Tamarisk Ecology and Management in the Grand Canyon and Southwestern United States

INTRODUCTION

The control of Tamarix spp. has been a focus of land management in the western United States for about 100 years, and these species have been in the consciousness of land managers for at least a century before that. Opinions about the merits and costs of Tamarix spp. have fluctuated over this time, and management strategies have also been adapted and honed.

I begin this report with a description of Tamarix. I then provide further detail on the historical context of Tamarix spp. becoming dominant in southwestern U.S. riparian areas, as well as strategies used for managing it in the 1800s-1900s. Next, I provide a brief overview of management strategies and their relative efficacies. I conclude with an overview of how restoration efforts have changed ecosystems at sites throughout the southwestern U.S.

GENERAL DESCRIPTION

Nine species of Tamarix species are present in the United States, of which three species are classified as “noxious” on a federal level (USDA Natural Resources Conservation Service 2020). Many others are classified as noxious in various states (e.g., four species classified as noxious in California; (California Department of Food and Agriculture 2020)). Colloquially, these species are generally referred to as “tamarisk”, and I will continue to refer to them collectively as such due to their similar biological characteristics (and hybridization between species) and similar management concerns.

HISTORICAL CONTEXT

Tamarisk has been present in the United States for at least two centuries, and possibly as early as the 1600s with Spanish settlement in what is now the Western U.S. (Douglass et al. 2013). By the 1830s, tamarisk was prevalent and used both ornamentally and functionally for erosion control, wind breaks, and shade (Di Tomaso 1998). It was only after several decades that the possible negative effects of tamarisk began to be recognized: in the early 1900s, farmers and water engineers began to recognize the role of tamarisk in reducing water flow in irrigation canals (Douglass et al. 2013). For decades after that, tamarisk was both welcomed by some and recognized by others as a nuisance plant, and beginning in the 1940s-1950s extensive efforts were taken to control it. Since then, strategies including mechanical, chemical, fire-based, and biological control have been attempted to reduce tamarisk in riparian areas (see “Management” section below). In the Grand Canyon area specifically, tamarisk has been present since the 1920s-30s and has been a dominant species in riparian areas since the 1960s (U.S. National Park Service 2015).

TAMARISK ECOLOGY

Tamarisk are woody plants that take the form of trees or shrubs. They have several characteristics that have enabled them to thrive in the American Southwest, and which are relevant to their management. In some cases, these characteristics have allowed them to thrive in contrast with native vegetation like cottonwood (*Populus spp.*) and willow (*Salix spp.*), particularly in the context of human-modified ecological regimes. These characteristics are:

1. **They have a deep taproot.** Like many arid plants, tamarisk have a deep taproot that allows it to access water deep underground. This may not categorically differentiate it from cottonwood, though rooting depths may be quantitatively different between species and across environmental conditions: some studies estimate similar rooting depths or even a superior uptake capacity by cottonwood (Sher et al. 2000) whereas others find that tamarisk may be able to better keep pace with declining water tables (Shafroth et al. 2000).

2. **They have a high tolerance for salinity.** Salts are present in groundwater at relatively low concentrations. As groundwater rises to the soil surface, salts can be deposited on the surface (Glenn and Nagler 2005). Under natural flow regimes, salts are periodically flushed from the system during flood events; however, "managed" flow regimes greatly diminish the potential for these flushing events. Early research documented higher salt tolerances by tamarisk as compared with native vegetation (see work cited in Di Tomaso 1998).

   While salt continues to be reported as a key driver of tamarisk's relative success, the empirical literature is less clear. Shaforth et al. (1995) investigated potential mechanisms through lab and mesocosm experiments and they found that cottonwood has reduced seedling survival under very high salinities - but only in the outdoor mesocosm. They did not find differences in other growth characteristics. Glenn et al. (1998) documented greater impacts on growth for cottonwood and willow compared with tamarisk in a greenhouse experiment. Given the literature, it is unclear whether salinity is a definitive factor leading to tamarisk's ability to thrive relative to its native competitors, but it may be a contributor especially as interacting with other factors.

