Abstracts — Session 1: Restoration and Revegetation

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Success of active revegetation after *Tamarix* spp. removal in Southwestern riparian ecosystems: A quantitative assessment of past restoration projects

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Abstract:

Infestation by the non-native tree *Tamarix* spp. has made habitat restoration projects necessary to maintain the ecological integrity of many riparian communities in the Southwest. These restoration projects may include *Tamarix* removal, manipulation of hydrographs, and active revegetation of native species. There is no single strategy for achieving success in these projects; rather success will vary by site based on specific site characteristics and methods used. Revegetation success, plant species diversity, and vegetative cover were evaluated at 28 sites in New Mexico, Arizona, and Nevada where active revegetation was completed after *Tamarix* removal. These data were incorporated into regression tree models with predictor variables that included number of years since removal (1-18 years) and multiple management, climate, soils, and hydrological variables to determine success of *Tamarix* control, revegetation success, and plant community responses. Our results suggest that there are easily measurable site characteristics that lead to greater native cover and richness, planting success, and *Tamarix* control. 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. 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*. These quantitative models are intended to assist researchers and land mangers to design more effective riparian restoration efforts in this critical arid lands ecosystem.

Salinity tolerance and mycorrhizal responsiveness of candidate species for use in restoration of *Tamarix*-dominated xeric riparian areas

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Abstract:

Thousands of hectares of riparian vegetation dominated by *Tamarix* have been controlled in the southwestern United States, using a combination of strategies including herbicide application, burning and mechanical removal. There is substantial scientific knowledge and numerous case studies that can inform revegetation of relatively mesic riparian sites with native cottonwood and willow. However, revegetation of upper floodplain or “xeric riparian” areas, where over bank flooding is impossible, soil salinity is high, groundwater is deep and mycorrhizal fungal symbionts are potentially absent, still presents a significant challenge to riparian land managers along the Rio Grande and other southwestern rivers. Our research aims to address this knowledge gap by identifying suitable native plant species and revegetation techniques for these xeric riparian sites. Components of this study include: 1) identification of candidate native plant species and communities via characterization of reference sites, review of historical botanical accounts of the Rio Grande valley, and communication with restoration practitioners; 2) germination trials where seeds of candidate native species are germinated in

solutions of differing salinity levels; 3) greenhouse trials to examine the effect of salinity and mycorrhizal fungi on seedling survival and growth; and 4) field experiments testing the efficacy of various revegetation methods in soils of varying texture and salinity. Results from these experiments will be used to develop cost-effective protocols aimed at restoring xeric riparian shrubland and grassland communities.

Competition and succession in tamarisk stands: towards biological control using native plants

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Abstract:

Tamarisk species (*Tamarix ramosissima* Ledeb., *T. chinensis* Lour., *T. gallica* L. and hybrids), have invaded riparian areas throughout western North America to the detriment of native plants and animals. Tamarisk is a relatively recent addition to North American plant communities, thus competitive and successional processes are still developing. Box elder (*Acer negundo* L. var. *interius* (Britt.) Sarg.) is a potential native competitor found in mid elevation canyons throughout western North America. The following questions were addressed: (1) Does tamarisk facilitate box elder establishment? (2) Is box elder or tamarisk the superior competitor? (3)What are the successional trajectories in mixed box elder and tamarisk stands? (4) Can mature tamarisks be killed by limiting available light (PAR) to levels that commonly occur under box elder canopies? (5) How much shade is needed to diminish the growth of or kill tamarisk? (6) Is there a shade threshold below which box elders, but not tamarisk, can grow?

Facilitation was studied by analyzing the survival of box elder seedlings planted in intact or cleared tamarisk stands. Competition was studied through neighborhood analysis and successional trends were analyzed through dendrochronology in mixed stands. The shade tolerance of mature tamarisks was analyzed by building light exclosures around mature tamarisks. Comparative shade tolerances were analyzed using shade cloth of varying interception levels in a greenhouse experiment in Fort Collins, CO. Field studies and experiments were conducted in canyons of Dinosaur National Monument (DNM), Colorado.

