RECLAMATION

Managing Water in the West

2011 Monitoring Report for Treatment of Saltcedar (*Tamarix spp*.) and Other Invasive Nonnative Vegetation – Orilla Verde Recreation Area

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Environmental Services Division
Fisheries and Wildlife Resources Group
Denver, Colorado

January 2012

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

2011 Monitoring Report for Treatment of Saltcedar (*Tamarix spp.*) and Other Invasive Nonnative Vegetation – Orilla Verde Recreation Area

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Introduction

The Bureau of Land Management (BLM) has implemented a program to control saltcedar (*Tamarix* spp.) and other invasive species along the Rio Grande within the Orilla Verde Recreation Area (OVRA) in New Mexico (USDI 2006). The Bureau of Reclamation (Reclamation) conducted baseline and post-treatment vegetation monitoring at sites within the treated area from 2006 to 2011.

Reclamation has monitored five sites in the upper reaches of the OVRA (Figure 1). Treatments began in October 2006 at the northern (upstream) end and will continue south (downstream) for the next several years. Initial treatments were implemented in sites where vegetation was comprised of mostly native species and where saltcedar was fairly sparse and could be removed by hand. In 2008, saltcedar was removed at two such monitoring sites following 2 years of baseline data collection. In 2009, saltcedar was removed from a site where it was the predominate vegetation following 2 years of baseline data collection. In each year, beginning in 2008, areas where resprouting had occurred were re-treated with a foliar application of herbicide.

Methods

Monitoring was conducted within two types of sites: treatment sites and reference sites. Within treatment sites, there were potentially two types of permanent transects monitored: treatment transects and reference transects. Two treatment transects were located in areas where saltcedar was most dense. In treatment sites that included areas dominated by native species where desired future conditions (post-treatment) existed for that site, two reference transects were also established. Within reference (*i.e.* control) sites, only two reference transects were established in healthy native willow communities with no saltcedar.

Within all transects, vegetative cover and woody stem density were measured in five 1-meter square (m^2) plots along a 25-meter (m) permanent transect. The percent cover by species was estimated for the herbaceous and overstory layer. The herbaceous layer included grasses, forbs and woody species 25 centimeters (cm) or less in height and the overstory layer included woody species greater than 25 cm. To determine stem density, the number of woody plant stems by species was counted within each plot and every individual stem branching below 25 cm was tallied. An example of the form used to record data is in Appendix A. Plots were located along the transect at 0-1 m, 5-6 m, 10-11 m, 15-16 m, and 20-21 m. The first plot was placed on the upstream (north) end of the transect; plots were alternated on each side of the tape, starting with the first plot on the right (west) of the transect, the second plot left (east), the third right, and so on. In the treatment transects within the treatment sites, the number of saltcedar stems within 1 m of the 25-m tape on the west side was also counted.

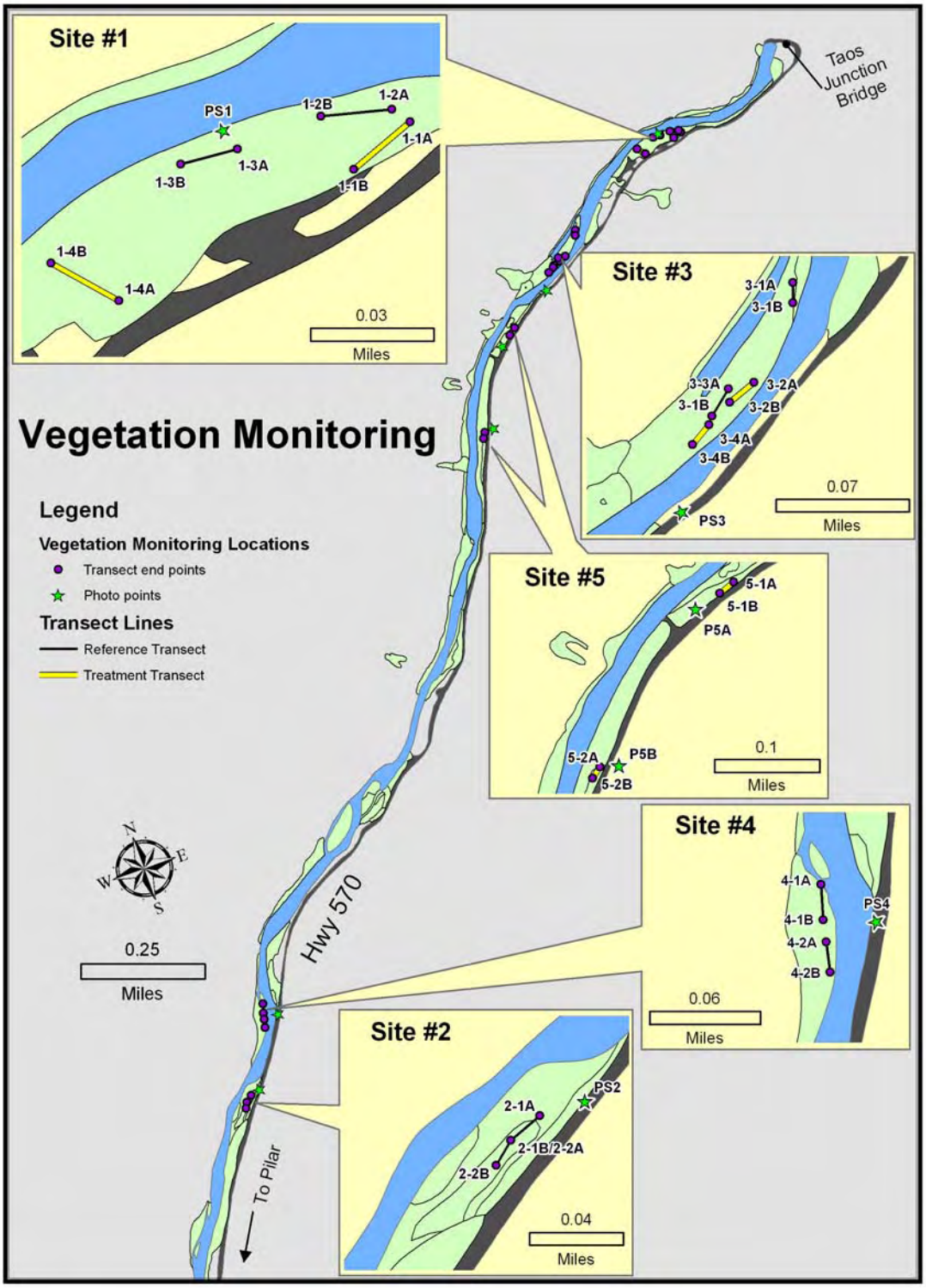


FIGURE 1.—Vegetation monitoring locations.

Statistical analyses included total cover (*i.e.* actual cover estimate) of native and introduced species and of plant, litter, and bare ground within the herbaceous layer. The total shrub cover and the stem density were statistically evaluated within the overstory layer. These analyses compared data between the treatment and reference transects within the treatment sites and compared data between years for all sites. In comparisons between treatment and reference transects, the Student's t-test of means was used to statistically compare normally distributed data, and the Mann-Whitney nonparametric test of medians was used to compare data that were not normally distributed. In comparisons within transect types and between years, the paired t-test was used for data from normal distributions and the signed rank test was used for data that was not normally distributed. Each of the herbaceous plant life-forms (*i.e.* native or introduced shrub seedlings, grasses, or forbs) were not statistically analyzed but were graphed for a comparison over time using relative cover. Relative cover is cover of a species or life-form expressed as a percent of total vegetation.

Overall canopy cover was estimated using a densiometer by taking four readings at the end point of each transect —two at each direction parallel to the transect and two at each direction perpendicular to the transect. These four readings were averaged to get one value for each point, or two values per transect, which were then averaged to get a canopy cover estimate for the transect. To avoid confusion, in this report "canopy cover" will be used to refer to percent canopy cover as measured with a densiometer at each end of transects and "overstory cover" will be used to describe the total percent cover of woody species measured within 1 m^2 plots along transects, as described above.

Photographs were taken from each end of transects to visually document changes in the vegetation over time and in response to treatment. A permanent photo station was established in association with each site (either within the site or from a distance) to capture overall conditions of the site. In 2010, photographs were also taken using a hemispheric camera with a viewing angle of 180° at each end of transects facing upward into the plant canopy. The objectives in using this camera were to gather permanent and more precise records of the geometry of canopy openings and changes in the canopy over time. The narrow canyon in which OVRA is located proved to be problematic because canyon walls were captured in the hemispheric lens, making it difficult to separate vegetation cover in the photos. Therefore, the use of the hemispheric photos to measure canopy cover was discontinued at this project site. Waypoints for photo station and transect locations are listed in Appendix B.

Treatment Sites (1, 3, and 5)

Treatment sites 1 and 3 were established in 2006 and were located in those areas with sparse saltcedar as described above. Both treatment and reference transects were included at these sites. Site 5 was established in 2008 and was dominated by a dense canopy of mature saltcedar. Only treatment transects were located within this site.

Reference Sites (2 and 4)

Reference sites were established in 2006. Data from two transects in each reference site were collected to examine trends in untreated sites. These sites could also potentially serve as reference areas of desired future conditions for those sites that were dominated by saltcedar and therefore did not have reference transects available on site (e.g. Site 5).

Results and Discussion

Treatment Sites

Site 1

Baseline data were collected in Site 1 in June 2006 and October 2007. Saltcedar was inadvertently removed from one of two treatment transects in 2007 with no herbicide treatment, therefore data from that year does not fully represent baseline (*i.e.* pre-treatment). Saltcedar was removed using the cut stump method in the other treatment transect in 2008 prior to monitoring in October of that year. This method of treatment entailed removing the saltcedar stem by hand cutting followed by an herbicide application to the stump. Saltcedar debris created by cutting was removed from the site. All saltcedar that were included in post-treatment monitoring measurements were resprouts.

Because data were collected before the monsoon season in 2006 and after the monsoon season from 2007 through 2011, there were considerable differences in the amount and type of herbaceous vegetation detected. Therefore, only 2007 baseline data were used as a comparison to 2008 through 2011 post-treatment data for the herbaceous layer. Late summer monsoonal rains did not appear to drastically affect shrub cover and density. Therefore both 2006 and 2007 baseline data were used as a comparison to 2008 through 2011 post-treatment data for the overstory layer.

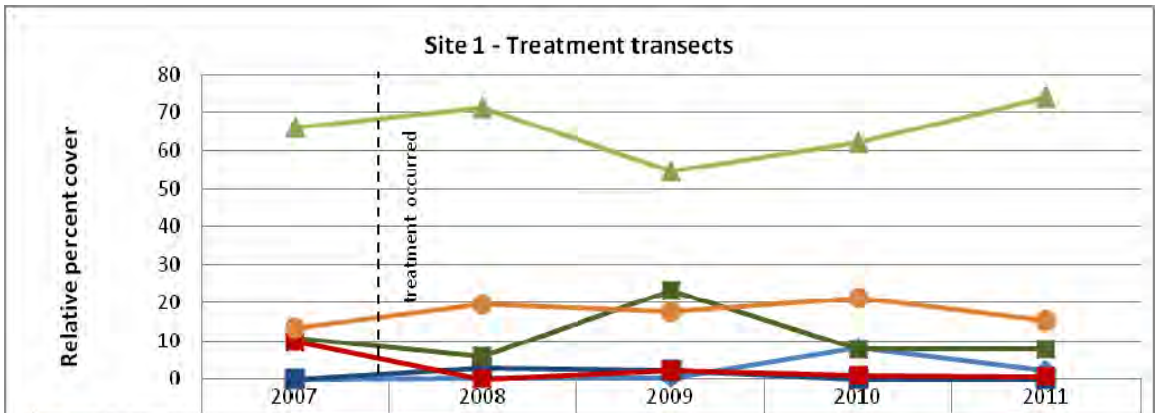
Scientific names for the plants detected within all transects are listed in Appendix C. The total percent cover by individual plant species, life-form (*i.e.* native or introduced shrub seedlings, grasses, or forbs), and cover type (*i.e.* vegetation, litter, bare ground, or basal area of shrubs) in the herbaceous layer of treatment and reference transects in Site 1 are shown in Table D-1 in Appendix D for all years of monitoring. The listed “Treatment” values are an average of 10 plots measured in the 2 treatment transects of Site 1. Accordingly, the listed “Reference” values are an average of 10 plots measured in the 2 reference transects of Site 1.

Fifty species were detected within the herbaceous layer of transects in Site 1 over the 6 years of monitoring. In 2007, the most abundant species based on percent cover in the treatment transects were slender wheatgrass, cheatgrass, and mullein. In 2008, the most common species were slender wheatgrass, mullein, Japanese brome, and Canada thistle and from 2009 to 2011 the most common species were slender wheatgrass, Japanese brome, and Canada thistle in the same transects. In the reference transects, the most common species in 2007 were Kentucky bluegrass,

slender wheatgrass, and sedge, which shifted to slender wheatgrass, sedge, and tall fescue in 2008 and to slender wheatgrass, redtop, and sedge from 2009 to 2011.

The relative cover of life-forms detected in the herbaceous layer of treatment and reference transects in Site 1 are graphed for a visual comparison between years 2007 (pre-treatment) and 2008- 2011 (post-treatment) in Figures 2 and 3. Native grasses were the most common life-form based on relative percent cover in both types of transects for all years of monitoring. Native species were more abundant relative to introduced species in all years in both types of transects (Table 1).

From 2007 to 2011, the total percent cover of native plants was statistically equal between reference and treatment transects except in 2009, when native cover in the reference transects peaked (Figure 4) and led to significantly higher percentage of native plants than in treatment transects that year (see Table 2 for statistical results and P-values for the herbaceous layer in Site1). This surge in native species, particularly grasses, also resulted in a significant increase in native cover from 2008 to 2009 within the reference transects. Although there were no statistical changes in cover of native species in treatment transects between consecutive years, a gradual decrease over time led to a significant decrease in native species over the monitoring period (2007 vs. 2011). In the reference transects, there was a significant decrease in the total percent cover of introduced species from 2010 to 2011; however this did not result in a statistical decrease of introduced species over the monitoring period when comparing 2007 to 2011 within Treatment Site 1 (Table 2). The total percent cover of introduced species fell to levels comparable to 2007 after a gradual rise (not statistically significant) through 2010 (Figure 4). There were no statistical changes in total cover of introduced species over time in treatment transects.



