project will not only assist with the preservation and restoration of the native flora and fauna of these valuable riparian ecosystems, but will standardize National Park Service (NPS) management efforts by utilizing safe and effective control methods to maximize results.

Exotic species management has become an increasing problem with managers responsible for preserving natural ecosystems. As with many exotic species, tamarisk infestations have become an overwhelming challenge for NPS managers. There has been a recent Department of the Interior-led Weed Management Initiative to increase exotic plant management to a broader scale that represents the distribution of the individual pest plant. Many park units are initializing tamarisk control programs without experienced or well-trained labor resources, there is a definite need for sharing information, expertise, and professional labor resources. A need for a concentrated approach to tamarisk control is outstanding, considering the degree of difficulty that control involves. Planning and prioritization of control efforts is critical to maximize limited resources and to achieve success of desired objectives.

Participating park units submitted their priority tamarisk control projects. Each project will be evaluated according to the Decision Criteria for Developing Saltcedar Management Programs or by an existing tamarisk control plan, vegetation plan, resource management plan from individual park units before implementation. Project scheduling will be developed by the program coordinator. Labor will either be provided by local resources or by an 8-10 person NPS exotic plant control program crew fully equipped with vehicles, chainsaws, herbicide application supplies and personal protective gear.

Proven methods will be used to provide for personnel safety and environmental sensitivity. Lake Mead National Recreation Area has developed effective control methods using cut-stump herbicide, low volume basal herbicide application, prescribed fire followed by basal spray of resprouts, heavy equipment and slash pile burning. These methods have been developed and refined to produce maximum control results that are widely accepted and have withstood multiple peer reviews.

The objective of the program will be to complete initial tamarisk removal from high priority areas and to develop maintenance schedules for park staff. Development of a professional corps of NPS resource managers equipped with the knowledge and expertise to continue exotic plant management programs. Removal areas will be documented and total acres of removals will be tallied. Monitoring the ecological recovery of the project areas will be the responsibility of each park unit.

Eradication of Exotic *Spartina* in San Francisco Bay

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The exotic *Spartina alterniflora,* a perennial grass. is swiftly spreading throughout San Francisco Bay wetlands and intertidal mudflats. It is native to the Gulf and Atlantic coasts and was introduced into San Francisco Bay in the mid-1970s. It has become nearly pervasive south of the San Francisco Bay Bridge. Potential impacts include degradation of habitat for the federally and state endangered California clapper rail. hybridization with the native *S. fallosa,* physical alteration of the wetlands due to accretion and stabilization of sediment, loss of shorebird feeding habitat and open mudflat, and displacement of native Flora. Land reclamation for industrial building in the past has destroyed approximately 82 percent of native wetland habitat. *Spartina alterniflora* poses a critical threat to the survival of the last remnants of tidal wetlands in San Francisco Bay.

Volunteer "Weed Warriors" on Santa Catalina Island

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The Catalina Island Conservancy is the steward for over 88% of Santa Catalina Island. About one third of the 600-plus species of plants on the island are non-native. An integral part of the management plan for the control and eradication of the island's wildland weeds is the involvement of volunteers in removing, surveying, and mapping wildland weeds. With proper training, support and recognition, volunteers become long-term partners and advocates for the conservation efforts occurring on Santa Catalina Island.

Factors Affecting Alien Annual Plant Abundance at a Site in the Western Mojave Desert: Effects of Human Disturbance, Microhabitat and Rainfall

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On a global scale, species richness of alien plants is generally highest in ecosystems with either high disturbance or intermediate soil nutrient levels, but it is not clear if these patterns occur at smaller scales, or if alien plant biomass follows the same trend. To clarify these issues, I simultaneously monitored species richness and biomass of alien annual plants at contrasting levels of disturbance and soil nutrients at a 150-acre site in the western Mojave Desert. Disturbance was greater outside than inside a fenced area that has been protected from sheep grazing and off-highway vehicle use for 15 years. Soil nutrients varied with topography, microhabitat, and rainfall year. Sampling was stratified to account for **this** variation and included all factorial combinations of the following environmental factors listed in decreasing order of disturbance or soil nutrient level: 1) anthropogenic disturbance (unprotected, protected); 2) topographic position (washlet, upland); 3) microhabitat created by creosote bush *(Larrea tridentata)* (Larrea-north, Larrea-south, and intershrub); and 4) rainfall year (high, low). Absolute and proportional species richness and above-ground live biomass of alien annual plants were measured at the height of annual plant growth in April each year. Individual biomasses of four alien species were analyzed, *Bromus m.adritensis* ssp. *rubens (Bromus* ***rubens),*** *Bromus trinii, Schisms* spp. and *Erodium cicutarium.*

Soil nutrients displayed strong positive associations with both richness and biomass of aliens, whereas disturbance was only positively associated with alien biomass. Alien richness and biomass did not peak at intermediate nutrient levels, but peaked at the highest levels measured **in** this study. This unidirectional increase likely occurred because the highest levels of soil nutrients in the Mojave Desert are moderate compared to other ecosystems, never reaching the concentrations generally associated with low alien richness. Disturbance was more weakly associated with alien richness and biomass, possibly because the contrast between the disturbance levels was relatively small compared to the contract between soil nutrient levels at this site. Thus, global patterns of alien richness and soil nutrient levels were useful for predicting where alien richness and biomass were highest at this Mojave Desert site, but patterns associated with disturbance were less conclusive.

Patterns of alien biomass were better described by analyzing individual alien species. Biomass of *SCbIS-11711S* spp. was higher in disturbed than undisturbed sites when rainfall was low whereas biomass of *BI'011111S bens* was higher in disturbed sites when rainfall was high. Alien species responded to soil nutrients differently, suggesting that life history characteristics of individual species can be more useful than global generalizations in predicting when and where aliens are likely to invade. *Bromus rubens* and *B. trinii,* species that originate from mesic regions, were more strongly associated with high nutrient levels than were *Schismus* spp. and *Erodium cicutarium* which evolved in more arid regions. Conditions that foster plant invasion seem to depend strongly on the life history characterisitcs of the potential invaders.

The composition of the seedling cohort differed greatly among years of contrasting rainfall. Proportional richness and biomass of alien species were higher during the high than the low rainfall year. Germination requirements may be less stringent for aliens than for natives, allowing them to germinate during years of low rainfall when most native seeds remain dormant. Periods of drought may reduce populations of aliens relative to natives if seedlings die prior to reproducing, but the chance of dying may depend on physiological tolerances to low water levels that reflect the life histories of individual species. Aliens that originate in relatively mesic regions may be more susceptible to local extinction caused by drought than those that evolved in arid regions.

Biocontrol of Tamarisk

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