River Bar Vegetation Mowing Response in the Middle Rio Grande

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Abstract—The Bureau of Reclamation routinely mows vegetation on side bars along the Rio Grande to assist with river flow management. To address the question of how such mowing affects vegetation composition and structure, three bars in the middle Rio Grande near Albuquerque, New Mexico were selected in 1994 for an experimental mowing program. Three 50-foot-wide strips on each bar were left unmowed, with the area between the strips mowed as usual. This mowing pattern was repeated in 1995 and 1996. In August 1996, vegetation composition, abundance and structure were measured under the two conditions of the treated bars and at one additional bar with no history of mowing. Species composition and abundance were compared among sites and treatments using ANOVAs and canonical discriminant analysis. The greatest negative effect was on the native cottonwood where there were significant declines of 70-90 percent on some sites with respect to cover, stems and individuals. Mowing also reduces the exotic Russian olive cover by 50-70 percent on sites where it is dominant. Although cover may decline, Russian olive often responds by resprouting and creating vigorous multiple-stemmed individuals. Coyote willow was affected less by mowing; at the site with the most willow cover (Belen), declines in both cover and the number of individuals were only about 32 percent. This relatively higher mowing tolerance may reflective coyote willow's greater adaptativeness to natural disturbances such as flooding. What is clear however, is that regardless of what shrubs are dominant, cottonwood is always the most negatively affected by mowing.

The Bureau of Reclamation (BOR) conducts mowing of the vegetation on side bars along the Rio Grande to assist with management of the river flow. Questions have arisen about the effect of this mowing on vegetation composition and structure. Are exotic species or natives affected by mowing? Is there an effect on overall biodiversity? How is the structure of shrub vegetation (stem number and size) affected? An experimental mowing and not-mowing program was begun by the BOR in 1994 on three river bars in the middle Rio Grande near Albuquerque, New Mexico. The bars were treated in the winters of 1994, 1995, and 1996. To evaluate the effects of mowing and not-mowing, the New Mexico Natural Heritage Program (NMNHP) measured vegetation composition, abundance and structure at these sites in the summer of 1996. Permanent monitoring sites were established and the results from the first year's sampling with respect to exotics and overall plant species diversity and stand structure are reported here.

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Methods and Materials

Study Sites

In 1994, three river bar sites along the middle reach of the Rio Grande near Albuquerque, New Mexico were selected for experimental mowing and not-mowing of vegetation. These sites had been subjected to ongoing mowing by the BOR for a number of years. They are located from north to south along the Rio Grande at the I-40, I-25 and NM 6 (Belen) bridges, respectively (fig. 1 and 2). On February 21, 1994 each bar was mowed in such a way as to leave three, 50-foot-wide strips unmowed with intervening mowed vegetation. Each strip was marked with either rebar or wooden stakes. The intervening areas were, on a continuing basis, mowed the following winters of 1995 and 1996. The style of mowing was not documented, but there are indications that mowers may have differentially treated cottonwoods by mowing around them in the treatment areas.

As a comparison, a site with no known history of mowing, south of the Central Avenue bridge and parallel to Tingley Beach, was included in the study. This site consists of a side bar and an island bar. Thus, there are three sites with a history of mowing that now contain strips of vegetation that have not been mowed for three years, plus one site that has never been mowed.

The I-40 site is located on the west bank of the river between the Central and I-40 bridges. It is dominated by Russian olive (*Elaeagnus angustifolia*) in the shrub layer, with some younger cottonwoods (*Populus deltoides* var *wizlezenii*) and seepwillow (*Baccharis salicifolia*). The understory is dominated by alkali sacaton (*Sporobolus airoides*) with fair amounts of Baltic rush (*Juncus balticus*) and saltgrass (*Distichlis spicata*) (fig. 3 and 4).

The unmowed side bar and island bar south of Central, hereafter referred to as the Tingley Beach site, is located on the east side of the river approximately a mile south of the Central bridge. The side bar has one major and a few smaller high-flow channels cutting through it. The nearby island bar lies 20 meters to the northwest across a shallow channel. It has a raised central portion, which is dominated by shrubs, with lower areas at the edges and north and south points dominated by grasses and alfalfa (*Medicago sativa*).

