

PROCEEDINGS OF THE 3RD NORTHERN ROCKIES INVASIVE PLANTS COUNCIL CONFERENCE

**AIRWAY HEIGHTS, WASHINGTON
FEBRUARY 10-13, 2014**



Edited by:
Mark Schwarzländer and John F. Gaskin



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Revegetation after Russian-olive (*Elaeagnus angustifolia* L.) Removal Along the Yellowstone River: a Cost and 2-year Success Assessment

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ABSTRACT

Restoration can improve sites that have been degraded by weed invasion and prevent secondary invasion by pre-empting niche space away from these unwanted colonists. We removed Russian-olive trees from a 1.9 ha site along the Yellowstone River in 2011 and installed a controlled revegetation experiment in 2012. Russian olive resprout rates in the year of removal were 4%, but sapling kill was necessary in the two years following removal because seedling recruitment would have generated a 21% population replacement rate in the first year and 10% in the second year. Survival of transplanted native trees and shrubs was high ($64\% \pm 32$ SD), even though the year in which we transplanted was one of the driest on record. Seeding the herbaceous layer also resulted in increased numbers of desirable species in the plots, but plant cover was very low. Our restoration was planted into mostly bare ground because there was little understory vegetation prior to removal due to the heavy shading of Russian olive and because our removal method of a tree shear on a skid steer created surface soil disturbance. After weed removal, conversion of bare ground to a functional native plant community that is capable of resisting other plant invasions often takes many years.

Key Words: riparian, revegetation, invasion, regeneration

INTRODUCTION

Riparian areas have been heavily utilized for agriculture for centuries as they often represent the most productive area in any landscape. Riparian corridors are unusually diverse and are significant contributors to regional biodiversity (Naiman et al., 1993). Because of the high contribution of riparian vegetation to ecosystem services, invasive species in riparian areas may be particularly damaging as dominant invasive species change community structure beyond their population boundaries (Gordon, 1998). We know very little about how community function changes after dominant invasive species are removed (DeMeester and Richter, 2010). Invasion of secondary weeds often follows eradication of a primary noxious weed species (Denslow and D'Antonio, 2005; Rinella et al., 2009), and the resulting plant communities can be so heavily modified that native consumer species such as birds and arthropods avoid these areas (Nelson

and Wydoski, 2008; Sogge et al., 2008). Here we show the short-term effects of Russian-olive tree removal and revegetation on plant communities. This report is a circumscribed, short-term assessment of a long-term study that examines the value of Russian olive removal and restoration to soil quality and arthropod communities as well as to economic variables such as forage quality.

Revegetation is a cultural activity that may have any number of goals including 1) pre-empting niche space away from undesirable plant species and preventing their establishment, 2) creating functional wildlife habitat, 3) increasing faunal biodiversity, 4) returning the plant community to a reference state (but see Monaco et al., 2012), and 5) improving ecosystem function (Ehrenfeld, 2000), including re-establishment of agricultural productivity. Because secondary invasion often occurs within restorations (Mulhouse and Galatowitsch, 2003; Zedler and Callaway, 1999; but see Rinella et al., 2012), it is unclear whether revegetation within restoration is effective for pre-empting niche space away from weeds. Most revegetation/restoration research lacks non-revegetated controls that illustrate how revegetation affects secondary invasion compared to the effects of executing other weed management techniques. Our research addresses this gap.

Riparian areas in the Northern Great Plains are in a state of constant flux: new habitats are created through disturbance (flooding, ice scouring) that transforms old habitats. Succession transitions from cottonwood and willow seedlings, to sapling thickets, to cottonwood forest, to shrubland, then to grassland. This successional trajectory results in non-linear changes in above-ground biomass production and soil abiotic properties (Boggs and Weaver, 1994). Much like the disturbance of flooding or ice scouring, noxious weed removal opens up space for establishment of undesirable species. This vacant niche may be exploited by native species or non-native species, depending on propagule availability and environmental factors that allow recruitment and establishment (Corenblit et al., 2007; Gabler and Siemann, 2012; Srivastava and Vellend, 2005). Depending upon the scale of invasion, removing Russian olive trees can create a high level of disturbance by removing a large amount of plant biomass and canopy cover (Figure 1), which effectively creates a new set point for plant succession to begin.

