Restoration Ecology

Restoration Ecology and Invasive Riparian Plants: An Introduction to the Special Section on *Tamarix* spp. in Western North America

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Abstract

River systems around the world are subject to various perturbations, including the colonization and spread of non-native species in riparian zones. Riparian resource managers are commonly engaged in efforts to control problematic non-native species and restore native habitats. In western North America, small Eurasian trees or shrubs in the genus *Tamarix* occupy hundreds of thousands of hectares of riparian lands, and are the targets of substantial and costly control efforts and associated restoration activities. Still, significant information gaps exist regarding approaches used in control and restoration efforts and their effects on riparian ecosystems. In this special section of papers, eight articles address various aspects of control and restoration associated with *Tamarix* spp. These include articles focused on planning restoration and revegetation; a synthetic analysis of past restoration efforts; and several specific research endeavors examining plant responses, water use, and various wildlife responses (including birds, butterflies, and lizards). These articles represent important additions to the *Tamarix* spp. literature and contain many lessons and insights that should be transferable to other analogous situations in river systems globally.

Key words: invasive species, restoration, riparian, saltcedar, tamarisk.

River systems throughout the world provide a wide array of ecosystem services and functions (Naiman et al. 2005) and are under great pressure to sustain both human endeavors and natural systems (Postel & Richter 2003). River corridors are highly susceptible to the colonization and spread of non-native species due in part to relatively high natural disturbance rates, the capacity for rapid, long-distance propagule dispersal, and various anthropogenic perturbations (Richardson et al. 2007). Proliferation of non-native plants in riparian corridors is relatively common globally, and there are instances of invasions associated with substantial ecological, economic, or management costs (Webb & Erskine 2003; Holmes et al. 2005; Shafroth et al. 2005). In cases where large-scale alien plant control has been undertaken, ecological restoration is often cited as a desired outcome.

The case of *Tamarix* spp. in western North America well illustrates some of the challenges, potential conflicts, and information needs associated with restoration in the context of invasive species control (Shafroth et al. 2005). *Tamarix ramosissima*, *T. chinensis*, and their hybrids (collectively known as tamarisk or saltcedar; hereafter referred to as *Tamarix*) are shrubs and small trees native to Eurasia, which have come to occupy approximately 400,000–650,000 ha in western North America since their introduction in the mid-1800s (Robinson 1965; Zavaleta 2000; Gaskin & Schaal 2002). *Tamarix* invasions are also reported from Australia (Griffin et al. 1989) and Argentina (Sergio Zalba, Universidad Nacional del Sur, personal communication). Portions of almost every large river system in the southwestern United States and far northern Mexico are now dominated by *Tamarix*, including the Colorado River, its tributaries, and its delta in Mexico, and the Rio Grande and many of its tributaries. *Tamarix* invasion has been associated with various negative effects such as reducing water quantity through high evapotranspiration rates, degrading wildlife habitat, increasing fire hazard, and displacing native riparian vegetation. Similar impacts have been attributed to alien riparian plants in other parts of the world (e.g., Holmes et al. 2005). However, evidence for *Tamarix* being the primary or sole cause of these effects is ambiguous. Still, given its broad distribution and variety of purported negative effects, controlling *Tamarix* is appealing to many different constituents.

In recent years, controlling *Tamarix* has become the focus of many natural resource managers throughout western United States. Tens of millions of U.S. dollars have been spent by national, state, and local governmental agencies. *Tamarix* removal techniques range from aerial spraying, tractor-mounted herbicide applicators, burning, mowing, to labor-intensive tree-by-tree application of herbicide. In addition, biological control by leaf-eating

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beetles (*Diorhabda elongata*) imported from various Asian and European areas is being studied and beetles have been released in numerous western states (Deloach et al. 2004). Once established, *D. elongata* can kill or severely weaken *T. ramosissima*, *T. chinensis*, and hybrids via repeated defoliation (Dudley et al. 2006). *Tamarix* removal has recently received a boost by the passing of a 2006 law that paves the way for $80 million USD to be spent on *Tamarix* and Russian olive (*Elaeagnus angustifolia*) control and associated restoration over the next several years (U.S. House of Representatives 2720 and U.S. Senate 177: Salt Cedar and Russian-olive control and demonstration act, http://www.govtrack.us/congress/bill.xpd?bill=h109-2720; accessed 18 January 2008).

Although heightened interest in *Tamarix* removal could have a number of positive consequences (e.g., support for research, monitoring, and restoration), there is still a need to address the challenges, potential conflicts, and information gaps associated with riparian restoration in the context of invasive species control (Shafroth et al. 2005; Richardson et al. 2007). Restoration of particular structural or functional attributes of riparian systems is not necessarily accomplished simply by removing the non-native vegetation. Often, rivers have been subjected to perturbations or changes that may confound or interact with the effects of non-native species (Richardson et al. 2007). For example. dense monotypic stands of *Tamarix* are frequently found along rivers with regulated flow regimes, whereas native species establishment and survival often surpass that of *Tamarix* along rivers with natural flow regimes (Glenn & Nagler 2005; Stromberg et al. 2007).