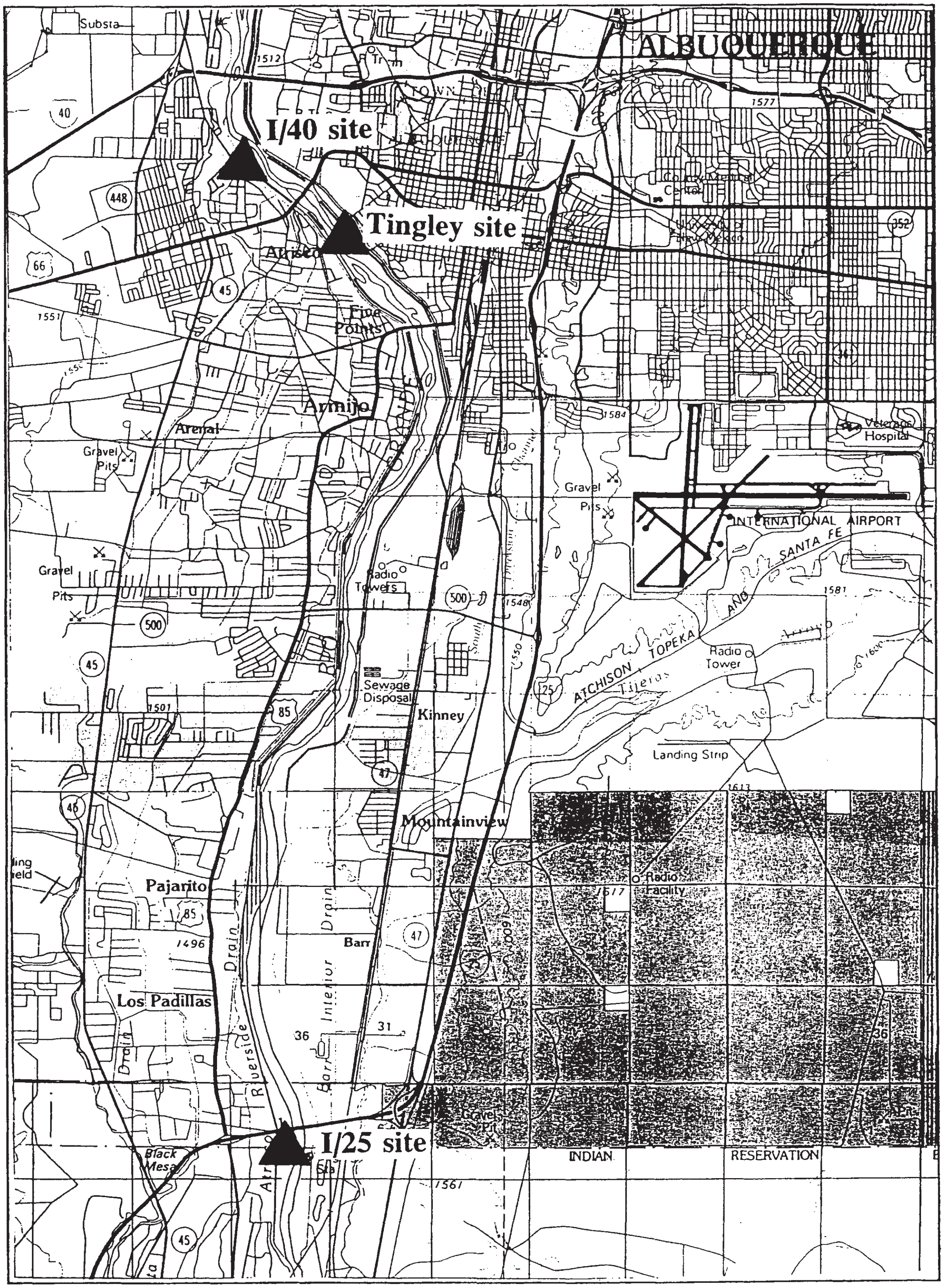

Figure 1—Map showing locations of I-40, Tingley Beach and I-25 study sites.

Figure 2—Map showing location of Belen study site.

Figure 3—Photo of I-40 site, looking down the Line 2 control (unmowed) transect. Many Russian olives and cottonwoods are now over three meters in height after three years.

Figure 4—Photo of I-40 site, looking south across Line 3 from the treatment (mowed) transect to the control (unmowed) transect in the background. Russian olive is abundant and cottonwoods are scattered on this site.

Figure 5—Photo of Tingley side bar site, looking north at line 2. Heavy coyote willow cover is typical of this site with some scattered cottonwood regeneration.

Transects were only established on the higher portion of the island bar, as this is area is more representative of the other bars being examined. Both the bar and the island are dominated by coyote willow (*Salix exigua*) in the shrub layer, with the understory dominated by meadow fescue (*Festuca pratensis*) (fig. 5 and 6).

The I-25 site is located on the west bank of the river immediately south of the I-25 bridge across the Rio Grande, and just north of Isleta Pueblo. In the spring of 1994 this site was burned when the neighboring bosque caught fire. The shrub layer is dominated by Russian olive with a fair amount of coyote willow. The major understory plants are alkali muhly (*Muhlenbergia asperifolia*), heath aster (*Aster ericoides*), vine-mesquite (*Panicum obtusum*) and saltgrass (fig. 7 and 8).

