Saltcedar (*Tamarix*)

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**<u>Introduction:</u>**

Saltcedar invasion is a primary concern throughout much of the west. It was brought to the United States in the mid-1800's and planted into the 1930's as an ornamental and for erosion control. It essentially became naturalized by the 1870's. Saltcedar occupies 1 to 1.6 million acres from northern Mexico to central Montana and from central Kansas to central California (Shafroth et al 2005) but Friedman et al (2005) indicates occurrence into northern Washington, Montana, and North Dakota. These data did not indicate if this included ephemeral or upland sites where riparian woody plants would not be expected.

There is much discussion about saltcedar and its affect on riparian and stream systems. The spread of saltcedar throughout the west has become such a cause for concern that the *Salt Cedar and Russian Olive Control Demonstration Act H.R. 2720* was passed in 2006:

"(1) to assess the extent of the infestation by salt cedar and Russian olive trees in the western United States;
(2) to demonstrate strategic solutions for –
    (A) The long-term management of salt cedar and Russian olive trees; and
    (B) The reestablishment of native vegetation; and
(3) to assess economic means to dispose of biomass created as a result of removal of salt cedar and Russian olive trees."

It is estimated that saltcedar (*Tamarix ramosissima* and *Elaeagnus angustifolia*) are the third and fourth most frequently occurring woody riparian plants in the 17 western states and are the second and fifth most dominant woody riparian species in the western USA (Friedman et al 2005). These numbers are based on a comparison with ten of what they considered the most frequently occurring woody riparian plants in the western USA (Friedman et al 2005). The frequency of occurrence of *T. ramosissima* has a strong positive relation with the mean annual minimum temperature, which is consistent with hypothesized frost sensitivity (Friedman et al 2005). In contrast, Friedman et al (2005) found the frequency of occurrence of E. angustifolia decreases with increasing minimum temperatures. There are at least twelve species of saltcedar plus hybrids that have been found in the U.S.

This is a short briefing paper and should not be considered a comprehensive literature review, but addresses some of the questions most often heard by the NRST and addresses some of the most recent saltcedar literature and discussions.

Shafroth et al (2005) addressed the following questions regarding saltcedar eradication or control:

1. Will saltcedar control result in significant and measurable increases in water yield?
2. Is saltcedar inferior wildlife habitat compared to the vegetation likely to replace it following control and revegetation?
3. What methods are used to control saltcedar, and what are the costs and benefits associated with different methods?
4. What vegetation types are likely to replace saltcedar, and under what conditions is restoration or revegetation likely to succeed or fail?

These questions coincided with most of mine as well, but one question that should be added is:

5. How does saltcedar affect the physical functionality of a riparian-wetland area?

**Discussion:**

Woody riparian vegetation grows in a variety of geomorphic settings ranging from bedrock-lined channels to perennial streams crossing deep alluvium and is dependent on interactions between ground-water and surface-water resources (Webb and Leake 2006).

Different riparian areas depend on the influent-effluent nature of the stream differently. There are rivers that have had this hydrologic characteristic eliminated by ground-water withdrawal, but in many cases the influent-effluent setting that creates alternating perennial-ephemeral reaches has been artificially restored owing to irrigation returns and waste-water effluent discharge (Webb and Leake 2006).

The natural flow regimes of the major western U.S. Rivers have been altered by dams, flow regulation, diversion of water for human use, and climate change. As a result, the floodplains of many rivers have become drier and more saline than in the pre-dam era, and riparian water tables have declined (Glenn and Nagler 2005). These conditions favored the replacement of native mesic trees such as cottonwood and willow by saltcedar, an introduced shrub from Eurasia. Saltcedar has a greater salt and drought tolerance, resistance to water stress, and fire tolerance than mesic native trees (Glenn and Nagler 2005). But, Pratt and Black (2006) found that five sampled invader species (including Tamarix amygdaloides, in the U.S. are not more tolerant to water stress than co-occurring native species, and actually were under greater water stress than the native species. T. ramosissima may have a greater variation in cavitation (the water potential at 75% loss of hydraulic conductivity) resistance which may be connected to denser xylem and may partially explain why it is able to invade a broad range of habitats in the western U.S. (Pratt and Black 2006). They found that the spread and invasive nature of the sampled species cannot be explained by hydraulic traits alone. As early as 1958, Elton hypothesized that in their new ranges invaders do not face as many specialist competitors, herbivores, or parasites compared to their native ranges and this release from enemies facilitates their spread.

