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TAMARISK CONTROL ON PUBLIC LANDS IN THE DESERT OF SOUTHERN CALIFORNIA: TWO CASE STUDIES

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"What uses five million acre-feet of water a year and has disrupted or destroyed more than a million acres of riparian vegetation? What threatens to eradicate the West's last remaining habitat for yellow-billed cuckoos and elf owls? What pulls water out of desert springs, thereby eliminating water supplies for bighorn sheep, rare pupfish and salamanders, and desert palm groves? Answer: the tamarisk (*Tamarix* sp.)."

Johnson (1987)

As a land manager, the Federal Government faces enormous challenges from exotic pest invasions and associated changes to the structure and stability of native ecosystems (Bureau of Land Management, 1988). On public lands administered by the Bureau of Land Management (BLM) alone, it is estimated that almost three million hectares are occupied by invasive exotic plant species (weeds). Assuming an annual rate of invasion of 14 percent, 930 hectares of BLM-administered land are infested everyday by weeds (Jerry Asher, personal communication). When one considers the fact that BLM administers only about one-third of the public land in the United States (The Keystone Center, 1991), the magnitude of the problem assumes staggering proportions. The scenario described in the quote

above portrays only some of the problems associated with the spread of the exotic plant tamarisk, a species on the California Exotic Pest Plant Council's list of exotic pest plants of greatest concern (California Exotic Pest Plant Council, 1993). In this paper we review the threats posed by tamarisk invasion and proliferation and examine the traits that make the plant such a successful competitor. In addition, we highlight two tamarisk control efforts conducted by the Bureau of Land Management in the southern California desert.

Profile of a Successful Invader

Tamarisk is native to Eurasia and is a major weed problem throughout the southwestern United States (Kerpez and Smith, 1987; Kunzmann *et al.*, 1989). It was introduced into the United States in the early 1800's as an ornamental and as a windbreak. Since then it has successfully invaded nearly every drainage system in the Southwest, occupying over 607,050 hectares (Brotherson and Field, 1987), including approximately 6,475 hectares in California (Johnson, 1987). The taxonomic status of the genus *Tamarix* has been the subject of a great deal of controversy, and as many as 54 species are formally recognized. The species considered in this document is generally referred to as *Tamarix ramosissima*, also referred to a "saltcedar" (Kunzmann and Johnson, 1989).

Several adaptive features contribute to the success of tamarisk as an invader (Table 1). First, tamarisk has one of the highest evapotranspiration rates of any known phreatophyte; plants that exhibit an obligate or facultative dependence on ground water. High rates of water use by tamarisk are observed when water is close to the surface (Van Hylckama, 1970). As with other plants the rate of evapotranspiration varies in response to density and environmental factors (Anderson, 1982; Davenport *et al.*, 1982a). Kerpez and Smith (1987) reported that a single acre of tamarisk can transpire 11,101 m^3 per year, and Brotherson *et al.*, (1984) observed that the longer a plant community was occupied by tamarisk, the more xeric the area became. Annual water use by tamarisk was greater than that of replacement native vegetation following root plowing in New Mexico (Weeks *et al.*, 1987). Antitranspirant coatings have been tested on tamarisk, but results are not promising given the cost of the technology (Davenport *et al.*, 1982b). Second, tamarisk is very prolific. A single large plant is capable of producing 500,000 seeds per year (Neill, 1983). The seeds are small and easily dispersed by wind. Seeds are produced from April to October and remain viable for several weeks, germinating within 24 hours once wetted (Kerpez and Smith, 1987). Third, tamarisk is capable of reproducing vegetatively, even when severely damaged. Plants that are cut off above the roots or burned are capable of resprouting. Fourth, tamarisk is resilient to a wide variety of stress factors including fire, drought, flood, and high salinity. One study in Utah demonstrated that tamarisk was capable of growing in soils containing soluble salt concentrations of 700-15,000 ppm (Garman and Brotherson, 1982). A recent study suggested that tamarisk can extract not only free water but soil moisture from unsaturated soils as well, giving it a competitive advantage over some native riparian species such as cottonwood and willow (Busch *et al.* 1992). In addition, tamarisk exudes salt from its leaves (Thomson *et al.*, 1969) suppressing the germination of native vegetation.

Collectively, the traits outlined above predispose tamarisk to be a vigorous invader of the wetlands of the Southwest. The plant is capable of tolerating wide variations in environmental characteristics (Brotherson and Winkel, 1986) unlike many native species. Once established the dense groves shade out many native species, thereby affecting their reproductive potential.

The suitability of tamarisk as wildlife habitat has been a subject of considerable debate. It generally provides unsuitable habitat for most wildlife because neither its foliage nor its flowers (including seeds) have any significant forage value in contrast to native species such as 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

doves (*Zenaida macroura*), Mississippi Kites (*Ictinia mississippiensis*), and various passerine birds are known to nest in tamarisk dominated habitats (Glinske and Ohmart, 1983; Brown and Trosset, 1989; Rosenberg *et al.*, 1991). Rice *et al.* (1983) determined that tamarisk foliage height diversity was an important determinant of avian community organization, although native plant species were more important determinants.