	2007	2008	2009	2010	2011
Nat shrub	0.0	0.4	0.3	8.2	2.3
Intro shrub	0.0	2.7	2.2	0.0	0.0
Nat grass	66.1	71.4	54.7	62.0	73.9
Intro grass	10.8	5.9	23.2	7.7	7.7
Nat forb	9.8	0.0	2.1	0.8	0.7
Intro forb	13.2	19.6	17.5	21.3	15.4

FIGURE 2.—Relative percent herbaceous cover by life-form in treatment transects within Treatment Site 1 in 2007 (pre-treatment) and 2008 to 2011 (post-treatment).

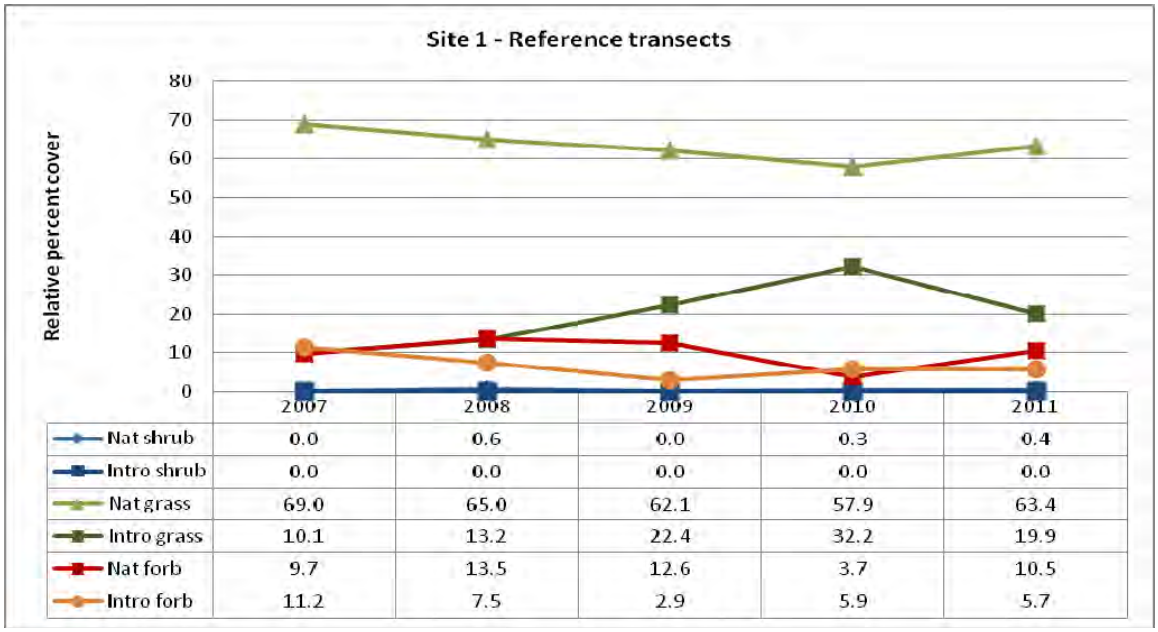


FIGURE 3.—Relative percent herbaceous cover by life-form in reference transects within Treatment Site 1 in 2007 (pre-treatment) and 2008 to 2011 (post-treatment).

TABLE 1.—Relative percent herbaceous cover of native vs. introduced species in treatment and reference transects in Treatment Site 1 from 2007 to 2011.

Site 1 – Relative percent cover										
	2007		2008		2009		2010		2011	
	Treat	Ref	Treat	Ref	Treat	Ref	Treat	Ref	Treat	Ref
Native species	75.9	78.7	71.8	79.2	57.1	74.7	71.0	62.0	76.9	74.4
Introduced species	24.1	21.3	28.2	20.7	42.9	25.3	29.0	38.0	23.1	25.6

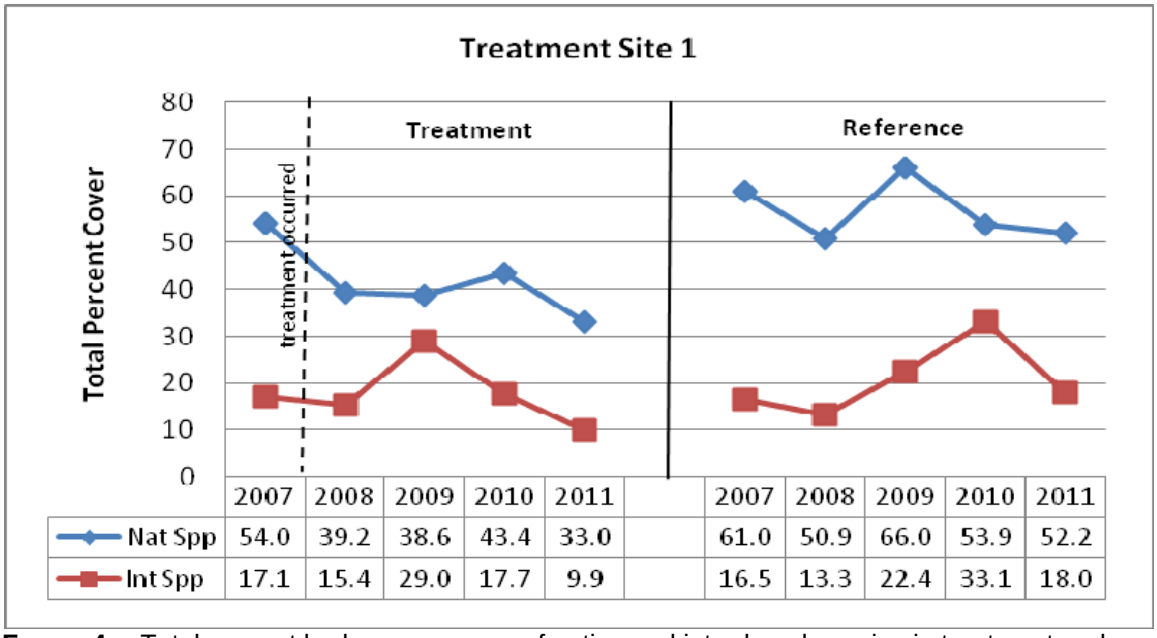


FIGURE 4.—Total percent herbaceous cover of native and introduced species in treatment and reference transects within Treatment Site 1 from 2007 (pre-treatment) and 2008 to 2011 (post-treatment).

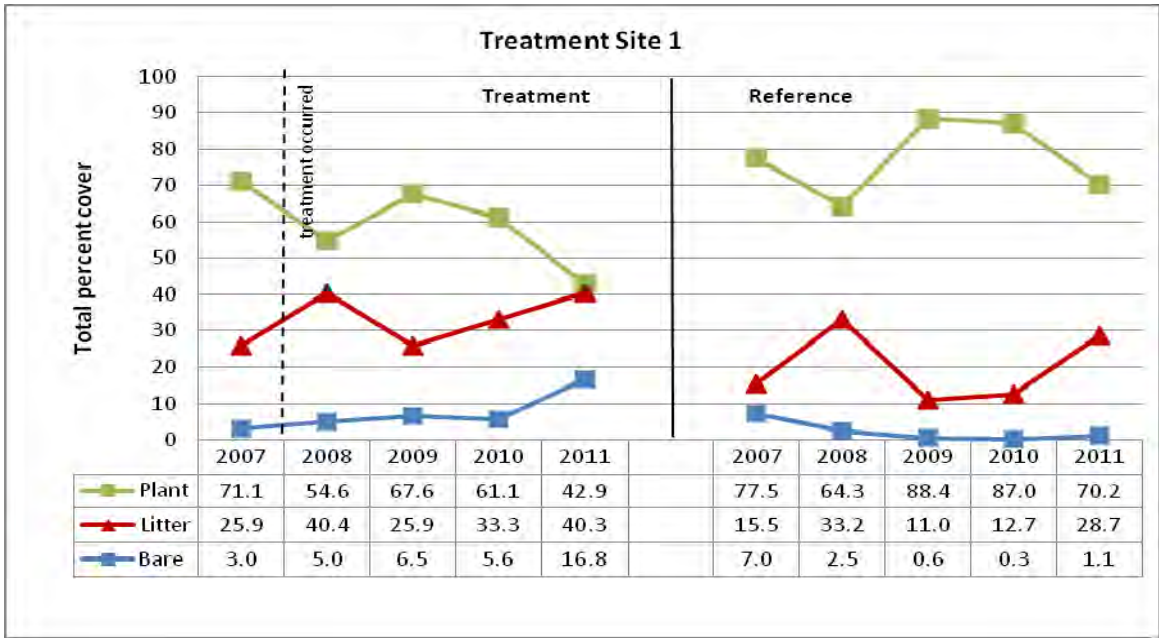
TABLE 2.—Statistical comparisons of total herbaceous cover between treatment and reference transects and between years in Treatment Site 1; Alpha=0.05.

	Native species	Introduced species	Plant	Litter	Bare ground
Treatment vs Reference					
2007	T1=R1 P=0.590[1]	T1=R1 P=0.926[1]	T1=R1 P=0.507[1]	T1=R1 P=0.252[2]	T1=R1 P=0.544[2]
2008	T1=R1 P=0.287[1]	T1=R1 P=0.129[2]	T1=R1 P=0.384[2]	T1=R1 P=0.156[1]	T1=R1 P=0.288[1]
2009	T1<R1 P=0.042[1]	T1=R1 P=0.563[1]	T1<R1 P=0.046[1]	T1=R1 P=0.053[1]	T1=R1 P=0.263[2]
2010	T1=R1 P=0.526[1]	T1=R1 P=0.092[1]	T1<R1 P=0.018[1]	T1>R1 P=0.017[1]	T1>R1 P=0.013[2]
2011	T1=R1 P=0.104[1]	T1=R1 P=0.180[1]	T1<R1 P=0.029[1]	T1=R1 P=0.232[1]	T1>R1 P=0.002[2]
Treatment					
07 vs 08	07=08 P=0.114[3]	07=08 P=0.677[3]	07=08 P=0.051[3]	07=08 P=0.059[3]	07=08 P=0.384[3]
08 vs 09	08=09 P=0.938[3]	08=09 P=0.221[3]	08=09 P=0.052[3]	08=09 P=0.110[3]	08=09 P=1.0[4]
09 vs 10	09=10 P=0.159[3]	09=10 P=0.307[3]	09=10 P=0.574[4]	09=10 P=0.959[4]	09=10 P=0.820[4]
10 vs 11	10=11 P=0.053[4]	10=11 P=0.165[3]	10>11 P=0.026[3]	10=11 P=0.228[3]	10<11 P=0.005[3]
07 vs 11	07>11 P=0.035[3]	07=11 P=0.226[3]	07>11 P=0.003[3]	07<11 P=0.031[3]	07<11 P=0.009[3]
Reference					
07 vs 08	07=08 P=0.094[4]	07=08 P=0.348[3]	07>08 P=0.049[3]	07<08 P=0.016[3]	07=08 P=0.105[3]
08 vs 09	08<09 P=0.014[3]	08=09 P=0.175[3]	08<09 P=0.006[4]	08>09 P<0.001[3]	08=09 P=0.100[4]
09vs 10	09=10 P=0.074[3]	09=10 P=0.112[3]	09=10 P=0.717[3]	09=10 P=1.0[3]	09=10 P=0.789[4]
10 vs 11	10=11 P=1.00[3]	10>11 P=0.037[3]	10>11 P=0.022[3]	10<11 P=0.004[3]	10=11 P=1.00[4]
07 vs 11	07=11 P=0.300[3]	07=11 P=0.837[3]	07=11 P=0.139[4]	07=11 P=0.099[3]	07=11 P=0.084[3]

[1] Student's t-test; [2]Mann Whitney W test; [3]Paired t-test; [4]Signed rank test
Highlighted boxes indicate a significant difference at the 95 percent confidence level.

Total plant cover was significantly less in treatment transects than in reference transects from 2009 to 2011 (Table 2). This appeared to be caused by a statistical increase in plant cover in reference transects from 2008 to 2009, which boosted cover to levels higher than treatment transects that sustained throughout monitoring (Figure 5). Total litter cover was significantly higher in treatment transects than in reference transects in 2010, while bare ground was significantly higher in treatment transects in 2010 and 2011. When comparing between years, there was a significant decrease in total plant cover and a significant increase in total litter cover in 2008 and 2011 in reference transects. In conjunction with the significant increase in plant cover and decrease in litter cover in 2009, there was no change in plant or litter cover over the entire monitoring period (2007 to 2011) in the reference transects. In treatment transects, there was also a significant drop in plant cover in 2011 and a corresponding significant increase in total bare ground (Table 2). Total cover of litter significantly increased in 2008 post-treatment. Over the monitoring period in treatment transects, total plant cover decreased significantly from 2007 to 2011 while total bare ground increased significantly during the same period in the treatment transects (Figure 5).

The differences in herbaceous plant cover between the treatment and reference transects from 2009 to 2011 may suggest that saltcedar treatment affected plant cover in Site 1; however an



	2007	2008	2009	2010	2011		2007	2008	2009	2010	2011
Plant	71.1	54.6	67.6	61.1	42.9		77.5	64.3	88.4	87.0	70.2
Litter	25.9	40.4	25.9	33.3	40.3		15.5	33.2	11.0	12.7	28.7
Bare	3.0	5.0	6.5	5.6	16.8		7.0	2.5	0.6	0.3	1.1

FIGURE 5.—Total herbaceous plant, litter, and bare cover in treatment and reference transects within Treatment Site 1 in 2007 (pre-treatment) and 2008 to 2011 (post-treatment).

effect is indefinite. Differences between reference and treatment transects were caused by an increase in reference transect plant cover from 2008 to 2009 and not by a decrease in treatment transect plant cover. Although herbaceous cover sustained at higher levels in the reference transects from 2009 on, Figure 5 shows that the general trend in total plant cover has been similar for both types of transects, which suggests that plant cover was driven by the same factors in each type of transect. On the other hand, it is possible that because plant cover did not increase at the same levels in both transect types in 2009, a treatment effect was observed.

Total plant cover in treatment transects was greater in 2007 prior to treatment in 2008 (although not quite statistically significant), however this result was consistent between treated and untreated sites, which indicated there may have been an influence from factors other than saltcedar removal. Whatever the causes for decreased plant cover in 2008, plants in the treated transects apparently recovered less rapidly than those in the reference transects. In 2011, plant cover significantly decreased in both reference and treatment transects, which may have been due to a relatively dry year (based on river discharge as shown in Figure 6).