The Belen site at the NM 6 bridge is on the west bank of the river just south of the bridge within Senator Willie M. Chavez State Park. The dominant shrub is coyote willow with more cottonwood and Russian olive than the Tingley site. The understory is dominated by alkali muhly with strong components of Nebraska sedge (*Carex nebrascensis*), seepwillow, and Indianhemp (*Apocynum cannabinum*) (fig. 9 and 10).

Figure 6—Photo of Tingley island bar site, looking northwest at the island from the side bar. The central raised portion of the island is dominated by coyote willow.

Figure 7—Photo of I-25 site, looking down Line 2 treatment (mowed) transect showing heavy Russian olive shrub cover typical of this site.

Figure 8—Photo of I-25 site, looking south across Line 2 from the treatment (mowed) transect to the control (unmowed) transect in the background. The mix of coyote willow and Russian olive is typical of mowed transects at this site. This area was burned in the spring of 1994.

Figure 9—Photo of Belen site, looking down Line 1 control (unmowed) transect showing heavy coyote willow cover.

Figure 10—Photo of Belen site, looking south across Line 1 from the treatment (mowed) to control (unmowed) transect in the background. Heavy coyote willow cover with scattered cottonwoods is typical of this site.

Sampling Methods

To measure vegetation composition and structure, permanent vegetation monitoring transects were established on all four sites. The mowed and unmowed strips were relocated from maps, field marks, and with the aid of BOR personnel. On the three experimentally mowed sites, a transect line was established down the center of each of the three unmowed strips, with three comparison transects established in the mowed adjacent areas, for a total of six transects per site. The mowed transects were always placed to the north of their unmowed mate. Also, three transect lines each were established at the unmowed side bar and island sites. Transect pairs were numbered one to three, working north to south, and labeled C or T for control (unmowed) or treatment (mowed). From this point forward mowed transects are referred to as "treatment" and unmowed transects as "control".

All transects were permanently marked at each end with a meter length of rebar driven into the ground with about a third of the length showing, then covered with white PVC pipe. Metal identification tags where attached to the start rebar of each transect. The rebar locations were recorded with a Global Positioning System (GPS) unit and differentially corrected to +/- 5 meters (UTM). Photos were taken along the transects from each end along with representative photos taken of each site and are provided in a supplementary folder.

Beginning at a randomly placed start-point on the transect lines, one meter square quadrat frames were placed on the upstream side of the transect lines at regular intervals, ensuring 10 quadrats per transect line for a total of 30 per treatment and 30 for control at each site.

In each quadrat, for each shrub species, the number of stems in 5 cm diameter root crown (DRC) classes were counted and the average height by DRC class estimated. Stem numbers were counted from the root-crown, and individuals were estimated on proximity of emergent stems. Additionally, the aerial cover of all vascular plant species was estimated using a modified Krajina cover scale (table 1).

Sampling was performed August 13-23, 1996, at the end of the peak of the growing season.

Analysis

Data were entered into the NMNHP data system following NMNHP quality control protocols, then analyzed using the SAS statistical package versions 6.11 for aix (SAS 1990). Species identifications were confirmed from the voucher specimens, and the specimens were deposited at the University of New Mexico herbarium.

Species composition and abundance were compared among sites and treatments, particularly with respect to exotic versus native species. Analysis of variance (ANOVA) was used to compare the average cover, number of stems and number of individuals per quadrat for the most common shrub species across site, treatments type and site/treatment type combined. ANOVA was also used to compare the most common understory species across site, treatment type and site/treatment types combined. Pair-wise comparisons were made using Fisher's Least Significant Difference (LSD) means test (Sokal and Rohlf 1981).

Table 1—Modified Krajina scale used to estimate aerial cover of all vascular plant species.

Symbol	Percentage cover	Scaler
	Percent	
+0	N/A	Outside quadrat
+	N/A	Solitary or very few
1	<0.1	Seldom cover
2	<1	Very scattered
3	1-4	
4	5-10	
5	10-25	
6	25-33	
7	33-50	
8	50-75	
9	>75	
10	100	

Species diversity was assessed with three different indices. Species richness was evaluated from the direct counts of species number per transect, a method considered valid when samples are of equal size (Ludwig and Reynolds, 1988). The modified Hill's ratio evenness index (E5) was used to assess species evenness. Hill's N1 diversity index, which estimates the number of abundant species present, was used to assess species diversity (Ludwig and Reynolds, 1988).

To evaluate overall relationship among sites and species, multivariate canonical discriminant analysis was performed on both the shrubs and understory species for site/treatment type combined. Canonical discriminant functions optimize a linear combination of the original variables to maximize discrimination among groups. The correlation between the canonical functions and the original variables can be determined and is reported as an among-group canonical structure. This structure can then be used in a way similar to correlation coefficients to evaluate the importance of each original variable in discriminating among groups.