The value of tamarisk to wildlife appears to vary geographically. Utilization of tamarisk 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 tamarisk 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.*, 1988). It is important to note that all published studies of the value of tamarisk as wildlife habitat have focused on birds. Purported benefits to selected birds do not necessarily extend to other animals. Additional research is needed on the relationship between tamarisk and other groups of species including invertebrates as compared to native vegetation types.

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

Tamarisk 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 tamarisk. 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). In the desert region of Australia tamarisk 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. Tamarisk dominance also results in a reduction in the numbers of native birds and reptiles (Griffin *et al.*, 1989) relative to native ecosystems.

Table 1. List of characteristics contributing to the success of tamarisk as a weedy invader (from Brotherson and Field, 1987 and references therein).

1. Continuous seed production for as long as growing season permits.
2. Cross-pollination by the wind.
3. Self-compatible when cross-pollination unavailable.
4. High seed output in favorable environmental circumstances.
5. Ability to produce seed under a wide range of environmental conditions.
6. Adapted for long or short range dispersal.
7. Vigorous vegetative reproduction capability.
8. Uprooting difficult because of stem brittleness.
9. Competes interspecifically by allelochemics due to presence of salt-glands.
10. Capacity to tolerate extreme range of environmental conditions.
11. Vigorous root sprouter following fire.
12. "Facultative phreatophyte" due to ability to live partially inundated or in total absence of saturated soils.
13. Difficult to control with foliar chemicals.

A secondary effect of tamarisk invasion is related to increased frequency of fire in impacted areas. The drought-deciduous nature of tamarisk 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 tamarisk coupled with the fire intolerance of many native shrubs in the southwestern deserts effectively leads to tamarisk dominance in native plant communities in a relatively short time period.

Some authors have suggested that invasion of tamarisk is a sign, not a cause, of habitat modification and degradation (Horton, 1977). Replacement of tamarisk by native plant species will likely require correcting environmental factors that favored the invasion of tamarisk in the first place (Anderson and Miller, 1990). Such factors will need to be identified (see Anderson and Miller, 1992) prior to active revegetation efforts. However, an area dominated by tamarisk is likely to remain so unless altered by natural cataclysms or man (Kerpez and Smith, 1987).

Tamarisk is extremely difficult to eliminate. Several options are available to control it, including root plowing, burning, mowing, flooding, chemical treatment and combinations of these techniques (Bureau of Reclamation, 1992). A biological control program is being explored by the U.S. Department of Agriculture's Agricultural Research Service in Temple, Texas (Cook, 1989). Most successful efforts to remove tamarisk have included a combination of physical and chemical control methods, or the cut-stump/herbicide method (Sudbrock, 1993). Death Valley National Monument has had success removing tamarisk at Eagle Borax Spring, the Los Angeles Department of Water and Power has successfully removed tamarisk in the Owens Valley and the Coachella Valley Preserve's palm oases have been cleared of all tamarisk (Barrows, 1993).

Recognizing the significant negative qualities of tamarisk, the BLM has developed major programs to remove the weed from two important areas in the southern California desert: the Salt Creek/Dos Palmas Area of Critical Environmental Concern and the Afton Canyon Area of Critical Environmental Concern.

The Tamarisk Removal Program at Dos Palmas Oasis

Site description. - Dos Palmas Oasis is located in the Salt Creek drainage of the central Colorado Desert near the northeast shore of the Salton Sea, in Riverside County, California (Figure 1). Approximately 1,619 hectares of public land within the Salt Creek drainage were designated as the Salt Creek Area of Critical Environmental Concern in the 1980 by the BLM (Bureau of Land Management, 1980). Currently, about 8,094 hectares of public land are scattered throughout the drainage, with several key parcels, including the headwaters of Dos Palmas oasis, held in private ownership.

Dos Palmas oasis was developed first as a ranch/spa in the 1940's - 1950's and later as one of two commercial fish farms in the area. Use of Dos Palmas as a fish farm continued until 1989, when The Nature Conservancy (TNC) bought the property (555 hectares), which was later transferred to the BLM. The acquisition of the Dos Palmas properties served as a catalyst for renewed acquisition efforts and plans for habitat restoration. Since 1989 additional land has been acquired by TNC or BLM. The California Department of Fish and Game has contributed to the effort by acquiring land, primarily at outlying oases.