The total percent cover of individual shrub species in the overstory layer of Site 1 is shown for treatment and reference transects in Figures 7 and 8, respectively. Three shrub species were detected in the overstory layer, of which coyote willow was the most common for all transects in all years. There were no statistically significant differences in the total percent overstory cover between the treatment and reference transects (Table 3). Total overstory cover increased significantly to 57.7 percent in 2009 in the treatment transects which was due to a significant increase in native species that year, specifically coyote willow.

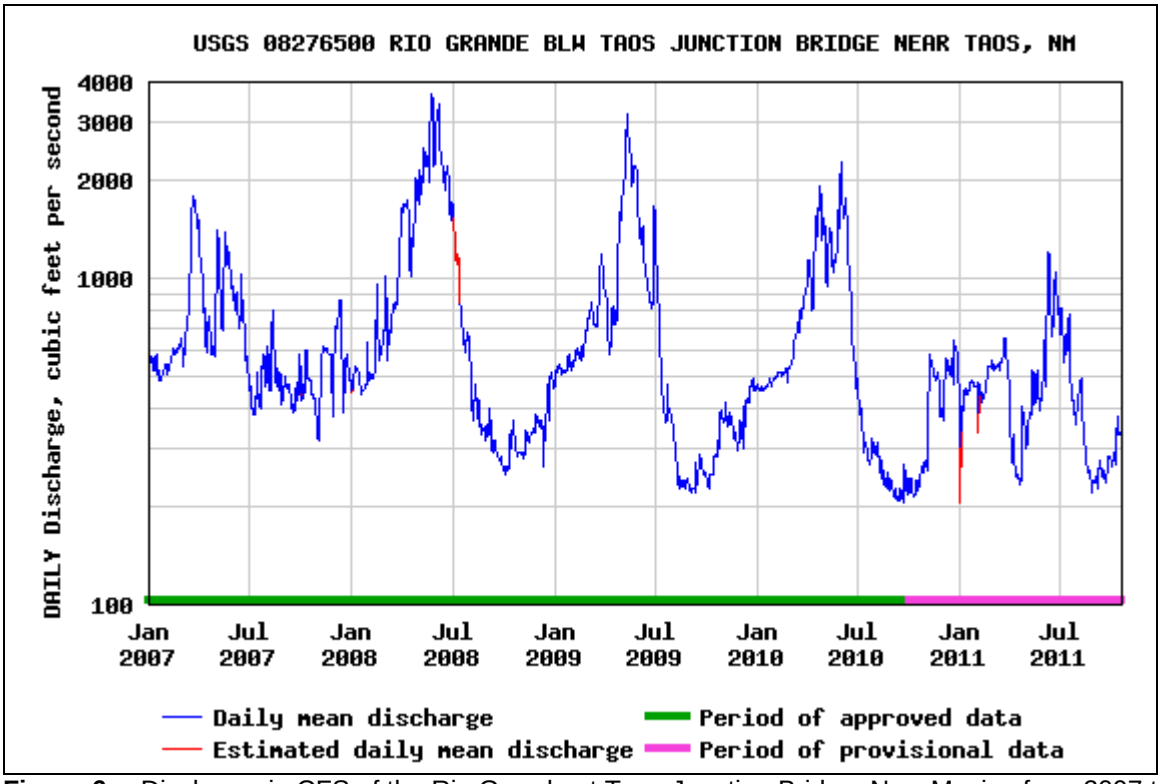
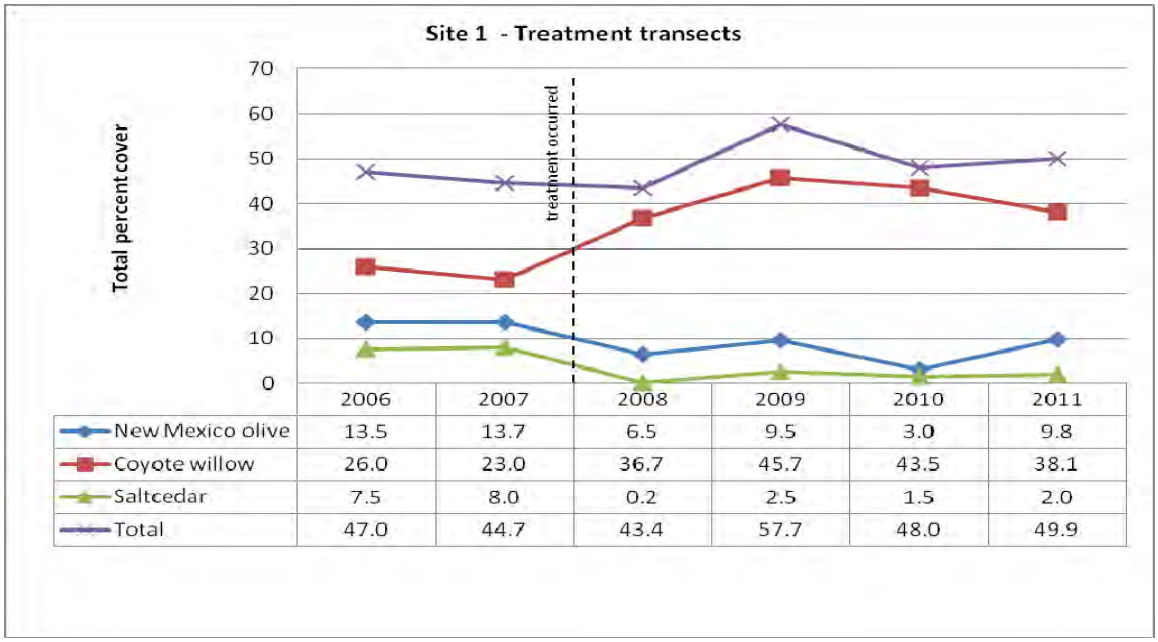


Figure 6.—Discharge in CFS of the Rio Grande at Taos Junction Bridge, New Mexico from 2007 to 2011. Source: United States Geological Survey



	2006	2007	2008	2009	2010	2011
New Mexico olive	13.5	13.7	6.5	9.5	3.0	9.8
Coyote willow	26.0	23.0	36.7	45.7	43.5	38.1
Saltcedar	7.5	8.0	0.2	2.5	1.5	2.0
Total	47.0	44.7	43.4	57.7	48.0	49.9

Figure 7.—Total percent overstory cover by species in treatment transects within Treatment Site 1 from 2006 to 2011.

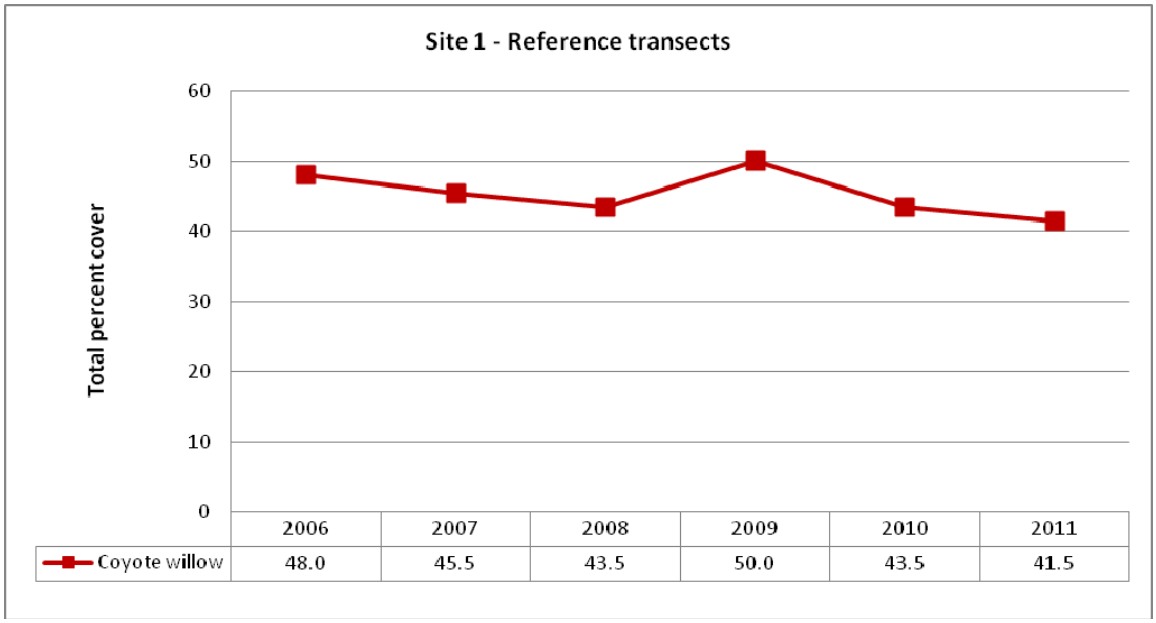


Figure 8.—Total percent overstory cover of coyote willow in reference transects within Treatment Site 1 from 2006 to 2011.

Table 3.—Statistical comparisons of total overstory cover and stem density between treatment and reference transects and between years in Treatment Site 1; Alpha=0.05.

	Tot. overstory cover	Nat spp total cover	Int spp total cover	Total stem density
Treatment vs Reference				
2006	T1=R1 P=0.916[1]	T1=R1 P=0.382[1]	T1=R1 P=0.078[2]	T1=R1 P=0.416[1]
2007	T1=R1 P=0.952[1]	T1=R1 P=0.449[1]	T1=R1 P=0.078[2]	T1<R1 P=0.009[2]
2008	T1=R1 P=0.986[1]	T1=R1 P=0.973[1]	T1=R1 P=0.368[2]	T1=R1 P=0.243[1]
2009	T1=R1 P=0.396[1]	T1=R1 P=0.490[1]	T1=R1 P=1.00[2]	T1=R1 P=0.389[1]
2010	T1=R1 P=0.762[1]	T1=R1 P=0.835[1]	T1=R1 P=1.00[2]	T1=R1 P=0.173[2]
2011	T1=R1 P=0.568[1]	T1=R1 P=0.647[1]	T1=R1 P=1.00[2]	T1=R1 P=0.970[2]
Treatment				
06 vs 07	06=07 P=1.0[4]	06=07 P=1.0[4]	06=07 P=1.0[4]	06=07 P=0.613[3]
07 vs 08	07=08 P=0.923[3]	07=08 P=0.547[3]	07=08 P=0.590[4]	07=08 P=0.510[3]
08 vs 09	08<09 P=0.001[3]	08<09 P=0.005[3]	08=09 P=1.00[4]	08=09 P=0.263[3]
09 vs 10	09=10 P=0.205[3]	09=10 P=0.265[3]	09=10 P=1.00[4]	09<10 P=0.022[4]
10 vs 11	10=11 P=0.835[3]	10=11 P=0.877[3]	10=11 P=1.00[4]	10=11 P=0.716[3]
06 vs 11	06=11 P=0.856[3]	06=11 P=0.475[3]	06=11 P=0.584[4]	06=11 P=0.541[4]
Reference				
06 vs 07	06=07 P=0.440[4]	06=07 P=0.440[4]	NA*	06=07 P=0.293[3]
07 vs 08	07=08 P=0.613[3]	07=08 P=0.613[3]	NA	07=08 P=0.729[3]
08 vs 09	08=09 P=0.709[3]	08=09 P=0.745[3]	08=09 P=1.0[4]	08=09 P=0.109[4]
09 vs 10	09=10 P=0.813[3]	09=10 P=0.824[3]	09=10 P=1.0[4]	09=10 P=0.910[3]
10 vs 11	10=11 P=0.618[3]	10=11 P=0.599[3]	10=11 P=1.0[4]	10=11 P=0.906[4]
06 vs 10	06=11 P=0.358[3]	06=11 P=0.533[3]	06=11 P=1.0[4]	06=11 P=0.609[3]

[1] Student's t-test; [2]Mann Whitney W test; [3]Paired t-test; [4]Signed rank test

Highlighted boxes indicate a significant difference at the 95 percent confidence level.

*NA= No introduced shrubs detected in transects

The overall canopy cover (as measured with a densiometer) is listed in Table 4. Canopy cover of treated transects decreased considerably from 72.1 percent in 2006 to 48.2 percent in 2007, which may have been due to the cutting of saltcedar in one of the treatment transects in 2007. Canopy cover increased to 57.3 percent in 2008 despite saltcedar treatment that year. It is possible that willow cover eventually expanded following the earlier removal of saltcedar. This appeared to be the case in the overstory plot measurements as well. The cover of coyote willow increased from 23.0 percent in 2007 to 45.7 percent in 2009 in treated transects (Figure 7) while willow cover in reference transects remained relatively stable over the same time period (Figure 8). Overall canopy cover increased gradually from 2006 to 2009 within the reference transects of Site 1, but decreased considerably to 19.8 percent in 2010 and 2011 from a high of 43.2 percent in 2009. There was a notable amount of beaver damage in both 2010 and 2011, which

TABLE 4.—Overall canopy cover of treatment and reference transects within Treatment Site 1 from 2006 to 2011.

Site 1 - Percent canopy cover											
2006		2007		2008		2009		2010		2011	
Treat.	Ref.	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.
72.1	24.2	48.2	30.6	57.3	37.0	45.9	43.2	50.2	19.8	46.1	19.8

explains the large drop in overall canopy cover that was not observed in overstory shrub cover in reference transects. Willow stems were browsed to the point of being too short to be captured in the densiometer, but total cover was not significantly affected due to resprouting of browsed stems. In one of the treatment transects (T1), resprouted saltcedar had reached heights of up to 4 m and could be why overall canopy cover of treatment transects did not show change with beaver browsing.

Table 5 shows the average number of woody stems per m^2 for both types of transects in Site 1. The values listed are an average of the 10 plots that were measured in each transect type. In 2007, density in treatment transects was significantly less than in reference transects (Table 3). A slight increase in the number of willow and saltcedar stems in treatment transects in conjunction with a slight decrease in willow stems in reference transects brought density to statistically equal levels in 2008. Stem density wassignificantly higher in 2010 than in 2009 in the treatment transects, which could be attributed to a considerable increase in the number of New Mexico olive stems, most of which were resprouts from stems inadvertently cut during treatment. No other statistical differences in stem density were identified from 2006 to 2011.

Table 5.—The average number of stems per meter squared for woody species in treatment and reference transects within Treatment Site 1 from 2006 to 2010.