When invasive species alter ecosystems, post-removal restoration may be particularly important (Gordon, 1998). In the case of invasive plant removal, revegetation is often the default restoration approach. Implicit within the revegetation approach is the theory that establishing a plant community passively brings both above-ground and below-ground fauna to the site (Hobbs and Cramer, 2008). Restoration of forests and grasslands are often studied to determine factors influencing their success, yet riparian restorations are rarely examined from this perspective (Ruiz Jaen and Aide, 2005).

In this paper, we report plant understory composition prior to Russian olive tree removal, and then yearly for two years after removal. We compare the plant communities of four restoration treatments as well as established control plots where no restoration was conducted and report the costs of removal, subsequent control, and revegetation. We test two specific hypotheses: 1) revegetation prevents secondary invasion, and 2) revegetation is necessary to establish desirable plant species after Russian olive removal.

MATERIALS AND METHODS

This study was conducted at the 22,500 ha USDA-ARS Fort Keogh Livestock and Range Research Laboratory located near Miles City, MT. The research laboratory is within the mixed grass prairie of the Northern Great Plains with an average elevation of 780 m. Native vegetation is predominately grama-needlegrass-wheatgrass (*Bouteloua-Stipa-Agropyron*) mix (Kuchler 1964) with less abundant small shrubs including silver sage (*Artemisia cana* Pursh *ssp. cana*), big sage (*Artemisia tridentata* Nutt.), winter fat (*Krascheninnikovia lanata* (Pursh) A. Meeuse & Smit, formerly *Ceratoides lanata*), and small trees such as