Other factors can further complicate restoration efforts in the context of invasive species removal, such as the disparity between the time scale of control operations versus the time scale required for recovery, the threat of secondary weed invasions following control of the initial target species, and the extent to which the non-native taxa might be providing valuable habitat structure or ecosystem functions. Further, the land and water management goals that lie behind invasive riparian plant control can be quite different, depending on national, regional, or local priorities.

The special section of articles that follows addresses some of the key aspects of restoration in the context of *Tamarix* removal in western North America. We suggest that many of the issues, principles, approaches, and results described in these articles could be applicable to similar situations along rivers in other parts of the world.

A recent period of dry years affected many parts of western North America and contributed to a surge of interest in controlling *Tamarix* based on the hypothesis that clearing areas of *Tamarix* will result in additional water becoming available for other uses. For decades, however, the extent to which clearing *Tamarix* or other riparian vegetation effectively results in significant and quantifiable increases in water yield has been questionable (Graf 1992; Glenn & Nagler 2005; Shafroth et al. 2005). Still, the water use issue drives many *Tamarix* control efforts, so continued research in this area is of high value. On this topic, Nagler et al. (2008) present results from a study of *Tamarix* evapotranspiration along the lower Colorado River, based on detailed measurements at three sites and extrapolated estimates for 34,000 ha of riparian vegetation using remotely sensed data.

There is a fairly extensive literature that has examined wildlife responses to *Tamarix*. However, the results of these studies have often been mixed, with some studies reporting negative effects of *Tamarix* relative to native vegetation and others reporting neutral or positive effects (reviewed in Shafroth et al. 2005). In this issue, two manuscripts examine bird use of *Tamarix* and place this in a restoration context. Sogge et al. (2008) present a synthesis of regional and national bird survey data to assess the extent to which *Tamarix* is used by bird taxa. The results of van Riper et al. (2008) relate to the important question of how much native vegetation is required or conversely how much *Tamarix* needs to be removed to optimize bird habitat. Both these studies raise doubts about the common assumption that *Tamarix* does not provide useful habitat for birds and the corollary that complete removal of *Tamarix* from an area is advisable if the goal is to restore bird habitat. Nelson and Wydoski (2008) examines differences in butterfly use of different riparian vegetation types, including areas dominated by *Tamarix*, native vegetation, mixed-native *Tamarix* vegetation, and areas where *Tamarix* was removed. Finally, the article by Bateman et al. (2008) focuses on the effects of *Tamarix* removal on six lizard species. For these six species, non-native plant removal either positively affected or had no significant effect on overall abundance.

Changes to water use or wildlife habitat depend largely on what type of vegetation occupies a site following *Tamarix* removal and any associated restoration actions. Three articles in this special section are largely focused on riparian vegetation issues. Shafroth et al. (2008) present a process for planning restoration efforts in the context of *Tamarix* control, including establishing goals and objectives, evaluating and prioritizing candidate sites, developing a site-specific plan, monitoring and adaptive management. Sections withiu this article describe site factors that need to be evaluated to understand revegetation potential, as well as details associated with different passive and active restoration approaches. Bay and Sher et al. (2008) use regression tree analysis to examine correlations between 20 local to regional scale environmental variables and several vegetation variables associated with revegetation success at 28 sites in western United States. One concern with *Tamarix* control is that it may simply open up areas that can be colonized by other non-native taxa ("secondary weed invasion"). Sher et al. (2008) compare *Bromus tectorum* (a weedy, non-native annual grass) abundance at three sites one year after different *Tamarix* control approaches were implemented.

We hope that this special section of articles will provide valuable contributions to the scientific knowledge base

required to make the best decisions regarding expenditures of resources aimed at controlling *Tamarix* spp. and restoring riparian ecosystems in western North America. In addition, we hope that scientific debate and study will continue on some of the more contentious and complex topics that are influencing policy decisions. Assessing the outcomes of the biological control efforts will be especially important in years to come. Clearly, the field of restoration ecology has much to offer riparian restoration efforts in the context of *Tamarix* control. Likewise, the growing literature on *Tamarix*, including the articles that follow, should be relevant to other riparian restoration efforts globally.

Acknowledgments

We thank all the authors who contributed to this set of articles and to Sue Yates, managing editor for Restoration Ecology, for her patience and support. We would also like to extend our appreciation to the U.S. Geological Survey's Invasive Species Program and World Wildlife Fund Chihuahuan Desert Program for their support of this effort.

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