Site 1 - Average number of stems / m^2												
	2006		2007		2008		2009		2010		2011	
Shrub species	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.
Coyote willow	11.2	22.8	10.3	29.8	12.6	27.9	10.6	18.3	11.4	18.8	12.6	12.4
New Mexico olive	4.3	0.1	4.1	0.0	2.6	0.1	2.7	0.0	20.8	0.0	18.6	0.3
Salt cedar	2.1	0.0	1.8	0.0	2.9	0.0	1.4	0.2	0.2	0.2	0.3	0.4
Total shrub	17.6	22.9	16.2	29.8	18.3	28.0	14.8	18.5	32.4	19.0	31.5	13.1

Table 6 shows the average number of saltcedar per 25 m^2 for the treatment transects in Site 1 from 2006 to 2011. The number of saltcedar stems more than doubled from 2006 to 2007, which may have been a result of cutting saltcedar in one transect. No follow-up herbicide application was used and the large increase in stems was likely attributed to resprouting saltcedar. In 2008, saltcedar was removed using the cut-stump method in the other treatment transect, and the number of salt-cedar stems decreased slightly from 2007 but was still relatively high, also due to a high incidence of resprouting. In 2009 and 2010, the number of saltcedar stems continued to decrease but again increased in 2011. In one of the treatment transects (T4), treatment has resulted in mortality of the majority of saltcedar as of 2011, with only one clump of resprouts from a saltcedar around 3 m in height accounting for all saltcedar stems counted (*i.e.* 24) within the transect.

Table 6.—The average number of saltcedar stems per 25 meters squared in treatment transects within Treatment Site 1 from 2006 to 2011.

Average number of saltcedar / 25 m^2						
Treatment transects	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Site 1	20.0	49.5	43.0	34.5	22.0	36.5

Based on statistical analyses, there didn't appear to be large effects to the cover and density of the overstory layer from saltcedar treatment in Site 1. There was a significant increase in the total cover of overstory shrubs in the treatment transects in 2009. This may have been due to the steady release of willow in response to the removal of saltcedar in the canopy. Some trends were observed that were not statistically tested. Measurements of saltcedar density in 25m^2 plots showed that the number of stems doubled from 2006 to 2008 following treatment, although no changes were detected in density of all shrubs at the 1m^2 plot level during this same time period. The considerable increase in saltcedar stems was likely a result of the methods of treatment that were used within this site. The prescribed treatment protocol for this site was the cut-stump method to be conducted in 2008, which involved hand-cutting followed by herbicide application to the tree stump. When saltcedar was inadvertently hand cut from one transect in 2007, herbicide application did not follow. The cut-stump method was used for the second transect in 2008, but no further treatment was conducted on the transect that had been previously cut until August 2009, when herbicide was applied to foliage of resprouted stems. Results indicated that a high number of saltcedar resprout in response to cutting and that follow-up herbicide treatment should continue until resprouting is controlled.

Photos taken of each site and from the end points of each transect from 2006 to 2010 are shown in Appendix E.

Site 3

Baseline data was collected in Site 3 in June 2006 and October 2007. Saltcedar was removed using the cut stump method with herbicide application as described for Site 1 in both treatment transects in 2008 prior to monitoring in October of that year. Site 3 is located on an island, across river from the access road (Figure 1); consequently all saltcedar debris that resulted from cutting was left on site. All saltcedar that were included in post-treatment monitoring measurements were resprouts.

Because data were collected before the monsoon season in 2006 and after the monsoon season in 2007 through 2011, there were considerable differences in the amount and type of herbaceous vegetation detected. Therefore, only 2007 baseline data were used as a comparison to 2008 through 2011 post-treatment data for the herbaceous layer. Late summer monsoonal rains did not appear to drastically affect shrub cover and density. Therefore both 2006 and 2007 baseline data were used as a comparison to 2008 through 2011 post-treatment data for the overstory layer.

Table D-2 in Appendix D shows the total percent cover by individual plant species, life-form (*i.e.* native or introduced shrub seedlings, grasses, or forbs), and cover type (*i.e.* vegetation, litter, bare ground, or basal area of shrubs) in the herbaceous layer of treatment and reference transects in Site 3 for all years of monitoring. The listed Treatment values are an average of 10 plots measured in the 2 treatment transects. The listed Reference values are an average of 10 plots measured in the 2 reference transects.

Fifty-eight species were detected within the herbaceous layer of transects in Site 3 over 6 years of monitoring. In 2007, the most abundant species based on percent cover in the treatment transects were cheatgrass, mullein, and Kentucky bluegrass. In 2008, the most common species were saltcedar, Kentucky bluegrass, and Carruth's sagewort, in 2009 they were saltcedar, Carruth's sagewort, common yarrow, and slender wheatgrass, in 2010 they were Carruth's sagewort, common yarrow, and smooth brome, and in 2011 they were Carruth's sagewort, smooth brome and saltcedar in the same transects. In the reference transects, the most common species were redtop, sedge, and smooth brome in 2007, 2008, and 2011. In 2009, the most common species in reference transects were sedge, slender wheatgrass, and smooth brome and in 2010 they were sedge, canary reed grass, and smooth brome.

The relative cover of each life-form detected in the herbaceous layer of treatment and reference transects in Site 3 is shown in Figures 9 and 10, respectively. Introduced grasses were the most

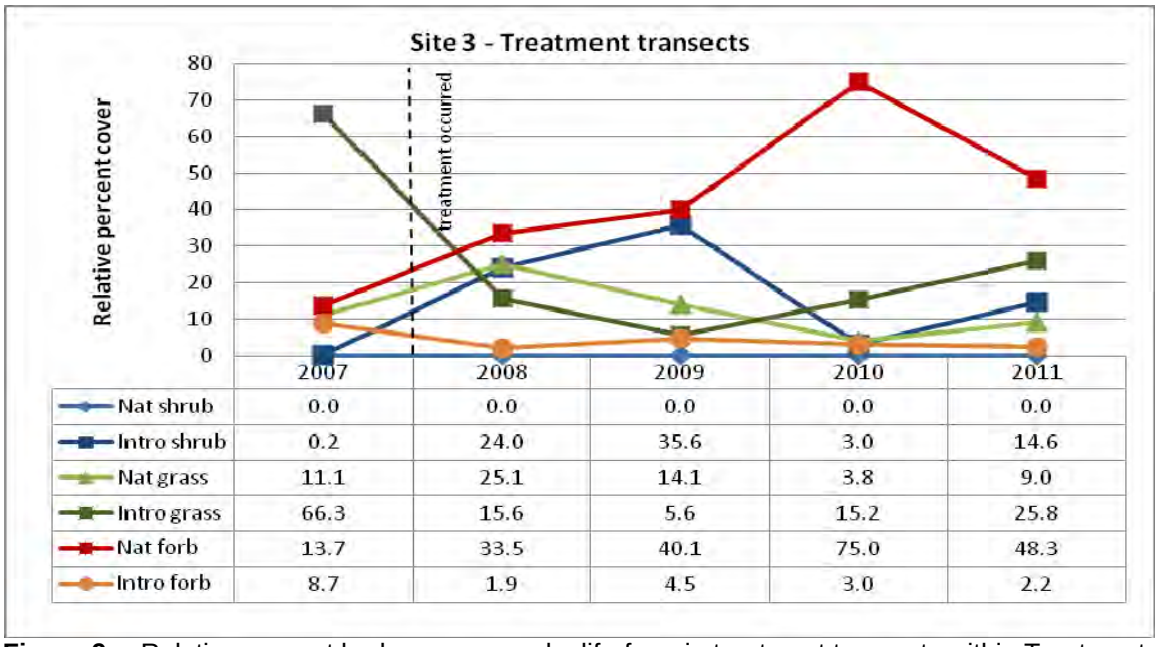


Figure 9.—Relative percent herbceous cover by life-form in treatment transects within Treatment Site 3 in 2007 (pre-treatment) and 2008 to 2011 (post-treatment).

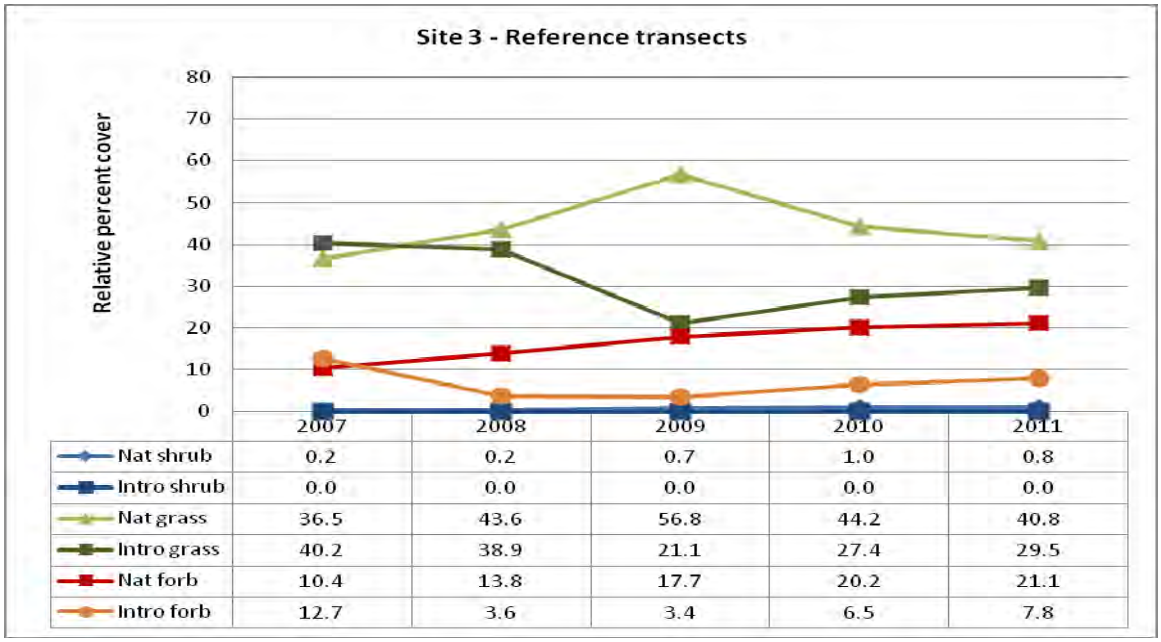


Figure 10.—Relative percent herbaceous cover by life-form in reference transects within Treatment Site 3 in 2007 (pre-treatment) and 2008 to 2011 (post-treatment).

common life-form based on relative percent cover in treatment transects in 2007, which shifted to native forbs post-treatment from 2008 through 2011. In the reference transects, introduced grasses were the most common lifeform in 2007 and native grasses were the most common lifeform from 2008 to 2011. Native species were more abundant than introduced species from 2008 to 2011 (post-treatment) in both types of transects based on relative cover (Table 7). In 2007, prior to treatment, there was a higher proportion of introduced species in reference transects as well as in treatment transects.

Figure 11 shows the total percent cover of native and introduced species in the herbaceous layer of both types of transects within Site 3 over the monitoring period. In 2007, prior to treatment, the total percent cover of introduced species was significantly higher in treatment transects than in reference transects (see Table 8 for statistical results and P-values for the herbaceous layer in Site 3). In 2009, native species total cover was significantly lower in treatment transects than in reference transects. In 2010 and 2011, total cover of both native and introduced species was significantly less in treatment transects than in reference transects and introduced species within the treatment transects had decreased significantly from 2007 to 2011.

TABLE 7.— Relative percent herbaceous cover of native vs. introduced species in treatment and reference transects in Treatment Site 3 from 2007 to 2011.

Relative percent cover										
	2007		2008		2009		2010		2011	
	Treat	Ref	Treat	Ref	Treat	Ref	Treat	Ref	Treat	Ref
Native species	24.9	47.1	58.6	57.6	54.2	75.2	78.8	66.1	57.3	62.7
Introduced species	75.1	52.9	41.4	42.4	45.8	24.5	21.2	33.9	42.7	37.3

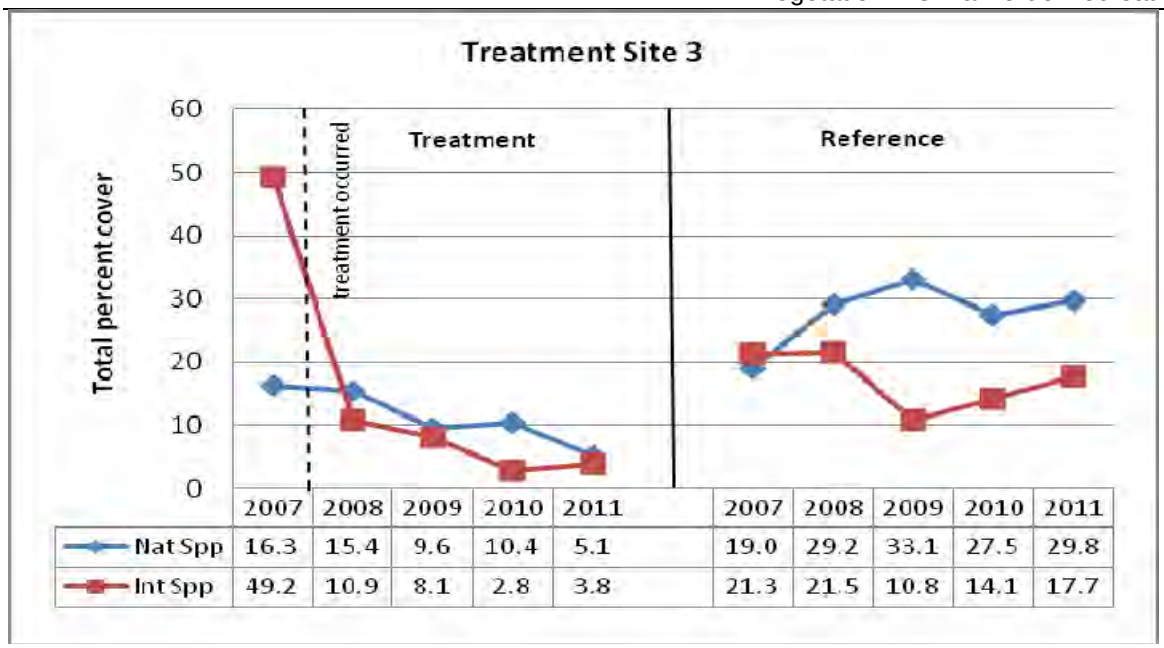


Figure 11.—Total percent herbaceous cover of native and introduced species in treatment and reference transects within Treatment Site 3 from 2007 (pre-treatment) and 2008 to 2011 (post-treatment).