Dos Palmas is one of the richest and most diverse wetlands in Southern California, providing excellent habitat for a representative array of Colorado desert wildlife. It supports several threatened and endangered species, including the Yuma clapper rail (*Rallus longirostris yumanensis*), desert pupfish (*Cyprinodon macularius*), California black rail (*Laterallus jamaicensis coturniculus*), and flat-tailed horned lizard (*Phrynosoma mcallii*). One species of springsnail (*Pyrgulopsis longinqua*) may be endemic to a single spring in the Salt Creek drainage, and another (*Tryonia protea*) is found only in three small springs in Salt Creek and one in Sonora, Mexico (Robert Hershler, *in litt.*). The landscape is

characterized by five vegetation assemblages; Desert Fan Palm Oases, Sonoran Freshwater Marsh, Screwbean Mesquite Bosque, Palo Verde - Ironwood Wash Woodland, and Alkali Scrub (Holland, 1986). Dominant plant species include: desert fan palm (*Washingtonia filifera*) usually growing in "oases" around surface springs or seeps, screwbean mesquite (*Prosopis pubescens*), honey mesquite (*P. glandulosa*), tamarisk, alkali bullrush (*Scirpus americanus*), cattail (*Typha* sp.), desert saltgrass (*Distichlis spicata*), and pickleweed (*Allenrolfea occidentalis*). Tamarisk is invading all of these habitats to varying degrees.

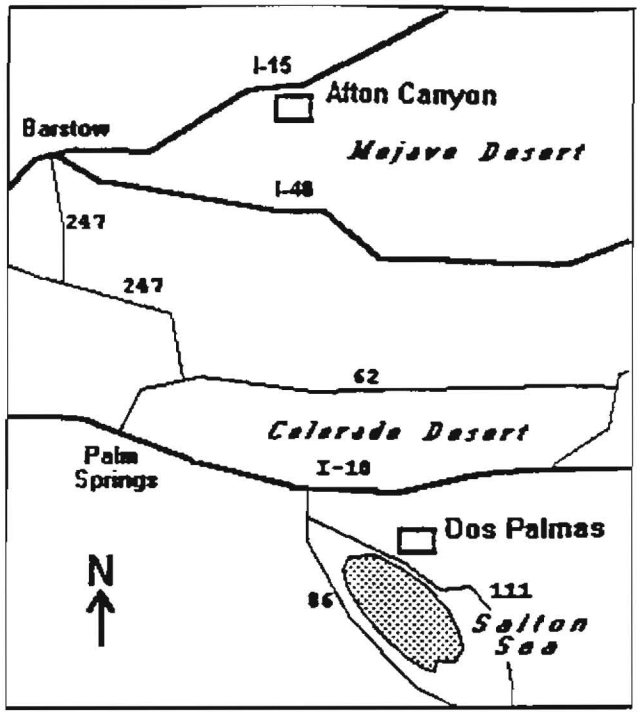

Figure 1. Location of Dos Palmas Oasis and Afton Canyon Area of Critical Environmental Concern.

At Dos Palmas and along Salt Creek, windrows and horticultural plantings likely contributed to the introduction and spread of tamarisk. As in other riparian areas throughout the Southwest, conditions are ideal for its growth. It is estimated that 800 hectares within the Salt Creek drainage have been invaded by tamarisk. In some areas it makes up 70-80% of the vegetative cover, substantially displacing native vegetation and reducing the value of this critical wetlands complex for wildlife. In Desert Fan Palm Oases, tamarisk appears to aggressively invade areas where the ground has been disturbed. Disturbances from historical palm harvesting activities (access road construction and staging areas), and the associated clearing of the thick fan palm frond litter that naturally covers the ground surface in undisturbed areas, have created conditions ideal for tamarisk germination. Areas within the oases that have not been disturbed by these activities, and that have retained their litter cover, have very little or no tamarisk present. Similarly in the Alkali Scrub vegetation assemblage, tamarisk appears to invade areas that have been disturbed by past human activities associated with the construction and maintenance of fish ponds, old fields, etc. In Palo Verde - Ironwood Wash Woodland and Sonoran Freshwater Marsh, tamarisk is present ubiquitously and appears to invade sandy/gravelly deposits deposited by flash floods and the banks of marshes and creeks respectively. Tamarisk invasion is least significant within the Screwbean Mesquite Bosque association, where soil moisture is most limiting.

A management plan was completed for the area in 1982 (Bureau of Land Management, 1982). The primary management goal for the Salt Creek/Dos Palmas area is to restore the ecosystem to a more natural state and improve habitat for the several threatened and endangered animal species that occur there. The removal of exotic plant species is a key element in the restoration effort both to make way for the reestablishment and proliferation of native vegetation and to increase the amount of surface water available to maintain the wetlands and associated riparian habitat.

Removal Program. - Tamarisk removal at Dos Palmas is based on the cut stump/herbicide treatment method (Sudbrock, 1993). One or two workers cut the tamarisk stems with a rotary brush cutter (for diameters of approximately one inch or less) or with a chain saw (for greater diameters), as close to the ground as possible. Another worker immediately applies an herbicide solution to the cut surface, the root collar and the sides of the stumps with a backpack sprayer using low pressure. The herbicide solution of choice in most areas is one part triclopyr butoxyethyl ester mixed with three parts

water. The solution is colored with a special dye to facilitate identification of treated vs. untreated stumps. In areas within 50 feet of surface water a triclopyr triethylamine salt herbicide or glyphosate-based herbicides that are non-toxic to fish will be used. After brush is cut, one or two other workers remove the cut materials and stack them in a brush pile nearby.

