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Chapter Thirty

SALTCEDAR INVASION IN DESERT WETLANDS OF THE SOUTHWESTERN UNITED STATES: ECOLOGICAL AND POLITICAL IMPLICATIONS

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INTRODUCTION

One of 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 (Soulé, 1990).

Saltcedar or tamarisk (Figure 1) 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 1800's 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

FIGURE 1. The flowers of saltcedar or tamarisk (*Tamarix ramosissima*) range from almost white to deep pink. Photograph by Jeff Lovich.

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. 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 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 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 Soulé (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 biodiversity by becoming more monotypic, and all springs become more similar in their species compositions 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 Waisel, 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 1). It is capable of tolerating wide variations in environmental conditions (Brotherson and 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.

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. Sand bars 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 (1984) 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.

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

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. fremontii* 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 electroconductivities 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 (*Ictinia 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. 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 (1991a) 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 some 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 (Figure 2). The unlined, earthen canal brought two major landscape changes to the Basin: it

FIGURE 2. Aerial view of the Dos Palmas Area of Critical Environmental Concern in Riverside County, California. The outline of the Coachella Canal can be seen following the base of the Orocopia mountains at an elevation of near sea level. The area was extensively developed for aquaculture and numerous artificial ponds are visible in this photograph. Most of the dark vegetation in the washes on the right side of the photograph is saltcedar. Photograph provided courtesy of Martin Einert, Bureau of Reclamation.

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; 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. 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; 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 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; 1993).

In the Draft Environmental Impact Statement/Environmental Impact Review (EIS/EIR) prepared by the BOR (USDI, 1993), in consultation with the U.S. Fish and Wildlife Service (USFWS), 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 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 pre-lining 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 salt cedar. 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 were 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; Zwölfer 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.*" 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. The "Peninsular Ranges" metapopulation of bighorn sheep (*Ovis canadensis 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 (*Felis 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 a Biological 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 *Diorhabda* (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 be 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 (Soulé, 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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