Table 8.—Statistical comparisons of total herbaceous cover between treatment and reference transects and between years in Treatment Site 3; Alpha=0.05.

	Native species	Introduced species	Plant	Litter	Bare ground
Treatment vs Reference					
2007	T3=R3 P=0.970[2]	T3>R3 P=0.016[1]	T3>R3 P=0.029[1]	T3<R3 P=0.023[1]	T3=R3 P=0.125[2]
2008	T3=R3 P=0.173[2]	T3=R3 P=0.154[1]	T3<R3 P=0.009[2]	T3=R3 P=0.057[1]	T3=R3 P=0.729[2]
2009	T3<R3 P=0.010[2]	T3=R3 P=0.939[2]	T3<R3 P=0.016[1]	T3=R3 P=0.260[1]	T3=R3 P=0.132[2]
2010	T3<R3 P=0.040[2]	T3<R3 P=0.007[2]	T3<R3 P=0.011[2]	T3=R3 P=0.223[1]	T3>R3 P=0.027[2]
2011	T3<R3 P=0.011[2]	T3<R3 P=0.010[2]	T3<R3 P=0.001[2]	T3>R3 P=0.004[1]	T3>R3 P=0.047[1]
Treatment					
07 vs 08	07=08 P=0.892[3]	07>08 P<0.001[3]	07>08 P<0.001[3]	07<08 P=0.008[4]	07=08 P=0.167[3]
08 vs 09	08=09 P=0.622[4]	08=09 P=0.232[4]	08=09 P=0.076[3]	08=09 P=0.552[3]	08=09 P=0.051[4]
09 vs 10	09=10 P=1.0[4]	09=10 P=0.115[3]	09=10 P=0.251[3]	09=10 P=0.336[3]	09=10 P=0.416[3]
10 vs 11	10=11 P=0.149[4]	10=11 P=0.203[4]	10=11 P=0.153[4]	10=11 P=0.277[3]	10=11 P=0.725[4]
07 vs 11	07=11 P=0.069[3]	07>11 P<0.001[3]	07>11 P<0.001[3]	07<11 P<0.001[3]	07<11 P=0.004[3]
Reference					
07 vs 08	07<08 P=0.004[3]	07=08 P=0.955[3]	07<08 P=0.010[3]	07=08 P=0.505[3]	07=08 P=0.190[4]
08 vs 09	08=09 P=0.576[3]	08=09 P=0.061[3]	08=09 P=0.331[3]	08=09 P=0.094[3]	08=09 P=0.553[4]
09vs 10	09=10 P=0.484[3]	09=10 P=0.154[4]	09=10 P=0.713[3]	09=10 P=1.0[3]	09=10 P=0.766[4]
10 vs 11	10=11 P=0.647[3]	10=11 P=0.064[3]	10=11 P=0.283[3]	10=11 P=0.177[3]	10=11 P=1.00[4]
07 vs 11	07=11 P=0.053[3]	07=11 P=0.546[3]	07=11 P=0.191[4]	07=11 P=0.124[3]	07=11 P=0.672[4]

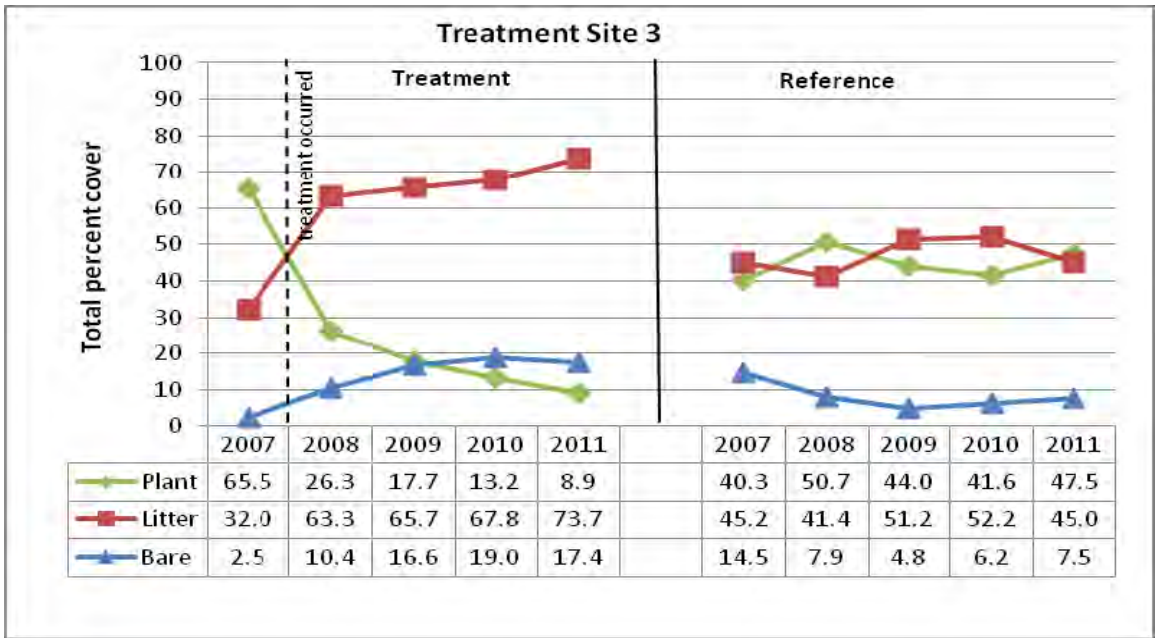
[1] Student's t-test; [2]Mann Whitney W test; [3]Paired t-test; [4]Signed rank test

Highlighted boxes indicate a significant difference at the 95 percent confidence level.

Figure 12 provides a visual comparison of the percent total cover of plant, litter, and bare ground in the herbaceous layer of Site 3 from 2007 to 2011. In 2007, total plant cover was significantly higher in treatment transects (65.5 percent) than in reference transects (40.3 percent), which was associated with high cover of introduced species (Table 8). From 2008 to 2011 the average total plant cover in treatment transects was significantly less than cover in reference transects. There was a statistical difference in litter cover between the two transect types in 2008 and 2011 when litter was higher in treatment transects. The amount of bare ground was significantly higher in treatment transects than in reference transects in 2010 and 2011. When comparing between years within transect types, plant cover was significantly higher while litter cover was significantly lower in 2007 than in other years in treatment transects. Finally, total plant cover in reference transects significantly increased from 2007 to 2008.

The changes in herbaceous plant and litter cover at Site 3 were related to saltcedar treatment and the methods of removal that were used at this site. Saltcedar was hand cut and the plant material was left on site. The slash left on the ground was categorized as litter, and its abundant cover inhibited the growth of understory herbaceous species. Thus, even though treatment transects had higher plant cover than reference transects prior to treatment, once the site was treated plant cover fell below the untreated transects and has not returned to pre-treatment levels 4 years after saltcedar removal. And although plant cover in untreated reference transects showed no change from 2007 to 2011, it significantly decreased in the treatment transects as litter and bare ground increased post-treatment. Average total plant cover reached a low of 8.9 percent in 2011, which appears to indicate that herbaceous vegetation has not recovered 4 years after treatment.

A shift in the common life-forms in treatment transects may have also been a result of saltcedar control at this site, although this shift occurred in reference transects as well so a cause for these changes is difficult to identify. The introduced cheatgrass was the predominate species in

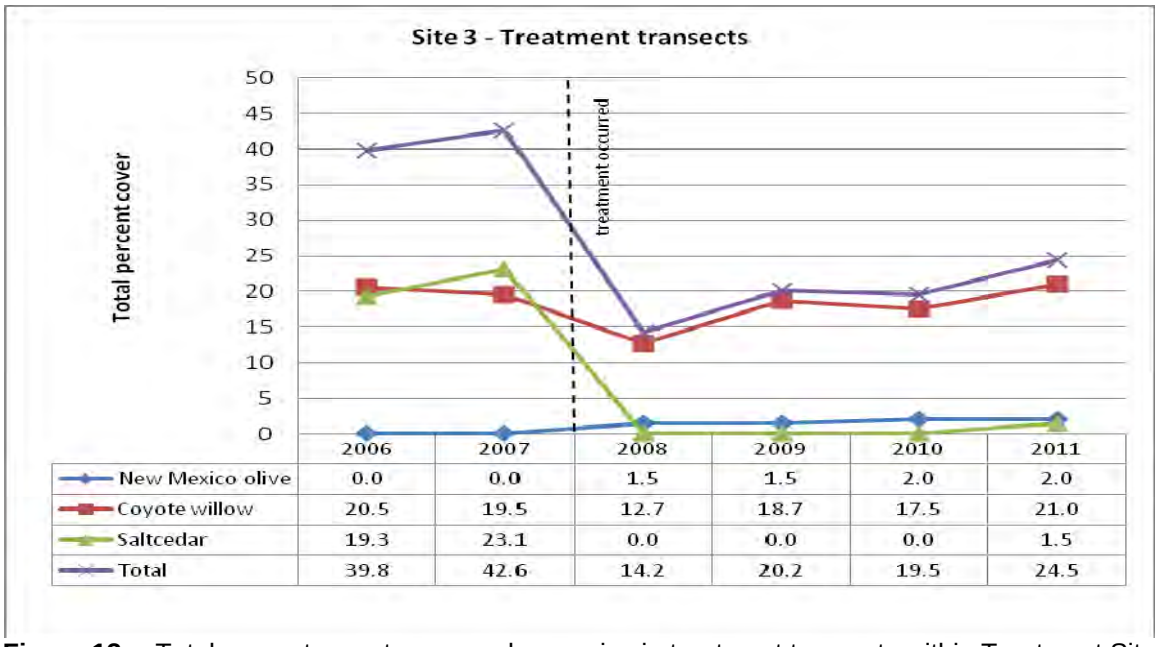


	Treatment 2007	2008	2009	2010	2011	Reference 2007	2008	2009	2010	2011
Plant	65.5	26.3	17.7	13.2	8.9	40.3	50.7	44.0	41.6	47.5
Litter	32.0	63.3	65.7	67.8	73.7	45.2	41.4	51.2	52.2	45.0
Bare	2.5	10.4	16.6	19.0	17.4	14.5	7.9	4.8	6.2	7.5

Figure 12.—Total herbaceous plant, litter, and bare cover in treatment and reference transects within Treatment Site 3 in 2007 (pre-treatment) and 2008 to 2011 (post-treatment).

treatment transects in 2007 and was barely detected in 2008 and not detected at all in 2009 through 2011, which would be a desirable effect if it was in fact caused by the removal of saltcedar. The native Carruth's sagewort became the dominant species post-treatment. There was also a considerable increase in introduced shrubs post-treatment in the herbaceous layer of treatment transects, which was related to resprouting of saltcedar that did not grow taller than 25 cm in 2008 and 2009. By 2010 and 2011, saltcedar was nearly absent in the herbaceous layer (Table D-2, Appendix D). It should be noted, however, that total plant cover in general decreased significantly post-treatment, so very few plants of any species were detected.

The total percent cover of individual overstory species within treatment and reference transects is shown in Figures 13 and 14, respectively. Three shrub species were detected in the overstory layer at Site 3. Coyote willow and saltcedar were the most common shrubs in treatment transects prior to treatment and coyote willow was the most common in treatment transects post-treatment and in reference transects in all years. Prior to treatment, the percent total shrub cover was statistically equal between the two types of transects, although the treatment transects had a significantly higher percentage of introduced species while the reference transects had a significantly higher percentage of native species (see Table 9 for statistical results and P-values for the overstory layer in Site 3). Post-treatment, total and native species cover in treatment transects was significantly less than reference transects and no introduced species were detected in the overstory layer. In comparing years, total and introduced species shrub cover in 2008 (post-treatment) was significantly less than in 2007 (pre-treatment) in treated transects. These results suggested that saltcedar removal decreased overstory cover, which is logical because saltcedar was a relatively large component of the overstory in these transects prior to treatment (thus a significant drop in introduced overstory species, as well). From 2006 to 2011 there was a decrease in introduced species cover in treated transects from 19.3 to 1.5 percent (Figure 13), which was not quite statistically significant (P=0.052). There were no significant changes in overstory cover in the reference transects over the study period.



	2006	2007	2008	2009	2010	2011
New Mexico olive	0.0	0.0	1.5	1.5	2.0	2.0
Coyote willow	20.5	19.5	12.7	18.7	17.5	21.0
Saltcedar	19.3	23.1	0.0	0.0	0.0	1.5
Total	39.8	42.6	14.2	20.2	19.5	24.5

Figure 13.—Total percent overstory cover by species in treatment transects within Treatment Site 3 from 2006 to 2011.

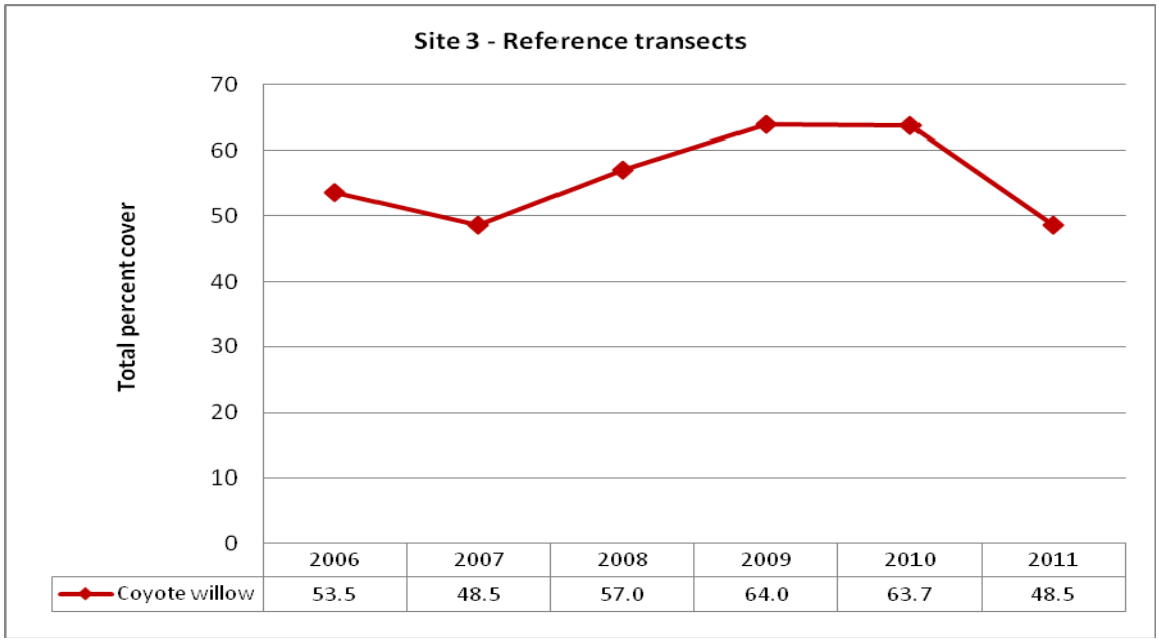


Figure 14.—Total percent overstory cover of coyote willow in reference transects within Treatment Site 3 from 2006 to 2011.