3. **They have high reproductive potential from seed.** Tamarisk as well as its native competitors, cottonwood and willow, all have high seed production and propagule pressure. Whereas cottonwood and willow disperse seedlings over a short amount of time (potentially adapted to coincide with spring flood events, which scour the substrate and create the conditions for seedling establishment), tamarisk disperses over a longer time period (which may be more adaptive under managed flow conditions) (Glenn and Nagler 2005). The establishment timing and salinity factors seem to be the main factors explaining higher tamarisk seedling viability compared with native competitors; studies investigating other factors (e.g., nutrient drivers, water availability) indicate that native vegetation is the stronger competitor compared with tamarisk (reviewed in Glenn and Nagler 2005).

4. **They resprout easily**, both from aboveground biomass if disturbed as well as from roots. When tamarisk are disturbed, they respond by increasing the number of stems and, accordingly, growing a fuller canopy. (Douglass et al. 2013) Management efforts are made all the more difficult by not being able to rely exclusively on aboveground vegetation removal.

5. **They grow rapidly as individuals and as stands.** Tamarisk can grow 3-4 m per growing season (Di Tomaso 1998), and given its reproductive capacity can blanket riparian areas quite quickly. However, it is unclear whether tamarisk have higher growth rates than some of its native competitors, especially as measured through controlled experiments. Several studies indicate that cottonwood seedlings have higher growth rates than tamarisk; possibly due to greater nutrient uptake as well as greater light capture abilities (see e.g., Sher et al. 2000). As with the salinity factor above, it may be that competition experiments are unable to capture the range of conditions that may lead to tamarisk becoming competitively dominant in natural conditions. Regardless of its competitive ability relative to native species; however, it is apparent that tamarisk does have high reproductive and growth capacity on an absolutely level. This is a plausible scenario given that competition may not be the primary factor driving vegetation patterns.

Whether or not tamarisk outcompetes native vegetation or simply thrives in areas where native vegetation cannot is debatable and may depend on the environmental conditions. Managed flow regimes influence some of the factors that make could make tamarisk relatively more successful than some of its native counterparts.

RATIONALE FOR REMOVAL

These ecological characteristics have led to an overall condition of tamarisk becoming a dominant vegetation type in southwestern riparian areas, which has been seen as undesirable by managers for several reasons:

1. It takes up water that would otherwise be used for native vegetation.

2. It takes up water that could otherwise be used for human consumption (municipal, agricultural, hydropower generation).

3. It creates unpredictable flooding regimes. The ability for tamarisk to spread along river banks can lead to its constricting of the river channel and, in smaller tributaries, potentially reduce or remove perennial surface water. For example, tamarisk led to the constricting of the Yampa River by 6% since the 1960s, affecting sediment and hydrological processes (Manners et al. 2014).

Collectively, these concerns were estimated in 2000 to lead to a cost of $280-450 per hectare in terms of its impact to municipal and agricultural water supplies, hydropower generation, and flood control efforts (Zavaleta 2000). Certainly, the ability for tamarisk to take up water that would otherwise be used for native vegetation or by human end users is at the core of management concerns and justifications for removal.

It is important to note that while tamarisk may be common and often dense enough to have an ecosystem-level effect on water consumption relative to its native counterparts, it does not possess inherently high abilities to take up and “waste” water. The mechanism by which tamarisk affects water availability is with regard to the process of evapotranspiration, through which water is taken up by plant roots and evaporated from leaf surfaces during transpiration – a necessary process associated with photosynthesis and plant cooling. Studies that have measured evapotranspiration of tamarisk relative to cottonwood indicate that stand-level rates are similar between the two species (Glenn et al. 1998), also reviewed in Glenn and Nagler (2005). Similarly, a study that evaluated sap flux rates in order to estimate tree-level daily water use found that estimates from the popular press were much higher than those empirically measured (Owens and Moore 2007). Given these updated estimates of tamarisk’s relative water impact, the water use concern is likely relative to a scenario where vegetation in general is simply less present on the landscape.

Other rationales for removal include its poor habitat quality as compared with native vegetation. Many bird and insect species use tamarisk for nesting as a less preferred alternative to native alternatives (e.g., willows or mesquite). These values are documented in DiTomaso et al. (1998) but likely are less of a management impetus compared with water use and flooding concerns. One notable exception is its importance for the Southwestern Willow Flycatcher (*Empidonax traillii extimus*), an endangered bird species that uses tamarisk as habitat (in combination with other native vegetation). While the flycatcher prefers non-tamarisk vegetation, the removal of tamarisk stands has been curtailed by endangered species concerns in some cases (see “Biological control” section below).