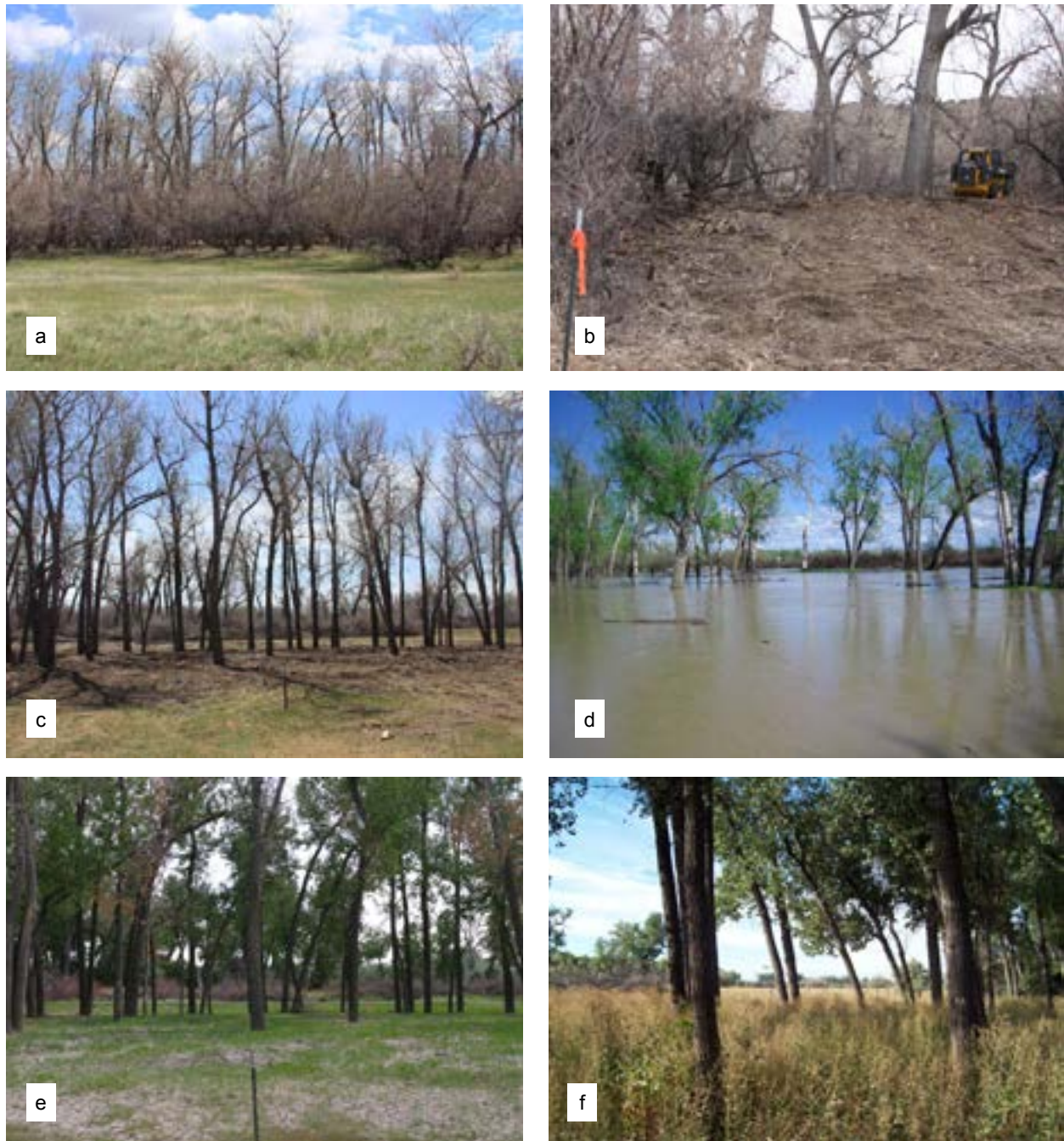


Figure 1. Photos before, during, and after removal. Photos a and c through f show Block 1 through time. Photo b shows what Block 4 looked like during the removal process. a) April 2010, pre-removal; b) April 2011, during removal; c) April 2011, post-removal; d) May 2011, during flood; e) April 2012, pre-restoration; f) June 2013, post-restoration. Photo (e) shows abundant cottonwood seedling recruitment after the flood, and (f) indicates that some of these seedlings survived through the following year.

juniper (*Juniperus communis* L.). Average annual precipitation is 340 mm with 60% received from April through September.

Approximately 8 miles of the Yellowstone River flows through Fort Keogh. Four replicate 0.5 ha blocks were established adjacent to the Yellowstone River on a Glendive fine sandy loam soil. All blocks were completely removed of Russian olive trees in April and May of 2011 using a John Deere 326D skid steer with a tree shear attachment (Grace Manufacturing). The cut stumps were immediately sprayed with a 1:3 mixture of Element 4 (triclopyr) and blue basal bark oil. The cost per hectare of removing these 2500 trees (excluding equipment costs) was 17.7 person hours, 39.5 liters of fuel, \$427 in herbicide costs (7.9 liters of triclopyr per ha). Figure 2 shows removal area. The resprouts and Russian olive seedlings were sprayed with 1 oz. Element 4, 3 tsp. Milestone (aminopyralid), and 1 oz. surfactant mixed in 11.4 liters of water with a backpack sprayer in fall of 2011 and 2012. Spraying was conducted in summer of 2013 in order to include salt cedar. Table 1 shows the number of Russian olive seedlings that herbicide was applied to and the cost per ha of these follow up treatments.



Figure 2. Aerial view of removal plots along the Yellowstone River near Miles City, MT.