Table 9.—Statistical comparisons of total overstory cover and stem density between treatment and reference transects and between years in Treatment Site 3; Alpha=0.05.

	Total overstory cover	Nat spp total cover	Int spp total cover	Total stem density
Treatment vs Reference				
2006	T3=R3 P=0.195[1]	T3<R3 P=0.003[1]	T3>R3 P=0.022[1]	T3<R3 P=0.009[1]
2007	T3=R3 P=0.637[1]	T3<R3 P=0.019[1]	T3>R3 P=0.020[1]	T3<R3 P=0.032[1]
2008	T3<R3 P<0.001[1]	T3<R3 P<0.001[1]	NA*	T3<R3 P=0.001[1]
2009	T3<R3 P=0.001[1]	T3<R3 P=0.001[1]	NA	T3<R3 P=0.003[1]
2010	T3<R3 P=0.001[1]	T3<R3 P=0.001[1]	NA	T3<R3 P=0.025[2]
2011	T3=R3 P=0.052[1]	T3<R3 P=0.015[2]	NA	T3<R3 P=0.036[1]
Treatment				
06 vs 07	06=07 P=0.620[3]	06=07 P=0.794[3]	06=07 P=1.0[4]	06=07 P=0.448[3]
07 vs 08	07>08 P=0.025[3]	07=08 P=0.270[4]	07>08 P=0.031[3]	07>08 P=0.030[3]
08 vs 09	08=09 P=0.126[3]	08=09 P=0.126[3]	NA	08=09 P=0.616[3]
09 vs 10	09=10 P=0.839[3]	09=10 P=0.839[3]	NA	09=10 P=0.944[3]
10 vs 11	10=11 P=0.259[3]	10=11 P=0.322[3]	10=11 P=1.00[4]	10=11 P=0.203[3]
06 vs 11	06=11 P=0.232[3]	06=11 P=0.768[3]	06=11 P=0.052[3]	06=11 P=0.423[3]
Reference				
06 vs 07	06=07 P=0.566[3]	06=07 P=0.566[3]	NA	06=07 P=0.383[3]
07 vs 08	07=08 P=0.171[4]	07=08 P=0.171[4]	NA	07=08 P=0.847[3]
08 vs 09	08=09 P=0.357[4]	08=09 P=0.357[4]	NA	08=09 P=0.125[3]
09 vs 10	09=10 P=0.528[4]	09=10 P=0.528[4]	NA	09=10 P=0.287[3]
10 vs 11	10>11 P=0.024[4]	10>11 P=0.024[4]	NA	10=11 P=0.128[3]
06 vs 11	06=11 P=0.697[3]	06=11 P=0.676[3]	NA	06=11 P=0.346[3]

[1] Student's t-test; [2]Mann Whitney W test; [3]Paired t-test; [4]Signed rank test
Highlighted boxes indicate a significant difference at the 95 percent confidence level.
*NA = No introduced shrubs detected in transects

Overall canopy cover of treatment transects remained relatively stable, decreasing somewhat post-treatment with the lowest percentage (37.2) in 2010 (Table 10). Canopy cover within reference transects increased considerably, however, from 0.7 percent in 2006 to 37.9 percent in 2011. Although no height measurements were taken, growth in willow within the reference transects was apparent based on photographs (see Site 3, Reference transects 1A and B and 3A and B in Appendix E). Since the actual percent cover of coyote willow did not show drastic changes from year to year within overstory plots in reference transects (Figure 14), it is likely that willow reached heights that were captured in the densiometer starting in 2007.

TABLE 10.—Overall canopy cover of treatment and reference transects within Treatment Site 3 from 2006 to 2011.

Site 3 - Percent canopy cover											
2006		2007		2008		2009		2010		2011	
Treat.	Ref.	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.
62.2	0.7	66.4	22.5	52.6	36.8	54.0	49.8	37.2	42.3	44.2	37.9

Table 11 shows the average number of woody stems per m^2 for both treatment and reference transects in Site 3. The values listed are an average of the 10 plots that were measured in each transect type. Stem density in treatment transects was significantly less than in reference transects both pre- and post-treatment (Table 9). Treatment transects were comprised of coyote willow and saltcedar, while reference transects were comprised primarily of coyote willow. Saltcedar in treatment transects had a larger diameter than willow in this stand. This would explain fewer stems than the reference transects which were dominated by willow of smaller diameter. Coyote willow in the treatment transects did not increase to levels of reference transects in the absence of saltcedar post-treatment, however. Comparisons between years showed significantly greater stem densities in 2007 (pre-treatment) than in 2008 (post-treatment) in the treatment transects (Table 9). This appeared to be due to a decrease in the number of willow stems since saltcedar densities did not change considerably following initial treatment.

Table 11.—The average number of stems per meter squared for woody species in treatment and reference transects within Treatment Site 3 from 2006 to 2011.

Site 3 - Average number of stems / m^2												
	2006		2007		2008		2009		2010		2011	
Shrub species	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.
Coyote willow	11.2	37.0	10.5	31.7	5.6	31.2	5.9	27.7	9.8	24.0	10.6	30.1
New Mexico olive	0.0	0.0	0.2	0.5	0.5	0.4	0.6	0.5	1.0	0.2	0.8	0.9
Salt cedar	7.9	0.0	6.6	0.0	5.8	0.0	6.0	0.0	1.5	0.0	3.4	0.0
Siberian elm	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oneseed juniper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Big sagebrush	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Total shrub	19.1	37.0	17.4	32.2	11.9	31.6	12.5	28.3	12.3	24.2	14.8	31.1

The decrease in willow density in 2008 may have been a result of disturbance caused by the mechanical removal of saltcedar or because growth was inhibited by saltcedar slash left on site. Density of coyote willow has been gradually increasing since that time, although this increase wasn't statistically significant.

Table 12 shows the average number of saltcedar per 25 m^2 for the treatment transects in Site 3 from 2006 to 2011. Resprouting of saltcedar did occur following initial cutting even though an herbicide was applied and saltcedar density was still quite high in 2008 and 2009 following removal. The number of saltcedar stems decreased to 16.5/25 m^2 in 2010, probably due to follow-up herbicide application in August 2009 (Figure 15). The number of saltcedar stems again increased in 2011 to 34/25 m^2, which appears to indicate that another herbicide application may be necessary.

Table 12.—The average number of saltcedar stems per 25 meters squared within treatment transects of Treatment Site 3 from 2006 to 2010.

Average number of saltcedar / 25 m^2						
Treatment transects	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Site 3	86.5	83.0	57.5	54.0	16.5	34.0

Figure 15.—Post-treatment resprouted saltcedar in Transect 3-2, October 2009 (left) and dead saltcedar in the same plot one year later, October 2010 (right).

Site 5

Baseline data were collected in Site 5 in August 2008 and 2009. Saltcedar was removed from this plot using the cut stump method - including herbicide application and removal of slash - in late August of 2009 and post-treatment data were collected in 2010 and 2011. Various trees and shrubs were planted within the site and in surrounding areas that had also been treated. Immediately following treatment, tree rings were counted on 7 of the larger stumps in this stand and the average age of cut trees was determined to be 36.6 years. Photos of both pre- and post-treatment were taken in August and October of 2009, respectively, for this site. All photos are shown in Appendix E.

Table D-3 (Appendix D) shows the total percent cover by individual plant species, life-form (*i.e.* native or introduced shrub seedlings, grasses, or forbs), and cover type (*i.e.* vegetation, litter, bare ground, or basal area of shrubs) in the herbaceous layer of treatment transects in Site 5. The values listed are an average of the 10 plots measured in the 2 treatment transects.

Twenty species were detected within the herbaceous layer of transects in Site 5 in 4 years of monitoring. The most abundant species based on percent cover were slender wheatgrass, perennial pepperweed, houndstongue, and virgin's bower in 2008; slender wheatgrass, Virginia creeper, and perennial pepperweed in 2009; and slender wheatgrass, perennial pepperweed, and Canada thistle in 2010 and 2011. Perennial pepperweed, Canada thistle and houndstongue are nonnative invasive species. Pepperweed and Canada thistle increased after saltcedar control and should be monitored closely to determine if cover of these species continues to increase post-treatment.

The relative cover of life-forms detected in the herbaceous layer of treatment transects in Site 5 is shown in Figure 16. Introduced forbs were the most common life-form in all years based on relative percent cover. The relative percent cover of native species (52.1 percent) was slightly higher than introduced species (47.9) in 2008; however from 2009 to 2011 the proportion of introduced species was higher than native species (Table 13). This outcome could not be attributed to effects from treatment since the shift was prior to saltcedar removal, however treatment did not reverse this trend.

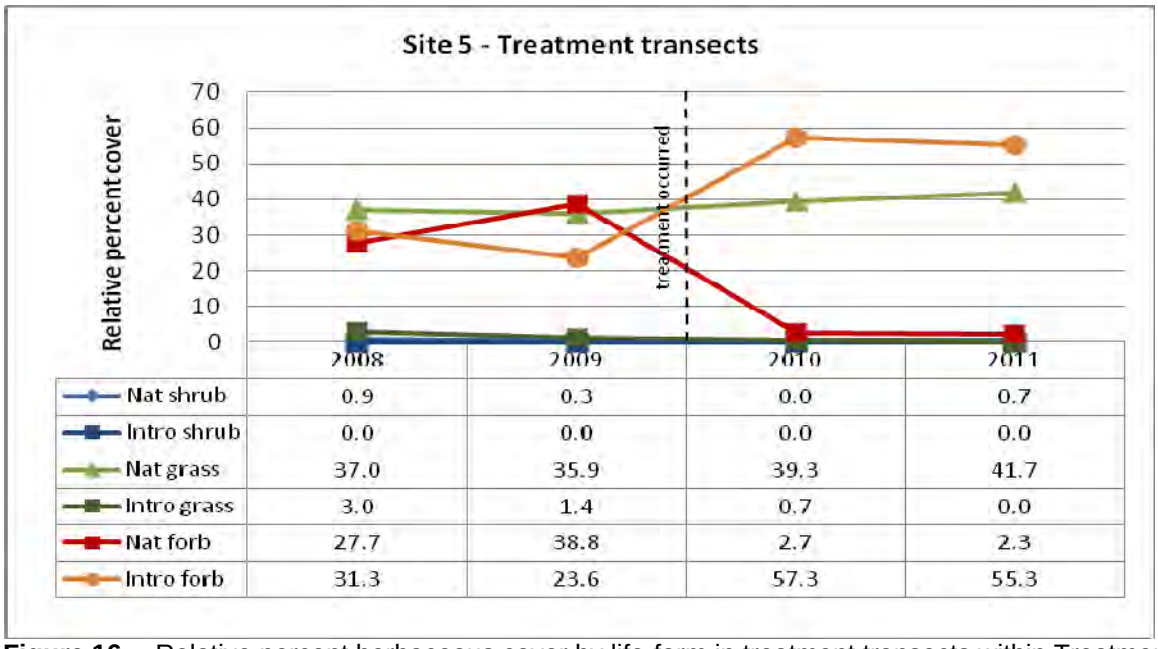


Figure 16.—Relative percent herbaceous cover by life-form in treatment transects within Treatment Site 5 in 2008 and 2009 (pre-treatment) and 2010 and 2011 (post-treatment).

TABLE 13.—Relative percent herbaceous cover of native vs. introduced species in treatment transects in Treatment Site 5 from 2008 to 2011.

Relative percent cover				
	2008	**2009**	**2010**	**2011**
Native species	65.7	75.0	42.0	44.7
Introduced species	34.3	25.0	58.0	55.3

Although there were slight shifts in the proportion of native to introduced species, there were no statistical differences identified in the percent total cover of native or introduced species between the years of monitoring (see Table 14 for statistical results and P-values for the herbaceous layer in Site 5). The lack of any sizeable change in native and introduced species cover over time is demonstrated in Figure 17.

Figure 18 provides a visual comparison of the percent total cover of plant, litter, and bare ground in the herbaceous layer of Site 5 from 2008 to 2011. Post-treatment (2010 and 2011), total cover of bare ground increased significantly compared to pre-treatment years (2008 and 2009; Table 14). No statistically significant changes in plant and litter total cover were identified over the monitoring period.

Table 14.—Statistical comparisons of total percent herbaceous cover between years in treatment transects within Treatment Site 5; Alpha=0.05.

	Native species	Introduced species	Plant	Litter	Bare ground
08 vs 09	08=09 P=0.489[1]	08=09 P=0.184[1]	08=09 P=0.789[1]	08=09 P=0.927[1]	No bare ground
09 vs 10	09=10 P=0.080[1]	09=10 P=0.332[2]	09=10 P=0.945[1]	09=10 P=0.407[1]	09<10 P=0.021[2]
10 vs 11	10=11 P=0.439[2]	10=11 P=0.939[1]	10=11 P=0.940[1]	10=11 P=0.601[1]	10=11 P=0.469[1]
08 vs 11	08=11 P=0.163[1]	08=11 P=0.403[1]	08=11 P=0.583[1]	08=10 P=0.342[1]	08<11 P=0.006[2]

[1] Paired t-test; [2]Signed rank test
Highlighted boxes indicate a significant difference at the 95 percent confidence level.