MANAGEMENT STRATEGIES

Many strategies for removing tamarisk from the landscape have been attempted over the past century. For the most part, these strategies are relatively ineffective unless used in combination or if used extremely aggressively. With the advent of “passive” biological control strategies, some of the emphasis for tamarisk management has shifted to ensuring that appropriate revegetation strategies are in place.

1. **Mechanical removal.** Mechanical removal involves the physical removal of tamarisk biomass from its site. Some of the earliest US Geological Survey efforts at tamarisk removal involved large-scale removal of aboveground biomass, but this was unsuccessful in the long term due to tamarisk’s high resprouting ability (Douglass et al. 2013). Now, successful mechanical removal necessarily involves the removal of below- as well as above- ground biomass to reduce the ability for resprouting to negate control efforts (Douglass et al. 2013).

2. **Chemical removal.** Several herbicides are now available that can be fairly effective at reducing tamarisk (reviewed in (Douglass et al. 2013)). These herbicides typically involve multiple tradeoffs: (a) Foliar sprays that are able to be used at scale (e.g., by aircraft) versus applications to the bark or a cut stump that may be more targeted. (b) Some of the more effective herbicides can impact many species, so there may be collateral impacts to native vegetation.

3. **Prescribed burns.** Prescribed burning has similar limitations as aboveground mechanical removal: tamarisk is able to recover from biomass loss relatively quickly and the benefits are soon negated. One study that tested the effects of prescribed burns at various times of the year found that burning led to very low mortality, indicating that it isn't a good long term strategy for control; however, this study did find that prescribed burning could be an effective way to address biomass (fuel) accumulation below the deciduous tamarisk plants. (Delwiche 2009)

4. **Biological control.** Tamarix species' native ranges span from the Mediterranean region to East Asia, and within these ranges they have "natural enemies" (herbivores and diseases). In particular, several species of *Diorhabda spp* (saltcedar leaf beetle) defoliate tamarisk within these native ranges and therefore compromise its growth, possibly leading to mortality. Following extensive testing of the effects of these beetles on both tamarisk and other species (DeLoach et al. 2003), the U.S. Department of Agriculture approved the release of these beetles in the United States for the purposes of reducing tamarisk through defoliation.

   This biological control agent has had some success in limiting tamarisk growth, with one study estimating 40% tamarisk mortality after five years of beetle exposure (Hultine et al. 2010). In fact, critics of the use of biocontrol suggest that the scale of defoliation events across large tamarisk stands may be alarming to the public without suitable investments in education and outreach. Moreover, the future role of saltcedar leaf beetles is debateable given competing land management concerns. Five year after approving use of the beetle, the USDA ceased promoting it in 2010 due to its potential impacts to Southwestern Willow Flycatcher, and endangered species for which tamarisk is a suitable nesting site. At present, the USDA website includes language strongly deterring the use of the beetle; however, state land management agencies and even other federal sites seem to endorse it either tacitly or explicitly: for example, the Colorado Department of Agricutlure offers tamarisk beetles for free to the public, and the Glen Canyon National Recreation Area (NRA) website states that "the tamarisk leaf beetle is emerging as a useful tool" (U.S. National Park Service 2015; Colorado Department of Agriculture Conservation Services 2016). Thus, reluctance owing to concerns about listed species may be tempered by practitioners' enthusiasm for strategies that have shown some efficacy.

   Though the beetle species in question were originally evaluated to have certain geographical constraints that would prevent spread to unintended areas, it has been expanding its range outside of the target region. As reported in Bedford et al. (2018), beetle species released in the Northern Rockies were thought to be limited to 111 km north of the Arizona border; however, in 2009 they were observed at Glen Canyon NRA. Bedford et al. used remote sensing to quantify the impact of the beetle on existing tamarisk stands in the Grand Canyon, and found that defoliation ranged from 1-86% within those stands. Grand Canyon managers are responding to the beetle migration by integrating knowledge of its spread into prioritization for restoration efforts.