Results

There were 67 species encountered in the study. The top three shrubs (Russian olive, Rio Grande cottonwood and coyote willow) and the top seven grasses and forbs were selected for univariate Analysis of Variance (ANOVA) and multivariate canonical discriminant analysis. ANOVA results indicated that there were significant differences among sites and treatments with respect to species cover, stems and individuals. Pair-wise comparisons between treatment and control are treated below followed by a summary analysis using canonical discriminant analysis.

Shrubs: Russian Olive, Cottonwood, and Coyote Willow

The sites show a range of variation with respect to overall shrub species composition and cover, irrespective of treatment (tables 2-4) The I-40 site is strongly dominated by Russian olive with only minor amounts of willow (table 2).

Table 2—Russian olive means and standard deviations by site and treatment for percent cover, average number of individuals and average number of stems per quadrat. The significant difference row indicates if the LSD showed a significant difference between the treatment and the control of the given site for species means. * = significantly different; NS = not significantly different.

Russian olive	I-40 control	I-40 treatment	I-25 control	I-25 treatment	Belen control	Belen treatment	Tingley side bar	Tingley island bar
Cover								
Mean	64.1	25.9	53.7	21.6	13.7	6.77	0.002	3.97
Standard deviation	41.1	29.2	35	23.5	27.9	15.2	0.009	16.6
Significant pair difference	*	*	NS	NS				
Number of individuals								
Mean	0.8	0.667	0.717	0.183	0.15	0.2	0.033	0.033
Standard deviation	1.13	1.0	0.838	0.359	0.494	0.596	0.183	0.183
Significant pair difference	NS	*	NS	NS				
Number of stems								
Mean	2.83	4.87	7.9	2.53	0.867	1.2	0.033	0.033
Standard deviation	4.19	8.79	9.14	6.42	2.37	3.69	0.183	0.183
Significant pair difference	NS	*	NS	NS				

Table 3—Coyote willow means and standard deviations by site and treatment for percent cover, average number of individuals and average number of stems per quadrat. The significant difference row indicates if the LSD showed a significant difference between the treatment and the control for the given site for species means. * = significantly different; NS = not significantly different.

Coyote willow	I-40 control	I-40 treatment	I-25 control	I-25 treatment	Belen control	Belen treatment	Tingley side bar	Tingley island bar
Cover								
Mean	0.585	0.5	19.7	25.4	58.8	38.6	68.4	50.2
Standard deviation	3.2	1.9	31	27.9	23.3	26.7	27.6	29.9
Significant pair difference	NS	NS	*	*				
Number of individuals								
Mean	0.017	0.033	1.1	1.15	5.3	3.43	4.22	5.78
Standard deviation	0.091	0.183	1.32	1.5	2.14	1.92	2.87	3.18
Significant pair difference	NS	NS	*	*				
Number of stems								
Mean	0.133	0.133	9.2	10.8	15.6	13.4	19.1	19.3
Standard deviation	0.73	0.73	14.9	13.7	9.91	10.4	14.5	13.5
Significant pair difference	NS	NS	NS	NS				

Table 4—Cottonwood means and standard deviations by site and treatment for percent cover, average number of individuals and average number of stems per quadrat. The significant difference row indicates if the LSD showed a significant difference between the treatment and the control for the given site for species means. * = significantly different; NS = not significantly different.

Cottonwood	I-40 control	I-40 treatment	I-25 control	I-25 treatment	Belen control	Belen treatment	Tingley side bar	Tingley island bar
Cover								
Mean	9.33	1.47	0	0	12.8	3.55	2.52	0.752
Standard deviation	24.4	7.58	0	0	18.1	12.4	9.07	1.63
Significant pair difference	*	NS	*	NS				
Number of individuals								
Mean	0.067	0.033	0	0	0.5	0.133	0.083	0.4
Standard deviation	0.286	0.183	0	0	0.965	0.49	0.265	0.77
Significant pair difference	NS	NS	*	NS				
Number of stems								
Mean	0.167	0.067	0	0	1.13	0.3	0.133	0.4
Standard deviation	0.747	0.365	0	0	2.45	1.29	0.434	0.77
Significant pair difference	NS	NS	*	NS				

In contrast, the unmowed Tingley Beach site is dominated by coyote willow and lacks significant Russian olive (table 3). The I-25 site is also dominated by Russian olive, but has a significant component of willow intermixed in the canopy. Similarly, the Belen site is dominated by willow, but has a significant amount of Russian olive. There was an overall differential distribution of cottonwoods as well. They were well represented at the I-40 site, common at the Belen site, scattered at the Tingley Beach site, and absent at I-25 site. Similar site trends were also evident in terms of number of stems and individuals (tables 2-4).