In our first year the cut stump treatment method has proven to be very effective. Inspection of treated areas indicates almost 90 percent kill of tamarisk. Re-sprouts will be treated with foliar applications of herbicide. The response of native vegetation, especially California fan palms, is being monitored. No noticeable response was observed six months after project initiation. Photographic plots will be resurveyed one year after the initial removal effort started, and positive response of the palms or other natives may be observed then.

Tamarisk removal at Dos Palmas is constrained by funding and manpower limitations. To overcome the latter constraint, the BLM entered into a Memorandum of Understanding with the Eagle Mountain Community Correctional Facility (located near Desert Center, California) to use inmate work crews in the eradication effort. The 1993 season ran from early February through late May, and employed the services of a 5-person crew for an average of 100 man-hours per week. Total man-hours for the season are estimated at 1,700. The total area treated is estimated at 4.05 hectares, which brings the labor cost to approximately 420 man-hours/hectare. At that rate, it will take the BLM over three years to treat a 16 hectare palm oasis, taking into account areas of very dense tamarisk and undisturbed areas where tamarisk is almost absent.

The high labor-to-clearing ratio is due in great part to the very dense nature of tamarisk stand infestations within the disturbed areas of the oasis. The ratio is expected to be much lower in other vegetation associations such as Screwbean Mesquite Bosque. In very sensitive environments such as palm oases, mechanized tamarisk removal is not a viable option, first because of the very dense nature of the palm stands, high water table, and high litter loading that characterize these oases, and second because the high level of soil disturbance it creates would only exacerbate tamarisk re-infestation later. Thus although removal by hand crews appears to be an extremely slow and costly proposition, it appears to be the only viable option.

An additional problem in tamarisk removal is the accumulation of huge quantities of slash and cuttings. In the arid desert environment slash piles decompose very slowly thus creating an unsightly landscape and a potential fire hazard. Controlled burning of slash piles was considered to be a risk to proximate native fan palm oases and an unacceptable contribution to the already polluted air of southern California. Tentative arrangements have been established with a nearby cogeneration facility to remove and burn the slash to generate electricity.

With the exclusive use of hand crews as described above, it is anticipated that 8 to 20 hectares of tamarisk will be removed annually within difficult and sensitive habitats such as palm oases, and that up to 40 hectares could be treated in less sensitive vegetation associations such as Palo Verde - Ironwood Wash Woodland. If mechanized equipment is made available for treatment in the least sensitive vegetation types, the figure should be much higher. Depending on the availability of funding and personnel the first phase of tamarisk removal within the 450 most critical hectares of Dos Palmas is expected to require approximately ten years, much less if heavy equipment is made available. During this period, it is anticipated that areas will be retreated at least once a year following the initial treatment to control re-sprouting and kill seedlings. Studies show that follow-up treatments can be done by a small crew in a short time, if it is done on a regular basis. Where possible, inmate crews or California Conservation Corps crews will be used for removal and maintenance. The use of pesticides will be supervised by a certified pesticide applicator.

Wherever possible, natural regeneration of native species will be relied upon to restore the vegetation cover in areas where tamarisk is removed. Some species, including arrowweed and saltgrass, are expected to regenerate quickly without human intervention in suitable areas. Once established, native plants generally provide more valuable cover and forage for wildlife (Kerpez and Smith, 1987). In areas where natural regeneration cannot proceed rapidly enough to prevent soil erosion and restore wildlife

habitat, native vegetation will be planted. To the extent possible nursery stock will be grown from local seeds. One successful planting technique used at the Cibola National Wildlife refuge involved seeding areas cleared of tamarisk with quailbrush (*Atriplex lentiformis*) and saltgrass (*Distichlis spicata*) to enhance wildlife habitat and compete against tamarisk re-sprouts. It is anticipated that these areas will be spot-planted with mesquite and/or any of the species naturally occurring within the vegetation associations found at Dos Palmas. A detailed revegetation plan is being prepared that will incorporate the findings of Anderson and Miller (1992) regarding the edaphic suitability of various microhabitats at Dos Palmas for native plant species.

The Tamarisk Removal Program at Afton Canyon

Site description. - Afton Canyon is located in the lower Mojave River drainage of the western Mojave Desert, southwest of Soda Dry Lake, in San Bernardino County (Figure 1). Currently, it is one of only three places where the Mojave River flows above ground. Camping, vehicle touring, equestrian use, and rockhounding are popular activities in the canyon and cattle grazing occurs year-round in the western portion of the canyon. Past off-highway vehicle (OHV) soil disturbance and overgrazing within the canyon have at times been severe. Due to these factors, approximately 9,300 hectares of public land encompassing the Mojave River at Afton Canyon were designated as the Afton Canyon Area of Critical Environmental Concern in the BLM's California Desert Conservation Area Plan (Bureau of Land Management, 1980).

Headwater tributaries in the San Bernardino Mountains account for 90 percent of the total Mojave River flow. Despite the recent construction of headwater dams and a significant water overdraft problem upstream from Afton Canyon, winter water flows can be highly variable. Controlling for major flood years, the ten year average surface flow through the canyon is less than 1,000 acre feet per year, with annual area precipitation averaging 10 cm (Bureau of Land Management, 1989). The entire canyon is currently in public ownership, with riparian stream length totalling 5 km.