CURRENT CONTROL EFFORTS AND POTENTIAL IMPACTS

Grand Canyon National Park is part of a multi-stakeholder, multi-year effort to control tamarisk along the Colorado River and its tributaries. This effort involved an extensive survey effort to determine the project scope and a phased approach to treating the many side canyons of the Colorado River, beginning in 2002 (U.S. National Park Service 2011). Different methods have been used for the removal based on site conditions, including manual removal, herbicide injections, herbicide applications to cut stumps, and herbicide application to basal bark (Makarick and Kloeppel 2005). The program is currently in a maintenance phase to treat any new tamarisk vegetation and monitor ecological effects.

Monitoring of treated sites from the Grand Canyon removal effort reveals mixed results: a study of 13 canyons that compared treated with comparable untreated sites after 1-3 years indicated that native species did not recover during this time period in either richness or cover estimates (Belote et al. 2010). Given the relatively short recovery period and aridity of the landscape, it is possible that there was simply not enough time to engender a significant ecological response. Studies of slightly older treatments also yield mixed results: a more widespread study of sites throughout the Southwestern U.S. and that observed sites 1-11 years after treatment also found very limited responses of native vegetation associated with tamarisk removal (Harms and Hiebert 2006). A similar study over a broad region and 3-8 years post-treatment found that native vegetation increased slightly, but non-native species also thrived where high-disturbance treatment methods were used (Gonzalez et al. 2017). Most promisingly, a recent study in tributary to the Colorado River found that native species increased over a period of five years and across a variety of treatment methods (mechanical, chemical, biological; Sher et al. 2018). It may be that this is a particularly favorable watershed for native species recovery, but it also may be that large regional studies obscure dynamics of local recovery. Indeed, Harms and Hiebert (2006) found quite different responses in the various regions comprising their study, and in some cases these responses were masked in the study-wide aggregation. Based on these results, it may be that treatment efficacy is dependent on local conditions and local vegetation types.

CONCLUSION

Tamarisk's role in the Western U.S. is very complex, with a long-standing cultural history and a confusing –almost paradoxical– ecological role. For decades it has been reported in the literature and popular press as being a super-competitor that drains valuable resources. Yet rigorous comparisons of competitive drivers (e.g., reproductive capacity, growth rates, water uptake, transpiration rates) suggest that tamarisk is no more competitive or able to capitalize on resources than other native species. One possible way to reconcile this is that native species may be dependent on certain river flow regimes whereas tamarisk can tolerate a human-modified flow regime. Without considerable more empirical work isolating the specific factors that allow tamarisk to thrive relative to other species, it is unclear whether removal and restoration efforts can be sustainable without larger changes to water management. Another possible explanation is that the cultural narrative of tamarisk has taken hold in a way that is hard to break – it may be that tamarisk is worthy of removal because people simply do not like it, but the biological and ecological justifications add confusion to the issue. Regardless, it will be interesting to see whether management efforts will result in localized or regional changes in the distribution of tamarisk in the United States.

REFERENCES

Bedford A, Sankey TT, Sankey JB, Durning L, Ralston BE. 2018. Remote sensing of tamarisk beetle (Diorhabda carinulata) impacts along 412 km of the Colorado River in the Grand Canyon, Arizona, USA. Ecological Indicators. 89:365–375. doi:10.1016/j.ecolind.2018.02.026.

Belote RT, Makarick LJ, Kearsley MJC, Lauver CL. 2010. Tamarisk Removal in Grand Canyon National Park: Changing the NativeNon-native Relationship as a Restoration Goal. Ecological Restoration. 28(4):449–459. doi:10.3368/er.28.4.449.

California Department of Food and Agriculture. 2020. Data Sheets for California Noxious Weeds.

Colorado Department of Agriculture Conservation Services. 2016. Tamarisk Biocontrol.

DeLoach CJ, Lewis PA, Herr JC, Carruthers RI, Tracy JL, Johnson J. 2003. Host specificity of the leaf beetle, Diorhabda elongata deserticola (Coleoptera: Chrysomelidae) from Asia, a biological control agent for saltcedars (Tamarix: Tamaricaceae) in the Western United States. Biological Control. 27(2):117–147. doi:10.1016/S1049-9644(03)00003-3.

Delwiche J. 2009. Saltcedar: Is Burning an Option?

Di Tomaso JM. 1998. Impact, Biology, and Ecology of Saltcedar (*Tamarix* spp.) in the Southwestern United States. Weed Technology. 12(2):326–336. doi:10.1017/S0890037X00043906.