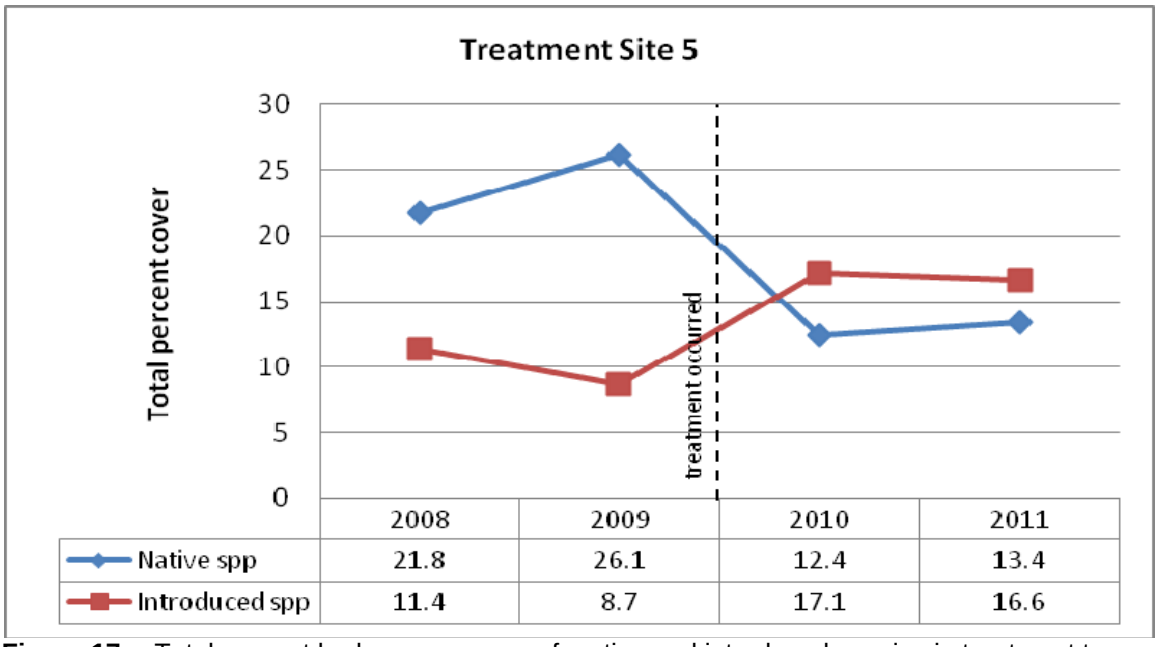


Figure 17.—Total percent herbaceous cover of native and introduced species in treatment transects within Treatment Site 5 from 2008 and 2009 (pre-treatment) and 2010 and 2011 (post-treatment).

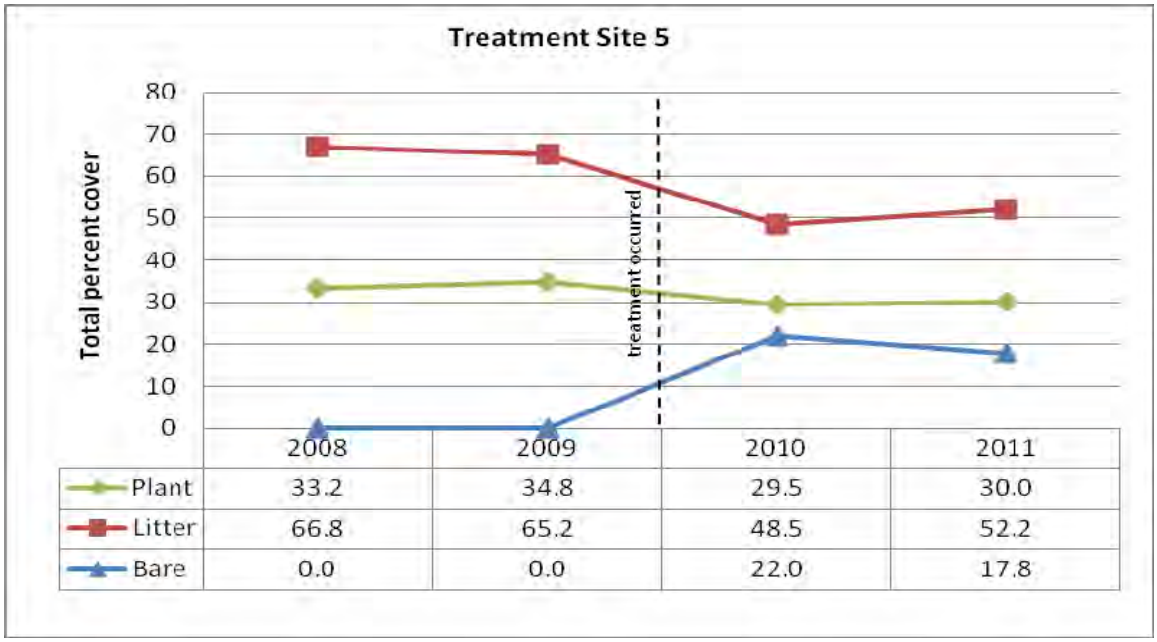


Figure 18.—Total herbaceous plant, litter, and bare cover in treatment transects within Treatment Site 5 in 2008 and 2009 (pre-treatment) and 2010 and 2011 (post-treatment).

The total percent cover of individual overstory species in treatment transects within Site 5 is shown in Figure 19. Saltcedar was the most common shrub species detected in the overstory layer within 1 m^2 transect plots until 2011, when cover of coyote willow surpassed that of saltcedar. During post-treatment data collection, saltcedar resprouts had grown greater than 25 cm and were included in the overstory layer – none were detected in the herbaceous layer. There was a significant increase in the percentage of total overstory cover from 2010 to 2011 due to increases in all overstory species (see Table 15 for statistical results and P-values for the overstory layer in Site 5).

The overall canopy cover (as measured with a densitometer) was almost complete pre-treatment, averaging 97.6 percent, but dropped substantially to 10.2 percent in 2010 following treatment (Table 16). This drastic decrease is not surprising since the stand was dominated by mature saltcedar prior to treatment. In 2011, canopy cover increased to 34.9, consistent with the increase in total cover of overstory species (Figure 19).

Table 17 shows the average number of woody stems per m^2. Before treatment, stem density was relatively low compared to the other treatment sites due to the dominance and large diameter of saltcedar in this stand. Stem density increased significantly post-treatment due to resprouting of saltcedar and the release of coyote willow (Table 15). These results indicated regeneration of coyote willow and the potential for this species to recolonize the site as long as resprouting of saltcedar is controlled and hydrology is favorable.

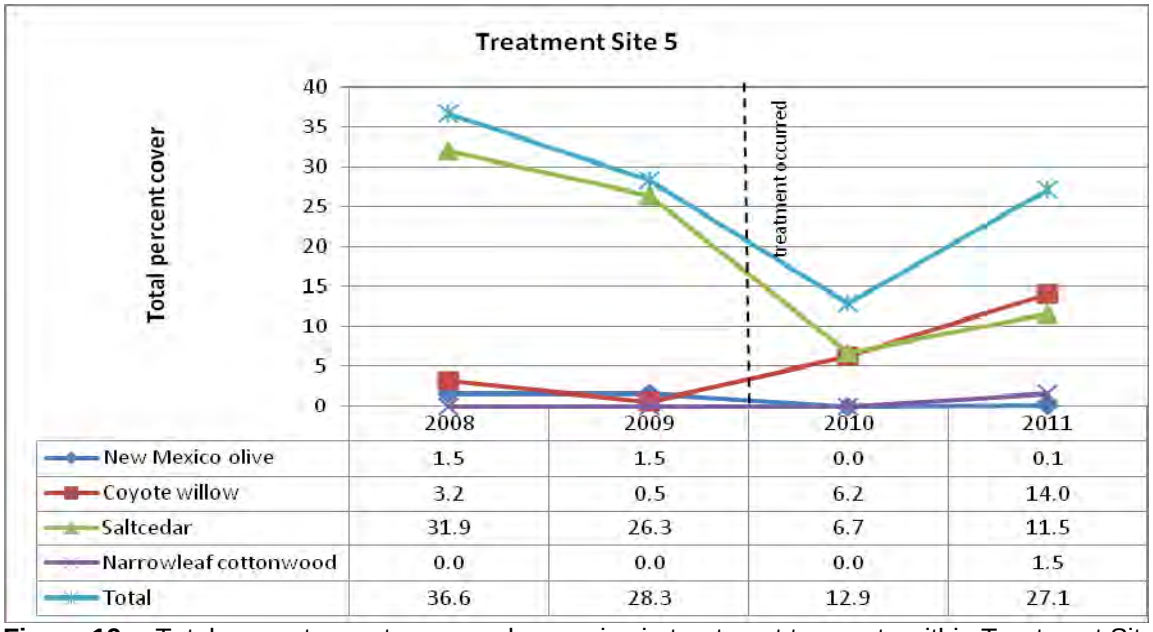


Figure 19.—Total percent overstory cover by species in treatment transects within Treatment Site 5 in 2008 and 2009 (pre-treatment) and 2010 and 2011 (post-treatment).

Table 15.—Statistical comparisons of total overstory cover and stem density between years in treatment transects within Treatment Site 5; Alpha=0.05.

	Total overstory cover	Nat spp total cover	Int spp total cover	Total stem density
08 vs 09	08=09 P=0.899[2]	08=09 P=1.0[2]	08=09 P=0.095[1]	08=09 P=1.0[1]
09 vs 10	09=10 P=0.323[1]	09=10 P=0.113[1]	09=10 P=0.187[1]	09<10 P=0.032[2]
10 vs 11	10<11 P=0.027[1]	10=11 P=0.059[2]	10=11 P=0.371[2]	10=11 P=0.944[2]
08 vs 11	08=11 P=0.542[1]	8=11 P=0.141[2]	08=11 P=0.150[1]	08<11 P=0.019[1]

[1] Paired t-test; [2]Signed rank test

Highlighted boxes indicate a significant difference at the 95 percent confidence level.

TABLE 16.—Overall canopy cover of treatment transects within Treatment Site 5 from 2008 to 2011.

Site 5 - Percent canopy cover			
2008	**2009**	**2010**	**2011**
97.7	97.4	10.2	34.9

Table 17.—The average number of stems per meter squared for woody species in treatment transects within Treatment Site 5 from 2008 to 2011.

Site 5 - Average number of stems/m^2				
Shrub species	**2008**	**2009**	**2010**	**2011**
Coyote willow	1.0	0.9	8.1	12.5
New Mexico olive	0.3	0.4	0.0	1.0
Salt cedar	2.3	2.3	14.9	4.1
Narrowleaf cottonwood	0.0	0.0	0.0	0.1
Total shrub	3.6	3.6	23.0	17.7

Table 18 shows the average number of saltcedar stems per 25 m^2 in Site 5. There was an increase in saltcedar stems in 2010 as a result of resprouting following treatment; this number more than doubled in 2011 to 118.5/25 m^2. The density of saltcedar actually decreased from 2010 to 2011 in 1 m quadrat plots. Saltcedar stems along the 25 m^2 transect were concentrated in small clumps of resprouts from remaining stumps. The large increase in saltcedar stems at this level indicates a need for additional treatment at Site 5.

Table 18.—The average number of saltcedar stems per 25 meters squared in treatment transects within Treatment Site 5 from 2008 to 2011.

Average number of saltcedar / 25 m^2				
	2008	**2009**	**2010**	**2011**
Site 5	32	29.5	48	118.5

Reference Sites

Sites 2 and 4

Table D-4 in Appendix D shows the total percent cover by individual plant species, life-form (i.e. native or introduced shrub seedlings, grasses, or forbs), and cover type (i.e. vegetation, litter, bare ground, or basal area of shrubs) in the herbaceous and overstory layers of transects in Sites 2 and 4 for all years of monitoring. The values listed are an average of the 10 plots measured in 2 reference transects per site.

Forty-four species were detected within the herbaceous layers of Reference Sites 2 and 4 over six years of monitoring. In 2007, the most abundant species based on percent cover in Site 2 were redtop, sedge, and smooth scouring rush. In 2008, the most common species were sedge, field horsetail, and redtop, in 2009 they were sedge, redtop, and dogbane, and in 2010 and 2011 they were sedge, redtop, and common plantain in the same site. In Site 4, the most common species were redtop, sedge, and spearleaf rabbitbrush in all years 2007 through 2010. In 2011, the most common herbaceous species shifted to redtop, sedge, and canary reed grass.

The relative cover of life-forms detected in the herbaceous layer of reference transects in Sites 2 and 4 is shown in Figures 20 and 21, respectively. Introduced grasses were the most common life-form based on percent relative cover in Site 2 in 2007, which shifted to native forbs in 2008 and 2009. Native grasses were the most abundant life-form in 2010 and 2011 at this site. In Site 4, introduced grasses were the most common life-form in 2007 and 2008, native forbs were the most abundant life-form in 2009, and native grasses were the most abundant life-form in 2010 and 2011. Both reference sites showed similar patterns in dominance of life-forms over the monitoring period; the exception was introduced forbs, which began steadily increasing in 2010 in Site 2 but remained low in Site 4.

There was a greater proportion of native species relative to introduced species from 2008 to 2011 in both sites; however in Site 2 proportions were essentially equal in 2011 (Table 19). In 2007 there was a greater proportion of introduced species (predominantly introduced grasses) in both sites.

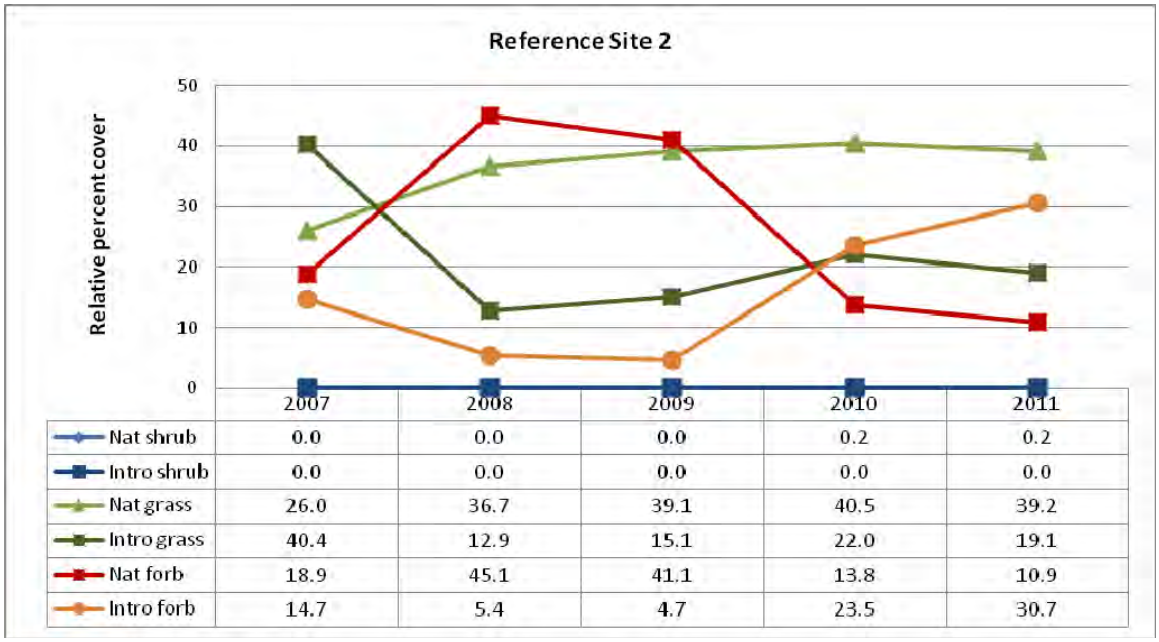


Figure 20.—Relative percent herbaceous cover by life-form in transects within Reference Site 2 from 2007 to 2011.