Regardless of these site differences, there are still several within-site treatment effects that are apparent on a pair-wise basis. It appears that the mowing affected cottonwood more than the exotic Russian olive, and that coyote willow was least affected. Generally, the controls (unmowed) had higher shrub cover, particularly for Russian olive and cottonwood, and less so for willow.

For Russian olive, cover significance declined between 50-60 percent relative to the unmowed transects on the I-40 site and I-25 sites where it was most abundant to begin with, and the same trend is indicated at the Belen site (table 2). But there was a differential response with respect to stems and individuals; on the I-40 site despite the reduction in cover, the number of individuals did not significantly decline and there is a suggestion that the number of stems may have increased with mowing. On the I-25 site Russian olive individuals and stems did decline, but this confounded by the intense burn that occurred on the site in 1994. The combination of mowing and burning may negatively impact Russian Olive.

Coyote willow cover was not as strongly affected by mowing. Treatment effects were only significant at the Belen site, with a decline 35 percent in willow cover, and a commensurate decline in the number of individuals on mowed transects, but the number stems actually increased. The I-25 site had a fair amount of willow, but no treatment effect was detectable. There was also a minor difference at the untreated Tingley Beach sites with the island showing slightly less cover for willow, but more stems. More than likely this reflects the younger age class of willows on the island with a greater number of stems, but less canopy for their size.

Cottonwood showed significant declines (70-90 percent) with mowing at both the Belen and I-40 sites. The same trend was evident for stems and individuals, but was only significant at the Belen site. No cottonwoods were present on the I-25 site, most likely due to the high mortality following the 1994 fire. The Tingley site cottonwoods showed a similar pattern to the willows, with a significant increase in stems on the island site and a corresponding trend of lower cover, which was probably related to stand age.

Herbaceous Cover and Diversity

On a site basis, there were several differences with respect to understory species dominance. Meadow fescue was abundant and dominated the Tingley Beach site, and was uncommon or absent at the other sites. There was also significantly higher cover of fescue on the island bar than on the side bar. Alkali muhly was a common associate, but never dominant. In contrast, alkali muhly dominated the Belen site along with Nebraska sedge. Alkali muhly was also a dominant on the I-25 site, but this time co-occurring with inland saltgrass, with a significant component of heath aster. Alkali sacaton was the primary dominant on the I-40 site with both inland saltgrass and alkali muhly as common co-dominants, and on the controls, Baltic rush and Nebraska sedge.

On a pair-wise analysis of treatment affects, there was a trend towards increasing grass cover with mowing (table 5). On the I-40 site, Alkali sacaton showed a strong, significant increase in cover and dominance with mowing; on the control sites it was a co-dominant with cover comparable to other graminoid species. Baltic rush tended to decrease on mowed transects, significantly so at the I-40 site. Nebraska sedge, although it showed a decrease on mowed transects at I-40, increased on mowed transects at Belen, and there was no overall significant difference between treatment and control. Inland saltgrass response was also equivocal; it dramatically increased with mowing on the I-25 site, but declined somewhat at the I-40 site. The common forb, heath aster, was most abundant at the I-25 site and showed a significant decrease on mowed transects. On other sites it was not abundant enough to detect a treatment effect.

With respect to diversity measures, there was only a slight indication of direct treatment effect with decreasing species richness (total number of species) with mowing (table 6). This was mostly evident at the Belen site, and in the comparison of all sites to the Tingley Beach site. The never-mowed Tingley Beach site had the highest species richness over all sites. Only the Belen controls had a similar number of species. With respect to the number of very abundant species (N1) and abundant species (N2), no strong patterns emerge. There is an indication that the I-40 site was not only lower in diversity, but tended to have fewer co-dominants as indicated by the lower N1 and N2 values in comparison to other sites. But overall, the ratio N2 to N1 as represented by E5 indicates that abundance was relatively evenly distributed among all sites except Tingley Beach Site. This may reflect the strong dominance at this site by willows with a diverse but lower cover understory.

An Overview with Canonical Discriminant Analysis

The canonical discriminant analysis of shrub cover of Russian olive, cottonwood, coyote willow and salt cedar demonstrated the overall differences between sites and treatments. Only the first two canonical functions were significant, with eigenvalues greater than 1.0, and accounted for 92.3 percent of the variation (table 7). Figure 11 is a graphical representation of the distribution of centroids (collective means) of the site/treatment combinations with respect to these first two functions. Function 1 accounts for 77.2 percent of the variation and is primarily responsible for separating sites. The canonical structure indicates that Russian olive and coyote willow cover are the primary discriminators along this axis, with salt cedar as a minor element (table 7). There is some overlap between I-25 Control and I-40 treatment (they have similar covers for Russian olive), and between Belen Control and Tingley Beach Island (they have similar willow cover). Function 2 serves to separate treatment and controls, but only accounts for

Table 5—Average herbaceous and graminoid percent cover per quadrat by site and treatment. The significant difference row indicates if the LSD showed a significant difference between the treatment and the control for the given site for species means. * = significantly different; NS = not significantly different.