It also produces seed over the entire summer growing season and can grow 3-4 m in height in a single growing season. On the other hand, under a natural flow regime, native trees are competitive with saltcedar in germination and establishment during a flood year and they have equal or faster growth rates. Cottonwood and willow have shown the ability to establish despite the presence of saltcedar on rivers that still experience a pulse flood regime or where floods have been reestablished (Glenn and Nagler 2005). It should also be recognized that water quality has improved and there are good tail-water fisheries in some areas we never had before due to these dams. Not all dams are bad and our values play an important part in determining what the desired ecologic state should be in our riverine systems.

1. **Will saltcedar control result in significant and measurable increases in water yield?**

Many resource managers seek to reduce saltcedar abundance and control its spread to increase the flow of water in streams that might otherwise be lost to evapotranspiration. However, increased water yield might not always occur and has been substantially lower than expected in water salvage experiments (Shafroth et al. 2005). Contrary to previous reviews, the current evidence does not support the conclusion that saltcedar has unusually high evapotranspiration rates or leaf area index that would allow it to desiccate water courses (Glen and Nagler 2005). Water-use studies indicate that increases in water yield following saltcedar control is likely to occur only when a saltcedar stand containing high leaf area is replaced by vegetation with a lower leaf area (see attached Table 1). The extent to which differences in evapotranspiration are manifested as a measurable, usable water yield increase or loss is variable (Shafroth et al 2005) and difficult to measure.

Table 1. Daily and annual ET estimates for Saltcedar and other southwestern riparian vegetation types--(Patrick et al. 2005. Control of *Tamarix* in the Western United States: Implications for water Salvage, Wildlife Use, and Riparian Restoration. Journal of Environmental Management Vol. 35, No. 3, pp 231-246.)

| Vegetation type | ET estimate [mm/day] (m/year) | Study Location | Method | Citation |
|---|---|---|---|---|
| Saltcedar | (1.2-3) | Gila River, AZ | Lysimeters | Gatewood & others 1950 |
| | (1.0-3.4) | Gila Rive, AZ | Lysimeters | Van Hylckama 1974 |
| | (0.7) | Gila Rive, AZ | Water Budget | Van Hylckama 1974 |
| | (1.3) | Gila Rive, AZ | Water Budget | Culler & others 1982 |
| | (1.7) | Colorado River, AZ-CA | BREB | Gay & Hartman 1982 |
| | 0-12.5 (0.7-1.4) | Virgin River, NV | BREB | Devitt & others 1998 |
| | 1-10 (1.1-1.2) | Rio Grande, NM | EC | Cleverly & others 2002 Dahm & others 2002 |
| | (>0.6-1.1) | Pecos River, NM | EC | Weeks & others 1987 |
| | 24.8 | Colorado River, Mexico | Sap Flux | Nagler & others 2003 |
| Cottonwood | (1.4-3.3) | Gila River, NM | Lysimeters | Gatewood & others 1950 |
| | 3.1-5.7 | San Pedro River, AZ | Sap Flux | Schaeffer & others 2000 |
| | 1-9 (1.0-1.2) | Rio Grande, NM | EC | Dahm & others 2002 |
| | 19.5 | Colorado River, Mexico | Sap Flux | Nagler & others 2003 |
| Mesquite | 1.6-2.4 (0.4) | San Pedro River, AZ | BREB | Scott & others 2000 |
| | (0.6-0.7) | San Pedro River, AZ | EC | Scott & others 2004 |
| Salt grass/saltcedar | 1-6 (0.7-0.8) | Rio Grande, NM | EC | Cleverly & others 2002 Dahm & others 2002 |
| Salt Grass | (0.3-1.2) | Various Sites | Lysimeters | Weeks & others 1987 |
| | 1.1-4.5 | Sonora, Mexico | Lysimeters | Miyamoto & others 1996 |
| Sacaton grass | 0.3-1.6 | San Pedro river, AZ | BREB | Scott & others 2000 |
| Bare soil & sparse annual weeds | 0.6 | Gila River, AZ | Water Budget | Culler & others 1982 |
| Annual weeds, grasses, & bare soil | (0.6-0.7) | Pecos River, NM | EC | Weeks & others 1987 |

See Cleverly et al. (2002) for a more comprehensive review of published saltcedar ET estimates.
Abbreviations: BREB: Bowen Ratio Energy Balance; EC: Eddy Covariance.

Owens and Moore (2007) used three separate methods to determine water use by salt cedar:

1. Literature review of woody plant water use.
2. Using reported levels of sap flux for salt cedar and the sapwood area of the plants.
3. Comparing the amounts of water lost from pan evaporation to the reported water use.