Table 1. Follow up Russian olive treatments in cleared areas

year	# treated/ha	total resprouts	total seedlings	person hours/ha	liters of herbicide/ha
2011	8	98	0	0.2	1.4
2012	49	71	515	0.4	8.4
2013	20	no data	238 ^a	0.4	3.2

^a counts of resprouts and seedlings were combined in 2013

^b Includes spraying approximately 42 saltcedar saplings per acre

Each block was divided equally into 5 treatments; (1) control with no revegetation (2) seeded herbaceous layer only (3) seeded herbaceous layer with shrub plantings (4) seeded herbaceous layer with tree plantings and (5) seeded herbaceous layer with trees and shrubs planted. For the tree and shrub plantings, one- year-old conservation grade woody stock was procured from local sources. Due to flooding in May of 2011, revegetation occurred in April of 2012. Figure 3 shows the temperature and precipitation patterns for Ft. Keogh from the time of Russian olive removal to our final data collection in 2013. All plots except the control plots were sprayed with Roundup (glyphosate) in the fall of 2011 and before woody species planting in spring of 2012. A skid steer and tractor, each equipped with a 20cm auger, were used to excavate planting holes for the trees and shrubs. Each plant received approximately 3.75L of water at

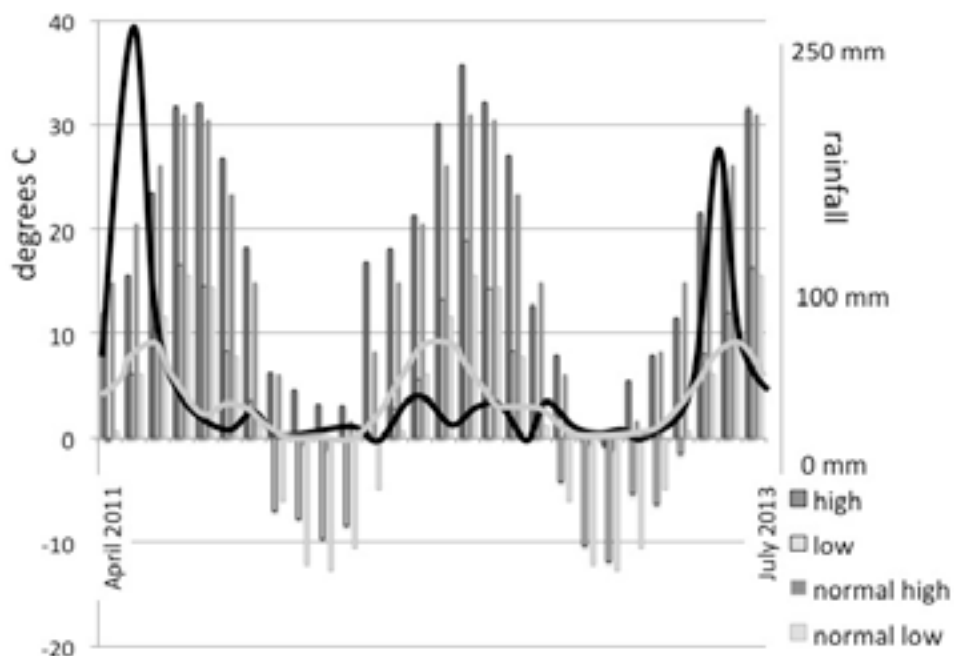


Figure 3. Measured monthly average high and low temperatures (bars) and precipitation amounts (line) during and after Russian olive removal at Ft. Keogh. Non-outlined bars and greyed line indicate normal levels.