Native riparian vegetation once dominated the canyon bottomlands but an estimated 70 percent of this vegetation has been replaced by tamarisk (Bureau of Land Management, 1989). This species is thought to have been introduced to the canyon in the early 1900's via railroad use, grazing and settlement in the vicinity. However, extensive tamarisk stands were not noted until the 1960's. Reduced river flows, extensive OHV soil disturbance, year-round cattle grazing and native tree woodcutting all likely contributed to tamarisk proliferation within the canyon.

Although drastically altered by tamarisk establishment, Afton Canyon remains a critical migratory stopover point for several neotropical bird species and provides essential riparian habitat for several sensitive/protected resident species. Included among the latter are desert bighorn sheep (*Ovis canadensis nelsoni*), southwestern pond turtles (*Clemmys marmorata pallida*), long-eared owls (*Asio otus*), loggerhead shrike (*Lanius ludovicianus*) and an unclassified endemic toad species (Von Seckendorff Hoff, UNLV, pers. comm.).

Afton Canyon proper is characterized by six vegetation assemblages: Mojave Riparian Forest, Mojave Freshwater Marsh, Alkali Meadows & Seeps, Mojave Desert Wash, Honey Mesquite Bosque and Alkali Scrub. As at Dos Palmas, tamarisk is invading all these assemblages to a certain degree, although tamarisk dominance/density decreases with increasing distance from the central channel of the Mojave River. Dominant plant species in decreasing order of dominance include saltcedar (*Tamarix ramosissima*), saltgrass (*Distichlis spicata*), arrowweed (*Pluchea sericea*), saltbush (*Atriplex polycarpa*, *A. lentiformis*), honey mesquite (*Prosopis glandulosa*), rushes (*Juncus textilis*, *J. balticus*), sedges (*Scirpus olneyi*, *S. acutus*, *S. americanus*), screwbean mesquite (*Prosopis pubescens*), Gooding's black willow (*Salix gooddingii*), desert willow (*Chilopsis linearis*) and Fremont cottonwood (*Populus fremontii*).

Native riparian ecosystems are recognized as an Unusual Plant Assemblage in the BLM's California Desert Conservation Area Plan, due both to their rarity in the California Desert and their importance to wildlife (Bureau of Land Management, 1980). As directed in the former document, a final management plan for Afton Canyon was completed with a primary management goal of improving riparian habitat condition while accommodating low-impact recreation, and continued livestock grazing compatible with riparian habitat protection (Bureau of Land Management, 1989). Tamarisk removal is a critical objective for achieving the stated goal.

Tamarisk removal at Afton Canyon. - The Barstow Resource Area Office of the BLM initiated an anticipated 10 year program to remove approximately 240 ha of tamarisk from Afton Canyon in 1992. The removal technique selected for use in the first two years of the program involved a combination of the cut stump/herbicide method (Sudbrock, 1993) and burning followed by herbicide application. Complete low level, infrared aerial photography of the canyon was completed to assist in determining removal area priorities, based on tamarisk seed sources and wildlife habitat value information. Office staff and BLM fire crews served as project personnel as available. The first treatment (July 1992) consisted of a planned 40 ha burn encompassing low to high density, young to old age class tamarisk. Prior to the burn, firebreaks were manually constructed around 100 native trees to limit fire impacts to potential native seed sources and to serve secondarily as staging/escape areas for fire personnel. Burnt saltcedar resprouts (average height < 1 m) were treated with a foliar herbicide application. Locales where fire did not carry within the treatment area, such as wet meadows and low density/young age class tamarisk stands, were treated with a cut stem-herbicide application. Portions of standing dead tamarisk remaining post-fire were cut in order to foster native plant germination and to increase ground cover utilized by wildlife. Natural revegetation then proceeded, with supplemental revegetation limited to the planting of 100 Fremont cottonwood trees and the manual dispersal of native grass, shrub and tree seed (15 kg total).

Of the planned 40 ha tamarisk burn in 1992, approximately 16 ha were impacted by low (3.2 ha), medium (8 ha), and high (4.8 ha) intensity fire. Large unburned stands remained in the western treatment area and partially burned ribbon stands remained along flow channels. Canopy and litter cover in the burn areas decreased dramatically post-fire, with a concurrent increase in bare soil. Although fire coverage was less than desired, overall access into the burned areas was greatly increased, facilitating herbicide application. Apparent fire mortality of tamarisk within high intensity burn areas was estimated to be low (10 to 25 percent). Fire mortality was not noted within low or medium intensity burn areas. Live fuel moisture, fuel loading and live to dead vegetation ratios were found to be critical components influencing combustibility/fire spread. An estimated 50 percent (8 ha) of the initial fire treated area required further cut stem-herbicide treatment, as these moderately burned stands occurred in small disjunct patches and lacked sufficient fuels to carry secondary burning. Approximately 20 percent (3.2 ha) of the initial fire treated area was secondarily burned in November, 1993, resulting in fire coverage similar to the initial burn.