It has been suggested that salt cedar uses up to 200 gal/day (757 L) in documents including North Dakota Extension Bulletins (Owens and Moore 2006). The mean water use of over 100 species of woody plants from around the world is 117.5 L (38 gal/day). If a value is greater than the mean plus 3 times the standard deviation (150 gallons), then it is generally a statistical outlier and is dropped from analyses. The reported 200 gallons is clearly outside of this limit and should be viewed skeptically. The second line of evidence is using reported levels of sap flux for *Tamarix* and the sapwood area of the plants. To achieve a flow of 200 gallons per day with the reported sap flux rates, a tree would need over 1800 cm2 of sapwood area. Actual sapwood measured at 2 sites of mature *Tamarix* on the Pecos River and 3 sites on the Rio Grande River is only one tenth of this amount. The entire amount of sapwood from a 200 m2 plot was not sufficient to allow water use of 200 gallons per day. The third line of evidence is to compare the amount of water lost from pan evaporation to the reported water use. Assuming an average canopy diameter of 20 feet, the energy available for evaporation from a free water surface can account for up to 120 gallons of evaporation over most of the distribution of *Tamarix*. *Tamarix* often supports a high leaf area index which would increase the surface area for water loss, but after accounting for conductance restrictions and conduit size, it is clear that these plants cannot transport that much water (Owens and Moore 2007).

2. **Is saltcedar inferior wildlife habitat compared to the vegetation likely to replace it following control and revegetation?**

Many wildlife taxa prefer native cottonwood, willow, and mesquite habitats to saltcedar, but saltcedar can also serve as adequate habitat for numerous species. Fleishman et al (2003) concluded that saltcedar did not reduce the bird habitat value of the riparian zone, so long as the vegetation formed a multileveled canopy structure. They found that neither species richness of plants nor dominance of non-native plants had a statistically significant effect on species richness, abundance or evenness of birds. Other replacement vegetation (e.g. xeric shrubs, grasses, annual weeds) is less likely to be an improvement for wildlife, although mixtures of vegetation types can result in high wildlife use. Complexity in wildlife response and variation in management priorities will continue to make generalizations difficult regarding wildlife habitat values (Shafroth et al 2005). Glenn and Nagler (2005) state that allowing saltcedar and native trees to coexist would maximize the habitat value of the riparian zone.

Moline and Poff (2006) found that tamarisk appears to be a good food for the common aquatic invertebrate shredder *Tipula* larvae. The ecosystem scale effect of tamarisk on stream invertebrates is still unclear, as Western streams tend to be flashy and leaf litter is frequently flushed from the system. Tamarisk leaves are small and may be easily transported downstream. The aquatic shredders constitute a relatively small portion of the aquatic invertebrate fauna in Western streams, so the positive overall impact of tamarisk on stream food webs may be small (Moline and Poff 2006). Ultimately, the determination of wildlife benefits is at the species level. When habitat conditions are manipulated for one species, another species' habitat suffers.

3. **What methods are used to control saltcedar, and what are the costs and benefits associated with different methods?**

Mechanical or chemical control can lead to high levels of saltcedar mortality. Results of biological control are still emerging, although extensive defoliation has occurred in open field settings. The method chosen generally depends on specifics of the landscape setting, costs, and management and socio-political constraints (Shafroth et al 2005). No matter which method is used, follow-up treatment and management will be required to improve or increase native vegetation.

A significant amount of herbicide reaches the soil surface even in a closed canopy which could negatively affect restoration efforts when high volumes of chemicals are applied to control tamarisk. If high volume chemical applications are reduced it could result in much greater herbicide retention by the tamarisk canopy, less herbicide reaching the soil surface, reduced application costs and more rapid restoration of desired species (Nissen et al 2007).

An effective strategy for restoration associated with saltcedar invasion must include the return of a more dynamic hydrological regime to regulated rivers, allowing saltcedar and native trees to coexist (Shafroth et al 2005). A strategy for revegetation should be based on the site characteristics (ground water depth and fluctuation), soil characteristics (salinity and texture), and flooding (natural versus regulated) (Bay and Sher 2006). They found that lower soil salinity and pH and coarser soil texture as well as proximity to permanent water, sufficient precipitation, and good drainage all favored native species in their tests on 28 sites in New Mexico, Arizona, and Nevada. Additionally, success increased with time since *Tamarix* removal, both increasing native cover and richness and decreasing *Tamarix* cover. Overall, those site characteristics that promoted native species success were the same as those that contributed to a lower cover of *Tamarix*.

Lesica and Miles (2005) research on the Fort Peck Reservoir, MT, suggests that three months of inundation will kill saltcedar.