planting time only. Weed barrier fabric (0.91m x 0.91m) was placed around 50% of the planted woody species. Woody species planted included narrowleaf cottonwood (*Populus angustifolia* James), plains cottonwood (*Populus deltoides* W. Bartram ex Marshall ssp. *monilifera* (Aiton) Eckenwalder), box elder (*Acer negundo* L.), green ash (*Fraxinus pennsylvanica* Marshall), golden currant (*Ribes aureum* Pursh), chokecherry (*Prunus virginiana* L.), buffaloberry (*Shepherdia argentea* (Pursh) Nutt.) and Woods’ rose (*Rosa woodsii* Lindl.). Herbaceous species seeded were: slender wheatgrass (*Elymus trachycaulus* (Link) Gould ex Shinners), western wheatgrass (*Pseudoroegneria spicata* (Pursh) Á. Löve), Prairie cordgrass (*Spartina pectinata* Bosc ex Link), switchgrass (*Panicum virgatum* L.), common yarrow (*Achillea millefolium* L.), prairie coneflower (*Ratibida columnifera* (Nutt.) Wood & Standl.), American vetch (*Vicia americana* Muhl. ex Willd.), Canadian milkvetch (*Astragalus canadensis* L.), white prairie clover (*Dalea candida* Michx. ex Willd.), purple prairie clover (*Dalea purpurea* Vent.), Maximillian sunflower (*Helianthus maximiliani* Schrad), blue flax (*Linum perenne* L.), Rocky Mountain bee plant (*Cleome serrulata* Pursh.), and Rocky Mountain penstemon (*Penstemon strictus* Benth.). We derived this species list from NRCS (2008) and the total application of all seed was 1.2 PLS per hectare. Table 2 shows the cost per hectare of revegetation.

Table 2. Cost per ha of revegetation

	person hours	materials (USD)
Prep spraying	1.6	\$6.8 ^a
Harrowing and seeding	0.7	\$105
Tree/Shrub transplanting	10 ^b	\$111 ^c

^a 1 liters of glyphosate/ha

^b this number increases to 15 when weed fabric placement is included

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^c this number does not include the cost of the weed fabric (\$83)

Herbaceous seed was broadcast seeded and a harrow and hand rake was used to ensure seed/soil contact. All plots were fenced to USDA-NRCS wildlife fence (NRCS 2006, 2008) specifications to protect the woody plants from wildlife and cattle browsing.

Vegetation cover was assessed by randomly locating six Daubenmire frames (0.1m²) within each of the five plots within each of the four blocks each summer. Plant cover by functional group (native perennial grass, exotic perennial grass, exotic forb, native forb, exotic annual grass) was collected using the point-intercept method (Jonasson 1988). We identified and recorded every herbaceous species growing in every subplot throughout the growing season. We classified all thirteen of our seeded herbaceous layer species as “desirable”. “Problem” species were exotic species that can be invasive under certain conditions: annual brome grasses, knapweeds, and salt cedar.

Data analysis:

The statistical software we used was JMP 10.0.2 (SAS Institute, Cary NC). We determined the effect of weed fabric on tree and shrub survival by running a standard least squares model for the effects of species identity, weed fabric presence, and their interaction on percent survivorship. Cover data were analyzed by analyzing the effects of year, restoration (yes or no), and their interaction on the change in 1) problem species cover and 2) native species cover from the previous year using a standard least square model. We did not separate the different restoration treatments as we do not expect trees and shrubs to interact with each other or the herbaceous layer until plants become larger and the restoration matures. Averages presented in the text are \pm one standard deviation and are raw cover percentage values rather than the calculated change values. The frequency of desirable species per restoration treatment (yes or no) for 1) 2012 and 2) 2013 were compared using a Dunnett’s test with the α level set to 0.05.

RESULTS

Our removal technique resulted in a 4% resprout rate the following year (Table 1). Resprouting continued in the following years, and a flush of new germination of Russian olive in the plots resulted in a 21% regeneration rate (515 out of 2500 trees removed) in 2012 and of 10% in 2013 (Table 1).

Tree and shrub survival from the time of planting in spring of 2012 to the following spring (2013) is shown in Table 3. Green ash had the highest survivorship of the tree species (84.6%), and Woods rose had the highest survivorship of shrub species (92.4%). Narrowleaf cottonwood had relatively poor survivorship at 25%. Weed fabric did not significantly affect survival ($F_{15,90} = 3.23, p = 0.67$). Overall survival of all transplants was 64% (± 32).