Tamarisk resprouting was first noted in the initial treatment area on 15 August 1992, two weeks following the initial fire treatment. Two herbicide application sweeps of the initial moderate and high fire intensity areas were completed within a three month period (August to November 1992), with herbicide use totalling 55 liters/ha. One herbicide application sweep of the 1993 burn treatment area (3.2 ha) and a third herbicide application sweep of the initial 1992 moderate/high burn intensity areas were completed in 1993, though herbicide amounts used in 1993 have yet to be calculated.

Burn-herbicide treated areas exhibited varying degrees of efficacy, with photoplots documenting 100 percent tamarisk mortality in some places. Overall, apparent tamarisk mortality was estimated to be fair (60 percent). High intensity burn areas exhibited apparent mortality rates of 70-100 percent. following the second herbicide application (Egan et al. 1993). At least one additional herbicide sweep will be necessary in the 1992 moderate/high intensity burn areas to kill sprouts not visible during the first three herbicide sweeps. Three additional herbicide sweeps will be necessary in the 1993 burn area.

and additional cut stem-herbicide application will be required in small unburned tamarisk patches throughout both 1992 and 1993 treatment areas.

Four ha of young to moderate age class, unburned tamarisk were treated with the cut stem-herbicide application component of the selected removal program in late 1992. Tamarisk canopy cover was eliminated and native trees in the proximity of this treatment exhibited tremendous canopy cover increases. Areas thus treated exhibited 100 percent tamarisk mortality from a single herbicide application. However, this quick mortality has its tradeoff in that this component of the Afton removal technique is extremely labor intensive.

Biologically, those areas where removal is 90-100 percent complete (terraces in the high fire intensity areas) have responded exceedingly well to treatments. Herbaceous cover has increased 100-fold when compared to pre-treatment and mammal densities/forage use are the highest recorded in the canyon. Native snags, formally useless to avian perching species now support high bird numbers. Cavity nesting birds, once virtually absent from the canyon, have been observed foraging and taking up residence. Native tree pole plantings are scheduled for early 1994 project work and are expected to attract several additional avian species that were once abundant along the Mojave River. Surface water levels in these areas have increased dramatically (up to 30 cm depth increase in some areas) and plant species diversity has increased at least three-fold.

Primary factors complicating treatment throughout the first two years of this program included: 1) incomplete fire coverage, 2) personnel limitations, 3) high project costs, 4) equipment failure, 5) winter flooding (additional tamarisk seed and sprouting material was washed into cleared areas), 6) continued authorized livestock grazing impacts including hoof soil-punching that provides ideal tamarisk germination strata, and utilization of native vegetation, and 7) unauthorized OHV soil disturbance that provides disturbed conditions ideal for tamarisk germination. First year treatment costs ($2.5K/ha) were thought to represent the high range in the spectrum of tamarisk removal expense, due to the learning curve associated with large scale vegetation treatments. Second year treatment costs have yet to be calculated, though the costs were significantly less than first year expenses. Depending on tamarisk stand density, protection provided to native trees and fire intensity/spread, future removal costs are expected to be in the $1.5 - 2.5K/ha range (Egan et al, 1993).

Conclusions

In summary, tamarisk removal on public land is constrained by funding and personnel limitations. Presently, very little funding is allocated annually to exotic plant removal on public lands and existing personnel are often inadequate to cope with the rapidly increasing problem of exotic plant invasions. The Palm Springs-South Coast Resource Area Office of the BLM has worked very closely with The Nature Conservancy and other organizations at Dos Palmas. Partnerships such as these are essential in the battle to protect natural areas from invasive exotic plants and restore native ecosystems.

Resource uses that conflict with desired ecosystem management objectives can also hinder efforts to restore native habitats, particularly when these uses are well established. Alterations to natural water flow regimes and upstream seed/vegetative sprout sources complicate invasion control even further when addressing downstream portions of major riverine systems. In order to overcome these seemingly insurmountable odds, the Barstow Resource Area Office, BLM, has developed several project initiatives and incorporated methods employed by others involved in similar projects. To date, a network of governmental agencies and private organizations that are involved in tamarisk control throughout the Southwest has been established to disseminate recent findings and develop cost-effective control methods. A technical review team involving all affected interests in Afton Canyon has been organized to determine the most efficient way to revegetate Afton Canyon with the least impact upon resource users. Local industry land owners have been contacted and agreed to donate necessary revegetation plant

stock material. Local Boy Scout, school and volunteer groups have been contacted and have agreed to assist in project work to any extent that they can, and an agreement has been made with a local prison for the use of inmate labor. In addition, the possibility of beaver (*Castor canadensis*) reintroduction is being explored to assist in controlling tamarisk reinvasion through germination substrate inundation, following sufficient native vegetation establishment. Collectively these integrated strategies for management of invasive exotic plants are our best chance of restoring native ecosystems in riparian areas of the California desert.