The Tamarisk Coalition (2006) developed cost estimates for non-native phreatophyte control assuming an Integrated Pest Management approach. Management of non-native phreatophytes consists of five components – planning with inventory/mapping, control, revegetation, monitoring, and maintenance. Without all five components it is unlikely that tamarisk control projects will be successful over the long term. Successful management also depends on changing approaches based on experience and newer technologies becoming available; i.e., adaptive management (Tamarisk Coalition 2006). The Tamarisk Coalition (2006) has a cohesive summary of all costs associated with solving the tamarisk problem. It presents the high, low, and most likely costs one might expect to improve and maintain site conditions. Individual project areas will need to develop refined cost estimates given their specific site conditions and control/revegetation approaches.

**4. What vegetation types are likely to replace saltcedar, and under what conditions is restoration or revegetation likely to succeed or fail?**

The composition of replacement vegetation is central to water salvage, wildlife habitat considerations, and prevention of reinfestation. Vegetation types likely to replace saltcedar depend on site conditions and the restoration approaches that can be implemented. In some cases revegetation with mesic riparian species is likely to be feasible, while in other situations planting more xeric or salt-tolerant taxa will be most appropriate. Failure to carefully plan and implement restoration efforts may result in recolonization of the site by saltcedar or other exotic species (Shafroth et al 2005).

Lesica and Miles (2005) found that saltcedar may be better adapted to colonizing many prairie streams in eastern Montana and other parts of the Northern Great Plains than native woody species. Cottonwood and willow are adapted to establish on snow-melt streams, by producing short-lived seed that germinates as flood waters decline in late spring. However, most tributaries of the Missouri east of the Musselshell River have low-elevation watersheds with little winter snow accumulation. Flooding of these streams is more likely to occur following summer convectional storms. Cottonwood and willow seed are not usually available at these times. However, saltcedar produces seed throughout most of the growing season and is able to take advantage of summer floods. They also suggest that saltcedar may be able to invade the western wheatgrass habitat type, especially with depressional wetlands or stock ponds. The long-term effects on this particular community are not known, however, they feel that the perennial grass cover will undoubtedly decline under the shade of the invading shrub.

Glenn and Nagler (2005) found that saltcedar does not have a competitive advantage over cottonwood and willow with respect to seedling growth and establishment under natural spring flood conditions. They also found that under a natural flow regime, native trees are competitive with saltcedar in germination and establishment during a flood year and they have equal or faster growth rates.

Mechanical removal was highly effective in reducing *Tamarix* cover at treatment sites, however a prevalence of re-sprouting and recruitment from seed along treated reaches indicates that follow-up treatment is necessary to prevent re-establishment of *Tamarix* along flow regulated rivers in two valley settings: one along an alluvial reach of the Middle Rio Grande, NM and the other in a confined, bedrock canyon reach of the Upper Green River, UT (Merritt et al. 2006). Historical reconstruction of channel narrowing and establishment indicate that long-term removal of *Tamarix* is likely to be more successful on abandoned fluvial surfaces, as recruitment continues along fluvially active channel margins (Merritt et al. 2006). They also found that the frequency of exotic herbaceous species was higher in areas disturbed during *Tamarix* removal, resulting in higher proportion of exotic herbaceous species in treated sites compared to controls. They suggest that to minimize risk of exotic species invasion by evaluating site conditions that might facilitate post-removal invasion (e.g., presence of local seed sources, vegetative propagule sources, vectors, the creation of ‘open sites’). Large magnitude, long-duration floods would be expected to result in changes in channel geometry, mobilization of bars and channel margin deposits, removal of herbaceous and woody vegetation, and establishment of more natural physical, biological, and plant successional processes (Merritt et al. 2006). Floods of large magnitude may be a possibility depending upon physical setting, geomorphic and hydrologic context, and socio-economic constraints. Such flooding could provide an efficient means of ‘passively’ restoring key ecological processes and riparian vegetation (Merritt et al. 2006).

A proper maintenance plan should be implemented no matter which means of restoration is implemented. Saltcedar seed sources on the soil surface will still have the opportunity to germinate. The expensive cost of restoration is driven higher if continued control of weed species is not planned and implemented.

5. **How does saltcedar affect the physical functionality of a riparian-wetland area?**

Usually, one of the primary reasons for tamarisk invasion (other than being planted for erosion control) is a lack of the hydrologic or erosion/deposition attributes and processes needed for a particular system. The Proper Functioning Condition (PFC) assessment is one qualitative method for assessing the condition of riparian areas while taking into account the system's potential and capability. The term PFC is used to identify the assessment process and is also a defined, on-the-ground condition of a riparian wetland area (Prichard et al 1998). PFC is a consistent approach for considering hydrology, vegetation, and erosion/deposition (soils) attributes and processes to assess the condition of riparian areas. A checklist is used for the PFC assessment which synthesizes information that is foundational in determining the overall physical functionality of a riparian area.