Cover of understory vegetation in our closed-canopy Russian olive stand prior to removal was low: 10% (Table 4). Problem species had 2.1% (± 3.0) and native species had 0.8% (± 2.2) cover. Understory composition responded dramatically to the removal treatment: native species cover rose to 7% (± 3.3) ($F_{1,38} = 6.98, p < 0.02$), whereas problem species cover and total species did not change. Total cover values were quite low in 2012 (4.9%, Table 4), probably due to the drought. From the year we planted restoration (2012) to the following year, total cover (Table 4) and total cover of both problem and native species increased significantly ($p < 0.01$), likely due to the higher rainfall in 2013 (Table 4). Cover of problem species increased from 1.7 (± 1.8) to 6.1% (± 2.4) and cover of native species increased from 3.0% (± 1.9) to 5.5% (± 3.3). We detected no differences in problem or native species cover between restored and unrestored plots in 2013 (all $p > 0.14$).

However, the presence of desirable species was higher in restored plots (Figure 4).

Table 3. Percent survivorship of planted tree and shrub species after the first winter.

Species	Percent survival	1 StDev
Narrowleaf cottonwood	25	0.42
Plains cottonwood	50	0.43
Box Elder	50.3	0.33
Green Ash	84.6	0.17
Golden currant	50.5	0.17
Chokecherry	63.1	0.31
Buffaloberry	65.8	0.20
Woods rose	92.4	0.22

Table 4. Total plant cover and growing-season rainfall amounts per year of the study

Year	% total plant cover	standard deviation	April-July rainfall (mm)
2010	10.0	6.2	335
2011	9.9	5.8	420
2012	4.9	3.3	78
2013	19.2	5.5	302

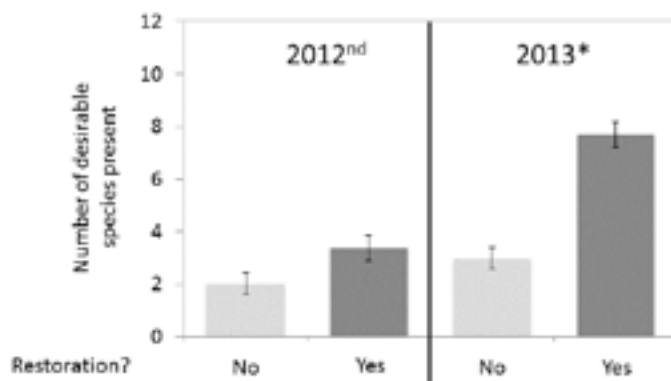


Figure 4. Number of planted herbaceous-layer species emerged in the plots the year of planting (2012) and the following year (2013). The number of planted species was not different between treatments in 2012 ($p = 0.19$, “nd” on the graph) but the following year was significantly higher in plots where seeding was performed ($p = 0.0002$, “*” on the graph). Bars are one standard error.

DISCUSSION

In 2012, southeastern MT experienced one of the four driest years on record since 1878 (National Climatic Data Center, Asheville NC), yet tree and shrub survivorship was high and planted herbaceous species persisted (either as seeds or juveniles) and were detected in the following year. Although standard vegetation sampling techniques were not sensitive enough to detect cover of planted species, we did detect an effect of restoration by measuring species presence/absence. Restoration was effective in increasing the number of desirable species in the plots with relatively high tree and shrub survivorship and some establishment of the majority of understory species that we planted. Two desirable species were present in control plots in the years before and after restoration, compared to an average of seven desirable species in planted plots. This supports the use of restoration as a tool to increase species diversity (Srivastava and Vellend, 2005). Our hypothesis that restoration would reduce secondary invasion was not supported, however: problem species abundance did not differ between restored and unrestored plots. While many studies show that restoration can introduce higher levels of problem species (summarized in Robichaud et al., 2000), we did not see lower levels in our control plots, probably because they experienced a very high level of disturbance similar to our restored plots.