Tamarisk facilitated box elder seedling survival. Box elder was the superior competitor; the presence of canopy box elders within one and two meters was significantly related to tamarisk but not box elder mortality. The presence of canopy tamarisk trees was not related to box elder or tamarisk mortality. Tamarisk establishment predated or was concurrent with box elder establishment on newly formed surfaces. Tamarisk initially dominated the canopy, but box elder eventually overtopped and killed the tamarisk. The shade generated by box elder canopies was capable of killing mature tamarisks in DNM. Box elder had superior shade tolerance to tamarisk, and maintained positive growth and survived under higher shade than tamarisk. The manipulation of competitive and successional processes through the promotion of box elder and other native tree establishment is suggested as a means of bottom up tamarisk control to complement traditional control techniques.

Revegetation obstacles following tamarisk control: Cheatgrass invasion and herbicide residues

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Abstract:

Although much is known about tamarisk removal, few quantitative studies exist to document challenges to restoration post-control. Each of the most popular control methods, i.e. mechanical removal and herbicide application, is likely to pose unique challenges, particularly for re-vegetation. For example, it is assumed that mechanical removal of tamarisk is likely to lead to further invasion by other weeds, whereas aerial applications of effective pesticides (such as imazapyr) will impede other weeds but are also likely to leave residues that prevent establishment of desirable species. To address these issues, we have established a restoration study near Florence, CO, where we have applied three different control methods to tamarisk infestations. Treatments included aerial application of imazapyr, mechanical control, mechanical control with spot applications, and reference (untouched) plots. 20m wide plots/strips of each of these were replicated five times in each of three locations along drainages infested by tamarisk. Within the mechanical control plots, we also investigated the effect of preparing the seed bed with tilling. After one growing season, we quantified the levels of re-infestation by *Bromus tectorum*, as a part of a long-term study. Within the chemical control plots, we measured soil residues of imazapyr after spraying and used these levels to develop a greenhouse bioassay to test response of common restoration species at different half-lives. Despite predictions otherwise, we observed the highest levels of *B. tectorum* in undisturbed plots, with mechanical removal of tamarisk and tillage appearing to reduce re-invasion in one of the sites. As expected, soil residues of imazapyr had dramatic effects on all native species tested, suggesting a high sensitivity even for those species that are commonly used after chemical control. These preliminary results may have important implications for management of sites after tamarisk removal, and demonstrate that existing paradigms may not apply to all locations.

Key factors and constraints in restoration of native plant communities in arid, monotypic infestations of saltcedar (*Tamarix* spp.) -strategies and techniques

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Abstract:

Critical knowledge gaps exist regarding vegetative recovery in aridic, monotypic saltcedar (*Tamarix* spp.) stands with no (desirable) understory. Formulation of revegetation strategies that provide site stabilization, resistance to further saltcedar and secondary weed infestation, and acceptable habitat values for affected wildlife species becomes particularly problematic in monotypic saltcedar stands under biological, fire and herbicidal (i.e., non-mechanical) control

scenarios. Amount and density of standing biomass (live and dead) remaining after control poses limitations in relation to seeding and planting techniques, seed interception in aerial (broadcast) applications, and seedbed preparation methods. Undisturbed soil surfaces impacted by saltcedar leaf litter accumulation, salinity, hummocky microxrelief, and nutrient limitations restrict potential for successful revegetation. Long duration of saltcedar occupation may deplete desirable microbial communities, particularly arbuscular (endo)mycorrhizae symbiotic and host-specific to native revegetation species. Selected results of innovative revegetation strategies at study sites on the Rio Grande and the Colorado River will be discussed that address three primary requisites for successful restoration on these site types: a) moisture capture and conservation; b) proper native species selection; and c) growth medium augmentation. These factors often include: soil surface and rhizosphere manipulation methods to facilitate removal of standing dead biomass, increase precipitation capture, improve soil moisture retention, and create micro-sites exhibiting lower salinity and increased protection from environmental extremes for improved seed germination; salinity remediation; seeding methodologies, including use of seed coating techniques; and mycorrhizal inoculation methods.