When assessing riparian-wetland areas using the PFC checklist, the vegetation items may be evaluated as a "yes" response with the presence of saltcedar depending upon the diversity of plant species, amount, and vigor, but checklist items for floodplain access and floodplain characteristics may be a "no" response, which increases the opportunity for the site potential characteristics needed for saltcedar invasion. A "no" response would be appropriate for the vegetation checklist items (diverse composition, possibly amount) with a monoculture of tamarisk and would probably rate out at something less than PFC. It may not be the presence of a stand of saltcedar that keeps a stream reach from PFC, but other attributes and processes that aren't functioning properly due to regulated flow regimes, incised channels, etc. that are creating the environment that is conducive to saltcedar germination. After all, saltcedar was brought in for erosion control, indicating that there may have been some kind of vegetation, hydrologic, or erosion/deposition problem. It should also be noted that saltcedar has been known to invade pristine sites (Shafroth et al. 2005).

Also, saltcedar has a longer seed dispersal period compared to cottonwood, so it has the ability to spread under conditions that are not suitable to cottonwood and willow germination and seedling development (Lesica and Miles 2005).

**Summary:**

Shafroth et al. (2005) summed it well. "Regional and local variation in the potential for water salvage, restoration, and habitat values demands that potential saltcedar control sites are carefully evaluated and prioritized prior to selection and project implementation. Failure to do so could lead to expensive and time-consuming efforts that do not reap desired economic or ecological benefits. Future projects should include a commitment to rigorous preproject and postproject monitoring to quantify the efficacy of control and restoration approaches, the responses of wildlife populations, and changes to water budgets over the long-term."

Glenn and Nagler (2005) reiterated what others have stated; managers should first understand the ecological relationships between native and invasive vegetation and the fauna that depend on them, and then have clear and measurable objectives for restoration before action is taken. There appears to be incomplete knowledge by many managers and scientists of the many functional roles saltcedar plays along riparian corridors. There is also confusion about objectives and methods. If water salvage is the goal, then replacing saltcedar with some native plants (e.g. cottonwood and willow) may actually increase evapotranspiration. If ecological restoration is the goal, then eradication of saltcedar without modifying the flow regime may degrade habitat further.

Management should consider the disturbance that is associated with livestock grazing that could provide saltcedar's bare-soil regeneration niche. Stock ponds and reservoirs should be monitored for infestations (Lesica and Miles 2005). Tamarisk invasion may be curtailed by managing for the more competitive, native cottonwood. Cattle prefer to browse cottonwood and willow compared to saltcedar. Livestock grazing should be carefully managed in the larger drainages to allow cottonwood and willow regeneration and growth to maturity. Beavers may have to be controlled in some areas to allow cottonwood stands to develop (Lesica and Miles 2005).

Numerous studies support that the drying and salinizing of river banks, and the lowering of water tables, due either to natural causes or flow regulation, are the primary mechanisms by which saltcedar has come to dominate Western riparian corridors (Glenn and Nagler 2005). Thus, an effective management strategy must include determining the feasibility of the return of a more dynamic hydrological regime to regulated rivers, allowing saltcedar and native trees to coexist to maximize the habitat value of the riparian zone (Glen and Nagler 2005). Large magnitude, long-duration floods would be expected to result in changes in channel geometry, mobilization of bars and channel margin deposits, removal of herbaceous and woody vegetation, and establishment of more natural physical, biological, and plant successional processes (Merritt et al. 2006).

A theme throughout all of the literature is that there is still much information needed to really determine the positive and negative effects of saltcedar in perennial, intermittent and ephemeral systems in the western USA. Should saltcedar be removed from dry washes or are they better off with saltcedar? Is a mixed stand of riparian vegetation that includes saltcedar detrimental to the functionality of a riparian system? *Tamarix* removal is only one element toward restoration of native riparian vegetation; in certain settings even its removal may have negative ecological effects in the absence of active restoration following removal (Merritt et al. 2006). In the end, each system's attributes and processes should be considered based on its potential and capability. This is especially critical in times of limited resources and it should be determined if improvement will occur on a riparian area based on physical functionality and societal needs. This discussion has provided some of the latest research and exhibits the need for the continuing quest to ask and answer key questions about saltcedar. The search for those answers continues.

Reviewed by Don Prichard, BLM National Operations Center and Dave Merritt, USFS Stream Team.

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