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LITERATURE CITED

Anderson, J. E. 1982. Factors controlling transpiration and photosynthesis in *Tamarix chinensis* Lour. Ecology 63(1):48-56.

Anderson, B. W., and E. R. Miller. 1990. Revegetation and the need to control exotic plant species. *In*, Yosemite Centennial Symposium Proceedings. Natural Areas and Yosemite: Prospects for the future. pp. 350-358.

Anderson, B. W., and E. R. Miller. 1992. Suitability of the Rancho Dos Palmas area for revegetation. Draft Report to Metropolitan Water District, Los Angeles. 66 pp. + iv.

Barrows, C. W. 1993. Tamarisk control II: a success study. Restoration and Management Notes. 11:35-38.

Brotherson, J. D. and V. Winkel. 1986. Habitat relationships of saltcedar (*Tamarix ramosissima*) in central Utah. Great Basin Naturalist 46(3):535-541.

Brotherson, J. D. and D. Field. 1987. Tamarix: impacts of a successful weed. Rangelands 9(3):110-112.

Brotherson, J. D., J. G. Carman, L. A. Szyska. 1984. Stem-diameter age relationships of *Tamarix ramosissima* in central Utah. Journal of Range Management 37(4):362-364.

Brown, B. T. and M. W. Trosset. 1989. Nesting-habitat relationships of riparian birds along the Colorado River in Grand Canyon, Arizona. Southwestern Naturalist 34(2):260-270.

Bureau of Land Management. 1980. California Desert Conservation Area Plan. Bureau of Land Management. California Desert District. Riverside, California.

Bureau of Land Management. 1982. Salt Creek Desert Pupfish/Rail Habitat Area of Critical Environmental Concern Management Plan. Bureau of Land Management. California Desert District. Riverside, California.

Bureau of Land Management. 1988. California vegetation management: final environmental impact statement. United States Department of the Interior.

Bureau of Land Management. 1989. Afton Canyon Area of Critical Environmental Concern management plan. Barstow, California.

Bureau of Reclamation. 1992. Vegetation management study: lower Colorado River. Phase I Report. Boulder City, Nevada.

Busch, D. E., N. L. Ingraham, S. D. Smith. 1992. Water uptake in woody riparian phreatophytes of the southwestern United States: a stable isotope study. Ecological Applications 2(4):450-459.

California Exotic Pest Plant Council. 1993. California Exotic Pest Plant Council draft list: exotic pest plants of greatest concern. CalEPPC News 1:6-7.

Cook, M. J. 1989. Tamarisk Control. #2. *In*, Pest Management Series on Integrated Pest Management on California Parklands. State of California, Department of Food and Agriculture.

Davenport, D. C., P. E. Martin, and R. M. Hagan. 1982a. Evapotranspiration from riparian vegetation: water relations and irrecoverable losses for saltcedar. Journal of Soil and Water Conservation 37(4):233-236.

Davenport, D. C., P. E. Martin, R. M. Hagan. 1982b. Evapotranspiration from riparian vegetation: conserving water by reducing saltcedar transpiration. Journal of Soil and Water Conservation 37(4):237-239.

Egan, T. B., R. A. Chavez, and B. R. West. 1993. Afton Canyon saltcedar removal first year status report. *In*, L. Smith and J. Stephenson (tech. coords.), Proceedings of the Symposium on Vegetation Management of Hot Desert Rangeland Ecosystems. Phoenix, Arizona.

Garman, J. G. and J. D. Brotherson.. 1982. Comparisons of sites infested and not infested with saltcedar (*Tamarix pentandra*) and Russian olive (*Elaeagnus angustifolia*). Weed Science 30:360-364.

Glinski, R. L. and R. D. Ohmart. 1983. Breeding ecology of the Mississippi Kite in Arizona. The Condor 85:200-207.

Griffin, G. F., D. M. Stafford Smith, S. R. Morton, G. E. Allan, and K. A. Masters. 1989. Status and implications of the invasion of tamarisk (*Tamarix aphylla*) on the Finke River, Northern Territory, Australia. J. Environ. Mgmt. 29:297-315.

Holland, R. F. 1986. Preliminary descriptions of the terrestrial natural communities of California. The Resources Agency, California Department of Fish and Game. Sacramento, California.

Horton, J. S. 1977. The development and perpetuation of the permanent tamarisk type in the phreatophyte zone of the southwest. USDA For. Serv. Gen. Tech.,Rep., U.S. Rocky My. For. Range Exp. Sta. 43:124-127.

Howe, W. H. and F. L. Knopf. 1991. On the imminent decline of Rio Grande cottonwoods in central New Mexico. Southwestern Naturalist 36(2):218-224.

Hunter, W. C., R. D. Ohmart, and B. W. Anderson. 1988. Use of exotic saltcedar (*Tamarix chinensis*) by birds in arid riparian systems. The Condor 90:113-123.

Johnson, S. 1987. Can tamarisk be controlled? Fremontia 15:19-20.

Kerpez, T. A., and N. S. Smith. 1987. Saltcedar control for wildlife habitat improvement in the southwest United States. U.S. Department of the Interior, Fish and Wildlife Service, Resource Publication 169. 16 pp.