Grasses and forbs	I-40 control	I-40 treatment	I-25 control	I-25 treatment	Belen control	Belen treatment	Tingley side bar	Tingley island bar
Heath aster								
Mean	0	0	27.4	15.6	0.333	0.002	0.25	0.417
Standard deviation	0	0	31.4	17.6	1.43	0.009	0.763	1.48
Significant pair difference	NS	*	NS	NS				
Inland saltgrass								
Mean	10.9	2.22	5.52	20.7	0	0	0	0
Standard deviation	26.5	8.17	10.6	20.4	0	0	0	0
Significant pair difference	*	*	NS	NS				
Meadow fescue								
Mean	0	0	0	0	0.967	0	5.05	26.6
Standard deviation	0	0	0	0	5.29	0	17.5	33.3
Significant pair difference	NS	NS	NS	*				
Alkali muhly								
Mean	3.5	6.68	21.1	22.4	25.8	30.5	2.89	2.42
Standard deviation	16.2	17.4	20.4	17.2	18.7	27.9	8.53	4.71
Significant pair difference	NS	NS	NS	NS				
Alkali sacaton								
Mean	7.6	34.6	1.25	0	0	0.167	0.337	0
Standard deviation	18.1	32.7	4.44	0	0	0.634	1.43	0
Significant pair difference	*	NS	NS	NS				
Baltic rush								
Mean	13.1	0	0	0	3.02	0.002	0.417	0
Standard deviation	25.1	0	0	0	10.5	0.009	1.48	0
Significant pair difference	*	NS	NS	NS				
Nebraska sedge								
Mean	3.5	0	0	0	16.2	20.1	0	0
Standard deviation	15.9	0	0	0	22.4	34.7	0	0
Significant pair difference	NS	NS	NS	NS				

Table 6—Average number of species, Hill's evenness and diversity index per transect by site/treatments.

Hills diversity indices	I-40 control	I-40 treatment	I-25 control	I-25 treatment	Belen control	Belen treatment	Tingley side bar	Tingley island bar
N0 (Number of Species)	11.0	9.67	13.7	13.3	18.0	13.7	19.7	18.3
N1(very abundant species)	5.15	5.78	8.27	8.29	9.55	6.39	5.13	7.50
N2 (abundant species)	4.30	5.09	6.92	7.34	8.19	5.26	3.38	5.45
E5 (evenness)	0.799	0.856	0.811	0.875	0.843	0.784	0.533	0.686

Table 7—Shrub cover canonical between group correlation structure for the two significant canonical discriminant analysis (CDA) functions.

Species	CDA function 1	CDA function 2
Russian Olive	–0.91	0.39
Cottonwood	0.03	0.71
Coyote Willow	0.97	0.22
Salt Cedar	0.58	-0.25
Eigenvalue	1.39	0.27
% of variation	77.2	15.1
Cumulative %	77.2	97.3

Shrubs

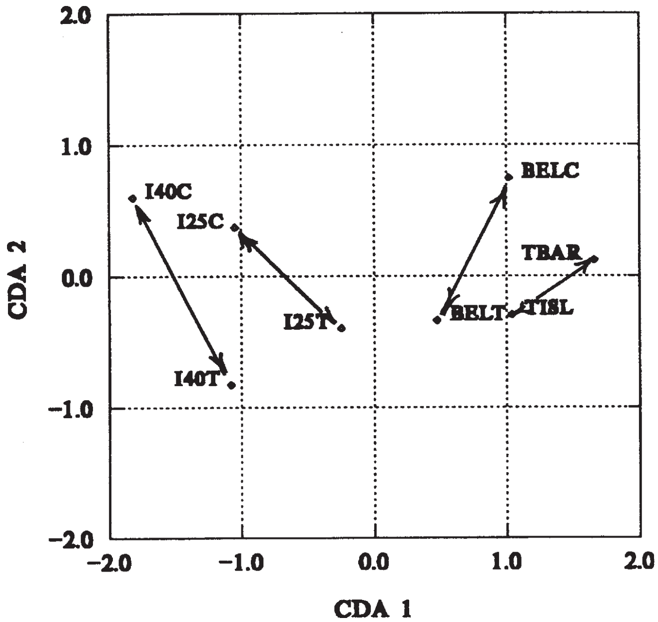

Figure 11—Shrub canonical discriminant analysis (CDA) site/treatment centroid position on functions 1 and 2. I40C = I-40 control transects; I40T = I-40 treatment; TBAR = Tingley side bar; TISL = Tingley island bar; I25C = I-25 control; I25T = I-25 treatment; BELC = Belen control; BELT = Belen treatment.