Douglass CH, Nissen SJ, Hart CR. 2013. Tamarisk Management. In: Sher A; Quigley MF, editors. Tamarix. Oxford University Press. pp. 333–353.

EFFECTS OF SALINITY ON ESTABLISHMENT OF POPULUS FREMONTII (COTTONWOOD) AND TAMARIX RAMOSISSIMA (SALTCEDAR) IN SOUTHWESTERN UNITED STATES. 1995. The Great Basin Naturalist. 55(1):9.

Glenn E, Tanner R, Mendez S, Kehret T, Moore D, Garcia J, Valdes C. 1998. Growth rates, salt tolerance and water use characteristics of native and invasive riparian plants from the delta of the Colorado River, Mexico. Journal of Arid Environments. 40(3):281–294. doi:10.1006/jare.1998.0443.

Glenn EP, Nagler PL. 2005. Comparative ecophysiology of Tamarix ramosissima and native trees in western U.S. riparian zones. Journal of Arid Environments. 61(3):419–446. doi:10.1016/j.jaridenv.2004.09.025.

Gonz'alez E, Sher AA, Anderson RM, Bay RF, Bean DW, Bissonnete GJ, Bourgeois B, Cooper DJ, Dohrenwend K, Eichhorst KD, et al. 2017. Vegetation response to invasive Tamarix control in southwestern U.S. rivers: A collaborative study including 416 sites. Ecological Applications. 27(6):1789–1804. doi:10.1002/eap.1566.

Harms RS, Hiebert RD. 2006. Vegetation Response Following Invasive Tamarisk (Tamarix spp.) Removal and Implications for Riparian Restoration. Restoration Ecology. 14(3):461–472. doi:10.1111/j.1526-100X.2006.00154.x.

Hultine KR, Belnap J, van Riper C, Ehleringer JR, Dennison PE, Lee ME, Nagler PL, Snyder KA, Uselman SM, West JB. 2010. Tamarisk biocontrol in the western United States: Ecological and societal implications. Frontiers in Ecology and the Environment. 8(9):467–474. doi:10.1890/090031.

Makarick L, Kloeppel H. 2005. FINAL REPORT FOR TAMARISK ERADICATION AND RESTORATION OF 63 TRIBUTARIES IN GRAND CANYON NATIONAL PARK. Grand Canyon National Park and Grand Canyon Wildlands Council.

Manners RB, Schmidt JC, Scott ML. 2014. Mechanisms of vegetation-induced channel narrowing of an unregulated canyon river: Results from a natural field-scale experiment. Geomorphology. 211:100–115. doi:10.1016/j.geomorph.2013.12.033.

Owens MK, Moore GW. 2007. Saltcedar Water Use: Realistic and Unrealistic Expectations. Rangeland Ecology & Management. 60(5):553–557. doi:10.2111/1551-5028(2007)60[553:SWURAU]2.0.CO;2.

Shafroth PB, Stromberg JC, Patten DT. 2000. Woody riparian vegetation response to different alluvial water table regimes. Western North American Naturalist. 60(1):12.

Sher AA, El Waer H, Gonz'alez E, Anderson R, Henry AL, Biedron R, Yue P. 2018. Native species recovery after reduction of an invasive tree by biological control with and without active removal. Ecological Engineering. 111:167–175. doi:10.1016/j.ecoleng.2017.11.018.

Sher AA, Marshall DL, Gilbert SA. 2000. Competition between Native Populus deltoides and Invasive Tamarix ramosissima and the Implications for Reestablishing Flooding

Disturbance. Conservation Biology. 14(6):1744–1754. doi:10.1111/j.1523-1739.2000.99306.x.

U.S. National Park Service. 2011. Tamarisk Management and Tributary Restoration.

U.S. National Park Service. 2015. Tamarisk Leaf Beetle - Glen Canyon National Recreation Area.

U.S. National Park Service MAPB1. 2015. Exotic Tamarisk Management - Grand Canyon National Park.

USDA Natural Resources Conservation Service. 2020. Plants Profile for Tamarix (tamarisk).

Zavaleta E. 2000. The Economic Value of Controlling an Invasive Shrub. AMBIO: A Journal of the Human Environment. 29(8):462–467. doi:10.1579/0044-7447-29.8.462.