Riparian vegetation response to control of invasive plant species: restoration or retrogression

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Abstract:

Tens of thousands of acres of *Tamarix* have been cleared from public and private lands throughout the western United States in recent decades. The objectives of these projects often include: controlling invasive species, salvaging water, reducing fuel loading and fire damage to native riparian forests, and restoring degraded riparian ecosystems. Many of these efforts could be improved through the incorporation of a strong conceptual framework based on a clearly stated restoration objective that includes: a consideration of site context; a solid monitoring framework aimed at quantifying recovery of important ecosystem attributes, investment in follow-up treatment, solid quantification of yield-on-investment (as opposed to acres of *Tamarix* cleared), with attention to long-term post-removal response of physical and biological systems. We monitored post-*Tamarix* removal response 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. Collectively over 120 hectares of *Tamarix* was removed along 320 km of river as a part of these efforts. Channel response, herpetile, bird, mammal and bat community composition were measured by collaborators in these replicated, block experimental designs. Our focus was on the response of plant communities to *Tamarix* removal. We quantified recovery through measuring plant species composition, riparian forest canopy structure, the effects of fuel reduction efforts on survival of native forests following wildfire, and the role of flooding and flow-related process in long-term recovery of plant communities.

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*. 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. We 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. The risk of invasion by other exotic species following *Tamarix* removal can be minimized 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'). Vertical forest structure was reduced in treated areas along both rivers, but recovery of such habitat structure has been expedited along the Rio Grande through active transplanting of native shrubs. Patterns of herbaceous vegetation recovery were strongly related to site-specific factors (light, litter depth, and available moisture); all factors that are influenced by *Tamarix* removal and can be manipulated by managers.

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. The relatively small magnitude, short-duration floods that occurred during this study did not result in restoration of relevant channel processes, nor were woody species differentially advantaged or disadvantaged by small, short duration floods. Whereas floods of larger magnitude may be impossible due to societal constraints along the Rio Grande, large floods are a possibility along the study reaches of the Green River. Such flooding could provide an efficient means of 'passively' restoring key ecological processes and riparian vegetation along a significant portion of the Upper Green River following removal of Tamarix, whereas more 'active' restoration will continue to be necessary along the heavily populated Middle Rio Grande. Such differences in physical setting, geomorphic and hydrologic context, and socio-economic constraints highlight the fact that understanding existing conditions, site history, site potential, and possible successional trajectories ('situational awareness' in military lexicon) are all necessary components of strategic riparian restoration. *Tamarix* removal is only one element toward restoration of native riparian vegetation; in certain settings even its removal may have negative ecological effects.

Systems Approach for Riparian Management

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Tamarisk management is a growing issue for millions of acres of infested land across the American West. Tamarisk have no natural enemies in the United States, and are swiftly replacing native vegetation thus degrading livestock/wildlife habitat, increasing wildfire intensity, decreasing recreational activities, and most notably, competing for limited water supplies.

There are no simple answers on how best to manage tamarisk population. Decisions are complicated by the complex riparian systems that the tamarisk live and the contentious social context in which planning is conducted. For example, tamarisk have been successful in replacing native vegetation, so they now provide important value in stabilizing the banks of

Western rivers prone to avulsion and erosion as well as endangered species habitat (although considered poor-is better than no habitat). Destroying these trees without rational planning may induce severe, costly erosion and displace endangered species.

As such, efficient management defies myopic, piecemeal approaches driven by political whim. Rather, planning benefits from the fusion of knowledge and experience widely distributed across physical and social scientists, engineers, resource managers, decision-makers, stakeholders, and the general public. Ideally, an environment is established that promotes shared learning leading to cooperative and adaptive management. Success requires a process for inclusive and transparent sharing of ideas complimented by tools to structure, quantify, and visualize the collective understanding and data, providing an informed basis of dialogue and exploration. System dynamics provides a unique mathematical framework for integrating the physical and social processes important to resource management, and for providing an interactive environment for engaging the public. System dynamics models are predicated on the classical formalisms of physical and social science; albeit, at reduced spatial and temporal resolution. This tradeoff in resolution and thus computational burden, allows real-time analysis over an extended decision space.