Our method of Russian olive removal resulted in an extremely high level of soil disturbance (Figure 1b and c). It is likely because of the high level of soil disturbance and very low cover in 2012 that the presence of weed fabric did not increase tree and shrub survivorship: any established competitors for water and light were very small. Thus the recommendation for using weed fabric (NRCS, 2006) was over-conservative in the short-term, although weed fabric may allow for greater growth rates and long-term survival in surviving trees and shrubs: this will be measured in upcoming years. Conducting Russian olive removal using a non-mechanical technique resulting in less soil disturbance (for example, a chainsaw) would likely result in very different restoration outcomes.

Our removal technique in combination with the 50-year flood the site experienced just after removal (Figure 1d) likely strongly affected both Russian olive resprout rates and the composition of the understory vegetation. Higher total plant cover in 2011 post-removal compared to 2012 may have been due to the high water availability and colonization of the site from the flooding. Our reported 4% resprout rate includes those trees that resprouted from tree roots that were exposed by the flooding. If we were only to report stump resprouts, this percentage decreases to 0.4%. However, our regeneration rates of 21% in 2012 and 10% in 2013 that include new seedlings illustrate the importance of inspection and periodic control of this invasive species. Because Russian olive trees do not become reliably reproductive until they reach ten years of age (Lesica and Miles, 1999), it is possible to control these nascent reinvasions by conducting re-entry kills less frequently than once per year, although herbicide applications are not always effective agents of mortality, and less so when trees are larger. In addition, spraying larger trees has a greater likelihood of damaging adjacent, desirable vegetation.

We chose to evaluate our treatments based on set objectives of 1) native and desirable plant species abundance and cover and 2) resistance to secondary invasion. Because of intensive agricultural use of riparian areas and the non-equilibrium dynamics already in operation in this system, restoration with the goal of matching conditions to intact reference sites is likely untenable (Monaco et al., 2012; Richardson et al., 2007; Zedler & Callaway 1999). In this case, tree removal followed by drought resulted in an extreme reduction in existing understory. Resprouting is common after removal (Stannard et al., 2002) and appears to occur without regard to climate and independent of interactions with other plants (Figure 5). Therefore, untreated Russian olive resprouts may have a competitive advantage over both secondary invasive species and desirable natives. In order to prevent Russian olive resprouts from competing with desirable vegetation, we recommend early re-entry kills. In our case with the substantial soil surface disturbance applied by our removal technique, both secondary invasive species and desirable natives must establish from seed, and their ability to do so is largely driven by climatic factors (Figure 5). Plants generally do not affect each other's growth until they are large

enough to influence resource acquisition (i.e. light, water, nutrients) of neighboring plants (as in Weiner et al., 2001). Our experimental time frame of two years post-restoration was not long enough to observe competitive dynamics, niche pre-emption away from secondary invasive species, or plant community function. Restoration can be successful at reducing the densities of undesirable species in the long term (Rinella et al., 2012). We hope that by continuing to track these plots, we can compare the function of our restored plant community with multiple analogues: intact cottonwood stands and a gradient of Russian olive population densities, however to do so now would be premature.

CONCLUSIONS

Restoration can improve sites that have been degraded by weed invasion. Our total plant cover by the end of this study was almost twice that found prior to Russian olive removal indicating that we had an increase in herbaceous forage, likely as a result of tree removal. We found that restoration plantings increased the number of desirable species at a site, but establishment rates and growth were slow and did not show a signal in terms of differential levels of desirable species cover between restored plots and unrestored controls. This indicates that particularly in semi-arid systems such as are found in southeastern Montana, auxiliary benefits of restoration on vegetation characteristics and ecosystem function (such as invasion resistance) may take many years to develop, even when restoration plantings successfully establish.

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