Kunzmann, M. R. and R. R. Johnson. 1989. Introduction. *In*, Tamarisk control in the southwestern United States. pp. 1-7. Kunzmann, M. R., R. R. Johnson, and P. S. Bennett (editors). U.S. Department of the Interior, National Park Service, Special Report No. 9 (Revised August, 1990). 144 pp.

Kunzmann, M. R., R. R. Johnson, and P. S. Bennett (editors). 1989. Tamarisk control in the southwestern United States. U.S. Department of the Interior, National Park Service, Special Report No. 9 (Revised August, 1990). 144 pp.

Neill, W.M. 1983. The tamarisk invasion of desert riparian areas. Education Foundation of the Desert Protective Council, Inc. Educational Bulletin No. 83-4:1-4.

Rice, J., R. D. Ohmart, and B. W. Anderson. 1983. Habitat selection attributes of an avian community: a discriminant analysis investigation. Ecological Monographs 53(3):263-290.

Rosenberg, K. V., R. D. Ohmart, W. C. Hunter, and B. W. Anderson. 1991. Birds of the lower Colorado River valley. The University of Arizona Press, Tucson.

Sudbrock, A. 1993. Tamarisk control I. Fighting back: an overview of the invasion, and a low-impact way of fighting it. Restoration and Management Notes 11:31-34.

The Keystone Center. 1991. Biological diversity on public lands: report of a Keystone Policy Dialogue. The Keystone Center, 96 p.

Thomson, W. W., W. L. Berry, and L. L. Liu. 1969. Localization and secretion of salt by the salt glands of *Tamarix aphylla*. Proc. Nat. Acad. Sci. 63(2):310-317.

Van Hylckama, T. E. A. 1970. Water use by salt cedar. Water Resources Research 6:728-735.

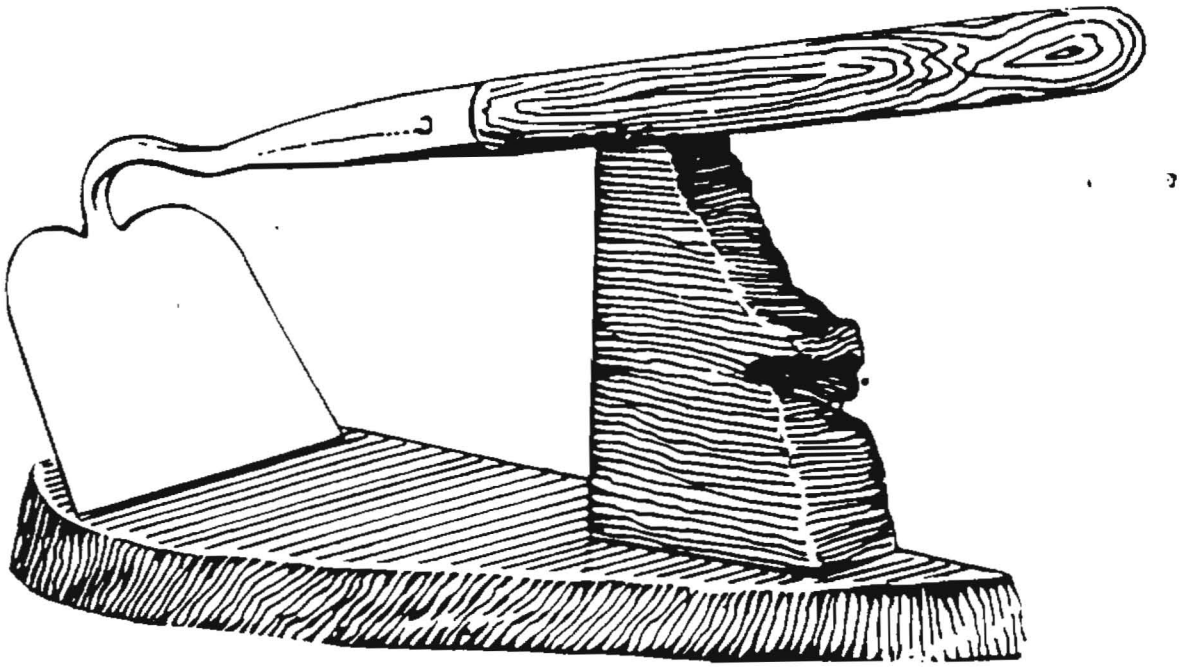
Weeks, E. T., H. L. Weaver., G. S. Campbell, and B. D. Tanner. 1987. Water use by saltcedar and by replacement vegetation in the Pecos River floodplain between Acme and Artesia, New Mexico. U.S. Geological Survey Professional Paper 491-G. 33 pp.

PROCEEDINGS

46th ANNUAL

CALIFORNIA WEED SCIENCE SOCIETY

THEME: "ENVIRONMENTAL STEWARDSHIP THROUGH WEED CONTROL"

RED LION HOTEL
SAN JOSE, CALIFORNIA

January 17, 18 and 19, 1994