Our objective is to ease resource related conflict through the application of computer-aided dispute resolution methods. We promote the use of decision-support technologies within a collaborative process to help stakeholders find common ground and create mutually beneficial resource management solutions. Such decision support models implemented within a dispute resolution context have been developed and applied in a number of river basins within the United States (Middle Rio Grande, Gila, Mimbres, and Willamette) and are actively being extended to water resource issues in Jordan. Such models have been used in sustainable water use planning; exploration of water use efficiencies in irrigated agriculture; cost-benefits analysis for alternative water conservation strategies; assessing tradeoffs in water allocations between irrigated agriculture, instream water use, and urban development; design of water markets; and, trans-boundary water resource planning. A key element in many of these efforts is the role of tamarisk management within the broader context of water planning.

In this presentation we will provide a basic overview of our computer-aided dispute resolution approach. Application will be drawn to several different projects for which decision support models will be demonstrated and results presented. Emphasis will be placed on projects involving tamarisk management.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Response of saltcedar and native grasses to five years of mowing or herbicide application

Alex Ogg, Steve Christy and Mike Wille

Abstract:
A site heavily infested with saltcedar near Manderson, WY was burned in March of 2001 and then mowed with a brush hog to remove standing burnt stems. The area was disked twice and seeded in April 2001with desirable grasses and forbs. Exceptionally dry conditions prevented the establishment of desirable species. However, there was vigorous regrowth of the saltcedar in 2001. The area was again mowed in October 2001 to remove the new stems. On July 30, 2002, long-term field plots were established to compare mowing to herbicide application for the

control of saltcedar and response of native grasses. Individual plots were 20 by 30 feet and each treatment, mowing or herbicide application, was replicated four times. The percent cover of Inland saltgrass (*Distichlis spicata*) and alkali sacaton (*Sporobolus airoides*) was estimated visually before treatments were applied. A hand-held power brush cutter was used to mow the saltcedar to within 2 to 4 inches of the soil surface. Plots were mowed once in 2002, twice in 2003 and once in 2004, 2005 and 2006. Pasturegard™ (triclopyr + fluroxypyr) was applied at 2 qts/acre plus 1/4% nonionic surfactant in 15 gallons total solution with a held-held boom sprayer as the herbicide treatment. Pasturegard was applied annually in late July thereafter until all saltcedar was killed. In July 2002, Inland saltgrass cover varied from 3 to 20% and alkali sacaton cover varied from 1 to 20% in the plots. Saltcedar populations varied from 50 to 200 per plot in July 2002. In July 2004, after two annual applications of Pasturegard, saltcedar populations were reduced 98% compared to annual mowing. There was no saltcedar in the Pasturegard plots in 2005 or 2006. After 3 years of mowing, saltcedar populations were reduced about 50%, and after 4 years of mowing they were reduced about 60%. In 2005 and 2006, saltcedar in the mowed plots was noticeably reduced in vigor. Based on the results of this study, annual mowing is relatively ineffective method for eliminating saltcedar, whereas 2 or 3 annual applications of herbicide appears highly effective for killing saltcedar. Between 2002 and 2006 there was a four-fold increase in Inland saltgrass in both treatments. Alkali sacaton increased two-fold in the mowed plots and three-fold in the herbicide plots.

Restoration planning in the context of tamarisk control in the western US

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Abstract:
There are an unprecedented number of ongoing and planned programs aimed at controlling non-native vegetation along rivers in the western US. The primary reasons stated for control efforts are to increase water yield, improve wildlife habitat and restore native vegetation. Central to all of these desired outcomes is the composition of the vegetation that occupies a site following control --i.e., water yield changes depend on ET differences between cleared vegetation and replacement vegetation, and wildlife habitat values depend on relative suitability of replacement vegetation vs. controlled vegetation. Given the central role of replacement vegetation, a key component in planning and site selection for control efforts should be consideration of the range of likely replacement vegetation types and the range of revegetation or restoration activities and associated costs that might be implemented in conjunction with non-native vegetation control. We synthesize information on different trajectories of vegetation change associated with tamarisk control and different management activities across multiple river systems in the western US. Our work will culminate in a planning framework to assist land and water managers with their efforts to prioritize sites for tamarisk control, based on the probability of converting different site types to various alternative vegetation types, and the likely associated restoration and maintenance costs.