Forbs and Grasses

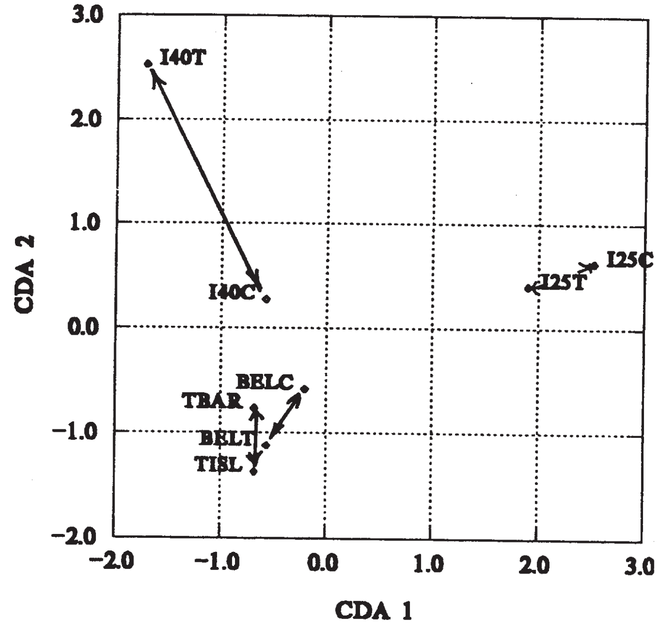

Figure 12—Forb and graminoid canonical discriminant analysis (CDA) site/treatment centroid position on functions 1 and 2. I40C = I-40 control transects; I40T = I-40 treatment; TBAR = Tingley side bar; TISL = Tingley island bar; I25C = I-25 control; I25T = I-25 treatment; BELC = Belen control; BELT = Belen treatment.

15.1 percent of the variation. The strong difference between treatment and control at the I-40 and Belen sites is evident and driven primarily by the difference in cottonwood cover and secondarily by Russian olive. Neither willow nor salt cedar appear to be very important discriminators.

The discriminant analysis based on understory herbaceous cover is less clear. There were three significant functions derived from the basis of 16 species' cover values. The I-25 site is clearly isolated along the positive end of the function 1 axis (fig. 12). This is primarily a result of positive correlations for heath aster and vine mesquite (*Panicum obtusum*), and to a lesser degree for Canadian horseweed (*Conyza canadensis*), Indian grass (*Sorgastrum nutans*) and alkali muhly. Conversely, the I-40 treatment is found on the far negative end of the axis primarily as a result of high alkali muhly and alkali sacaton cover. The I-40 treatment is further separated along the second axis by alkali sacaton, and to a lesser degree Russian thistle (*Salsola kali*) (table 8).

Axis 2 also isolates the Belen and Tingley Beach sites on the negative side as a function of negative loading on meadow fescue, smooth horsetail (*Equisetum arvense*) and Nebraska sedge. The only noticeable treatment effect in functions 1 and 2 is for the I-40 site, and it is primarily driven by high grass cover on the treatments. There are a few limited treatment effects apparent along canonical axis 3 for the Belen site and I-25 site (fig. 13). These differences are driven

Table 8—Herbaceous and graminoid cover canonical between group correlation structure for the three significant canonical discriminant analysis (CDA) functions.

Species	CDA 1	CDA 2	CDA 3
Cuman ragweed	0.58	–0.21	0.27
Indianhemp	–0.16	–0.37	0.72
Heath aster	0.94	0.25	–0.09
Seepwillow	–0.43	0.02	0.62
Nebraska sedge	–0.2	–0.42	0.86
Thymeleaf sandmat	–0.46	0.16	–0.35
Canadian horseweed	0.73	–0.18	–0.34
Inland saltgrass	0.57	0.31	–0.03
Smooth horsetail	–0.09	–0.47	–0.69
Meadow fescue	–0.23	–0.5	–0.68
Baltic rush	–0.18	0.04	0.03
Alkali muhly	0.48	–0.14	0.81
Vine mesquite	0.93	0.23	–0.04
Russian thistle	–0.49	0.81	–0.01
Indian grass	0.56	0.27	0.18
Alkali sacaton	–0.51	0.85	–0.02
Eigenvalue	1.88	1.43	1.16
% of Variation	33.6	25.5	20.8
Cumulative %	33.6	59.1	80

Forbs and Grasses

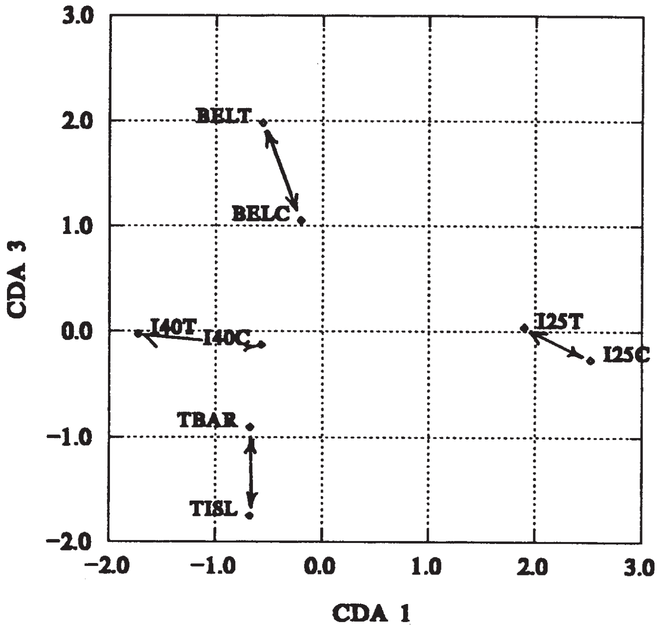

Figure 13—Forb and graminoid canonical discriminant analysis (CDA) site/treatment centroid position on functions 1 and 3. I40C = I-40 control transects; I40T = I-40 treatment; TBAR = Tingley side bar; TISL = Tingley island bar; I25C = I-25 control; I25T = I-25 treatment; BELC = Belen control; BELT = Belen treatment.

primarily by differential cover of Nebraska sedge and alkali muhly. For the Tingley Beach site, there was a slight difference between the island and the sidebar, primarily driven by relative meadow fescue and smooth horsetail cover.

Discussion

Mowing has a differential impact on various species, which is highly apparent on some cases regardless of specific site conditions. The greatest negative effect was on the native cottonwood, where there were significant declines on some sites with respect to cover, stems and individuals. Mowing also reduces the exotic Russian olive cover, but not as effectively as it reduces the cottonwood. In contrast to cottonwood, Russian olive seems to respond well in some cases by resprouting and creating vigorous multi-stemmed individuals. The native coyote willow does not seem to be very affected by mowing or not mowing. However at Belen, the one mowed site strongly dominated by willow, willow cover and number of individuals was reduced by about a third. Since coyote willow is a disturbance-adapted species it is not surprising that it shows less effect from the mowing then the other two later successional stage species, and that it may even respond positively to mowing. What is clear is that regardless of which other shrubs were dominant, cottonwood was always the shrub most negatively affected by mowing.

The general trend for the grass cover to increase on mowed transects is not surprising, since mowing, by reducing the shrub cover, increases the amount of light available to the understory. However, in many cases the increase in understory cover on mowed transects was not very great, and is rarely statistically significant. For the one common forb and the common rush and sedge, cover actually decreased on mowed transects, in two cases significantly so. The rush and the sedge are both native wetland obligate species, and their decrease could indicate a negative impact on wetland quality as a result of the mowing.

Mowing may be having a negative effect on overall species richness as indicated by the high species richness at the unmowed Tingley sites and by the tendency for unmowed transects to have higher average species richness than mowed transects at the same site. The dominant shrub species at a site also appears to be a factor in species richness, as species richness was lower on those sites with higher Russian olive cover (I-25 and I-40).

Evenness appears to increase on mowed transects, at least at the two sites dominated by Russian olive (I-25 and I-40). However, at the Belen site the unmowed transects had higher species evenness. The never-mowed Tingley Beach site had the highest species richness but the lowest species evenness; this indicates that mowing is increasing species evenness by reducing less-common species and favoring an even distribution of common ones.

Hill's N1 diversity index measures species diversity by combining species richness and evenness to produce an estimate of the number of abundant species. Since it combines richness and evenness and since these showed opposite trends, it is not surprising that the sites intermediate on both were the ones that showed the highest diversity. In fact, the sites highest in average Hill's N1 diversity index, I-25 and Belen, were also the ones intermediate not only in species richness and evenness, but also in dominant shrub species.

The greatest difference in exotic versus native species is more related to the differences between sites, rather than to direct treatment effects. The difference between sites is especially marked when comparing the I-40 and I-25 sites to the Belen and Tingley sites; the first two being strongly dominated by Russian olive and the second two by coyote willow. The differences between these sites may be due to differences in soil moisture and possible flooding disturbance. The two willow sites may be lower in elevation and thus flooded more frequently and have wetter soils at depth. Furthermore, the I-25 site was burned in the spring of 1994, providing an additional variable that may be affecting species composition and abundance.

The conclusions drawn here are based on a very limited sample of sites and replications within sites, and on the basis of only one reading after three years of treatment. Continued, effective and uniform treatment may enhance differences in the future. Adding additional sites with treatments will also help further isolate environmental characteristics from treatment effects. At the same time, there should be more detailed comparative studies on soils, landforms, hydrology and fire history done in order to make effective and definitive statements about the causes of differences in species composition, dominance and the overall structure in relation to mowing.

Acknowledgments

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