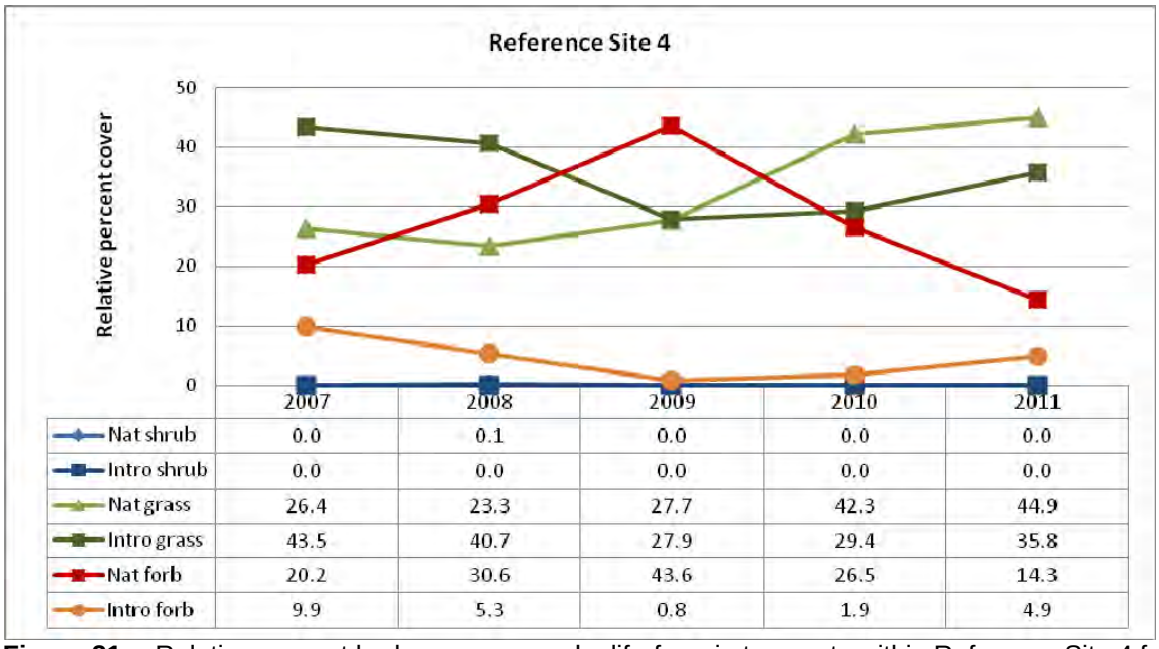


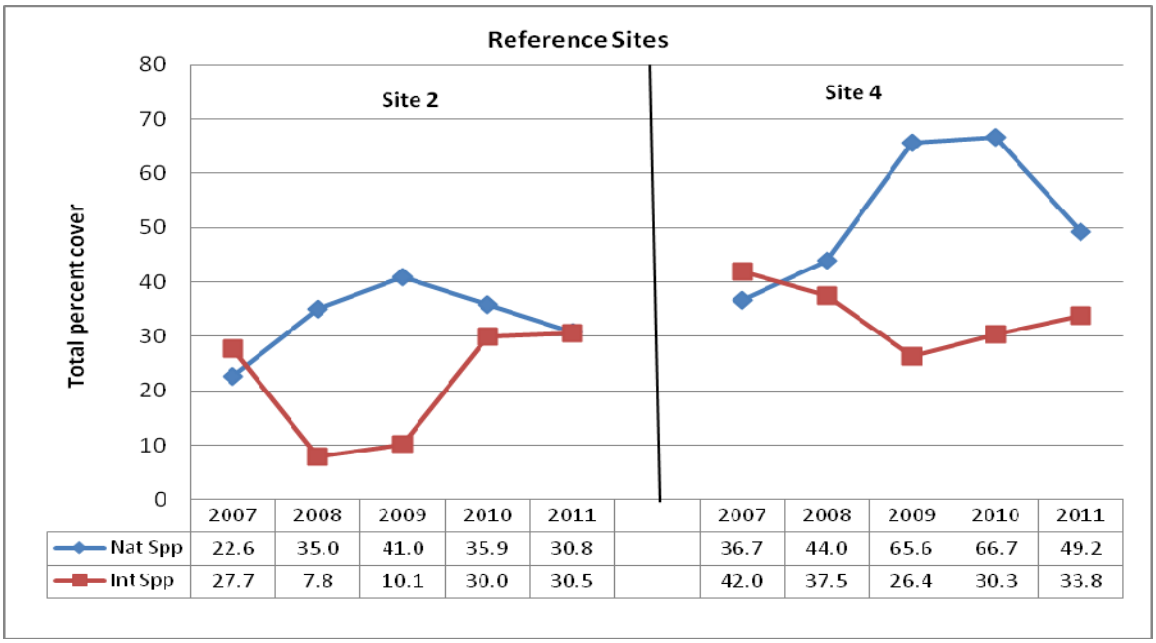
Figure 21.—Relative percent herbaceous cover by life-form in transects within Reference Site 4 from 2007 to 2011.

TABLE 19.— Relative percent herbaceous cover of native vs. introduced species in reference transects in Reference Sites 2 and 4 from 2006 to 2011.

Relative percent cover										
	Site 2					Site 4				
	2007	**2008**	**2009**	**2010**	**2011**	**2007**	**2008**	**2009**	**2010**	**2011**
Native species	44.9	81.8	80.2	54.5	50.2	46.6	54.0	71.3	68.8	59.3
Introduced species	55.1	18.2	19.8	45.5	49.8	53.4	46.0	28.7	31.2	40.7

The total percent cover of native plant species was significantly less in 2007 (22.6 percent; Figure 22) than in 2008 (35.0 percent) and also significantly increased over the monitoring period from 2007 to 2011 (30.8 percent) in Site 2 (see Table 20 for statistical results and P-values for the herbaceous layer in Sites 2 and 4). Introduced species cover in Site 2 was significantly less in 2008 and 2009 than in other years. In Site 4, total percent cover of native plants statistically increased in 2009, but significantly decreased in 2011 resulting in no change over the monitoring period. There was no statistical change in total cover of introduced species in Site 4 over the study period.

Figure 23 provides a visual comparison of the total percent cover of plant, litter, and bare ground in the herbaceous layer of Sites 2 and 4 from 2007 to 2011. Although there were significant increases in total plant cover in 2009 and 2010 in Site 2, this increase was not quite statistically significant (P=0.053) over the monitoring period (Table 20). Total litter cover increased significantly over the course of monitoring from 2007 to 2011. Total bare cover increased significantly in 2008 and decreased significantly in 2010. The increase in total cover of bare ground in Site 2 was due to scouring floods in 2008 and 2009. In Site 4, total plant cover increased significantly in 2009 in the herbaceous layer. Plant cover was on a continuous increase through 2010, but significantly decreased in 2011, resulting in no change over the monitoring period. Total litter cover gradually decreased through 2010 – decreasing significantly in 2009 – but significantly increased in 2011, resulting in no change from 2007 to 2011.



	Site 2 2007	Site 2 2008	Site 2 2009	Site 2 2010	Site 2 2011	Site 4 2007	Site 4 2008	Site 4 2009	Site 4 2010	Site 4 2011
Nat Spp	22.6	35.0	41.0	35.9	30.8	36.7	44.0	65.6	66.7	49.2
Int Spp	27.7	7.8	10.1	30.0	30.5	42.0	37.5	26.4	30.3	33.8

Figure 22.—Total percent herbaceous cover of native and introduced species in transects within Reference Sites 2 and 4 from 2007 to 2011.

Table 20. —Statistical comparisons of total percent herbaceous cover between years in Reference Sites 2 and 4; Alpha=0.05.

	Native species	Introduced species	Plant	Litter	Bare ground
Site 2					
07 vs 08	07<08 P=0.019[1]	07>08 P=0.008[1]	07=08 P=0.285[1]	07=08 P=0.090[1]	07<08 P=0.001[1]
08 vs 09	08=09 P=0.108[1]	08=09 P=0.430[1]	08<09 P=0.038[1]	08=09 P=0.097[1]	08=09 P=0.180[1]
09 vs 10	09=10 P=0.153[2]	09<10 P=0.005[1]	09<10 P=0.012[1]	09=10 P=0.688[1]	09>10 P=0.009[1]
10 vs 11	10=11 P=0.183[2]	10=11 P=0.890[1]	10=11 P=0.320[1]	10=11 P=0.824[1]	10<11 P=0.008[1]
07 vs 11	07<11 P=0.042[1]	07=11 P=0.692[1]	07=11 P=0.053[1]	07>11 P=0.013[1]	07<11 P=0.007[1]
Site 4					
07 vs 08	07=08 P=0.060[1]	07=08 P=0.497[1]	07=08 P=0.622[1]	07=08 P=0.640[1]	07=08 P=1.0[1]
08 vs 09	08<09 P=0.004[1]	08=09 P=0.172[2]	08<09 P=0.014[1]	08>09 P=0.011[1]	08=09 P=1.0[2]
09vs 10	09=10 P=0.667[1]	09=10 P=0.181[1]	09=10 P=0.085[1]	09=10 P=0.095[1]	09=10 P=1.0[2]
10 vs 11	10>11 P=0.010[1]	10=11 P=0.484[1]	10>11 P=0.001[1]	10<11 P=0.003[1]	10=11 P=1.00[2]
07 vs 11	07=11 P=0.089[1]	07=11 P=0.349[1]	07=11 P=0.498[1]	07=11 P=0.407[1]	07=11 P=1.00[2]

[1] Paired t-test; [2]Signed rank test
Highlighted boxes indicate a significant difference at the 95 percent confidence level.

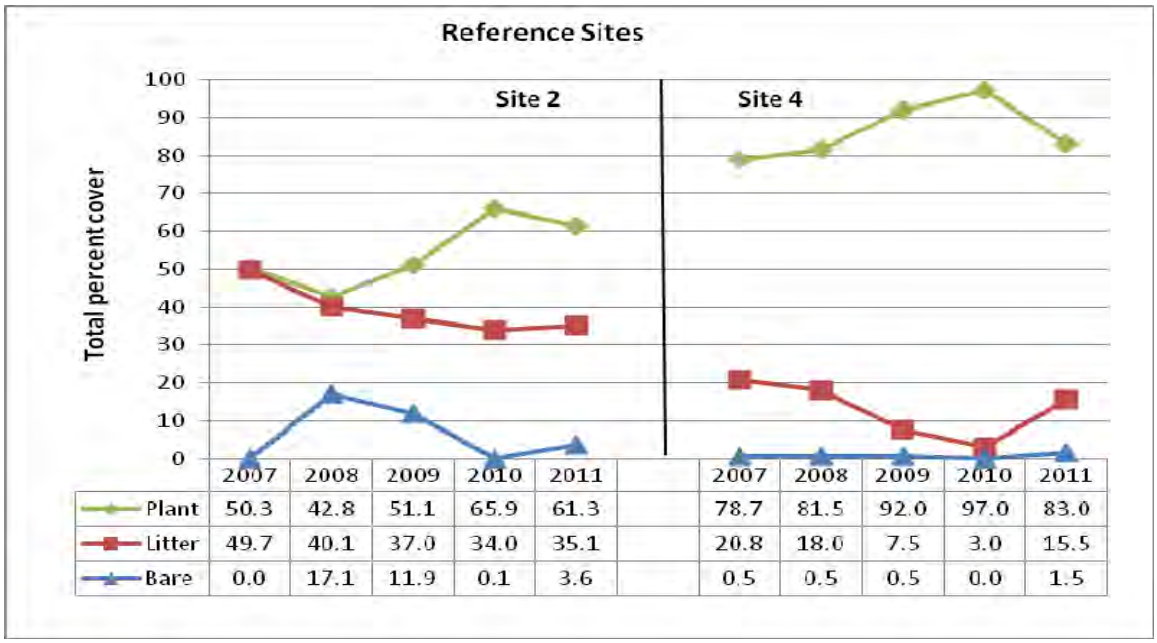


Figure 23.—Total herbaceous plant, litter, and bare cover in transects within Reference Sites 2 and 4 from 2007 to 2011.

Coyote willow was the only species detected in the overstory layer in both sites throughout 6 years of monitoring. Figure 24 shows total cover of coyote willow over the monitoring period. No statistical differences in the total cover of willow were detected between years in Site 2 (see Table 21 for statistical results and P-values for the overstory layer in Sites 2 and 4). In Site 4, total willow cover significantly decreased from 2006 (64.5 percent) to 2011 (46.5 percent). In the interest of using Reference Sites as a gauge for native species development in the OVRA, trends observed in Site 2 were more closely aligned to the reference transects in Treatment Sites 1 and 3 – where there were also no statistical changes in total overstory cover during the study period – than in Site 4.

Overall canopy cover in reference transects remained relatively stable until 2009, when it increased by about 20 percent in both sites (Table 22). In 2010, canopy cover remained at 2009 levels in Site 2 while it dropped by more than 25 percent in Site 4. In 2011, there was a noticeable decrease in canopy cover of coyote willow in both Reference Sites 2 and 4. The height of willow in Site 4 is visibly shorter in the 2011 Photo (see Site 4, Transect 1B, Appendix D), which would have affected overall canopy estimates by reducing the amount of canopy captured in the densiometer.

Table 23 shows the average number of woody stems per m^2 for Sites 2 and 4 from 2006 to 2011. The values listed are an average of the 10 plots that were measured in each transect type. Stem density in both sites was significantly higher in 2008 than in other years (Table 21). Willow stem density within reference transects in Treatment Sites 1 and 3 did not undergo such drastic increases during this same time period. In Site 2, stem density significantly decreased in 2011, which brought stem density to levels detected at this site when monitoring began in 2006.

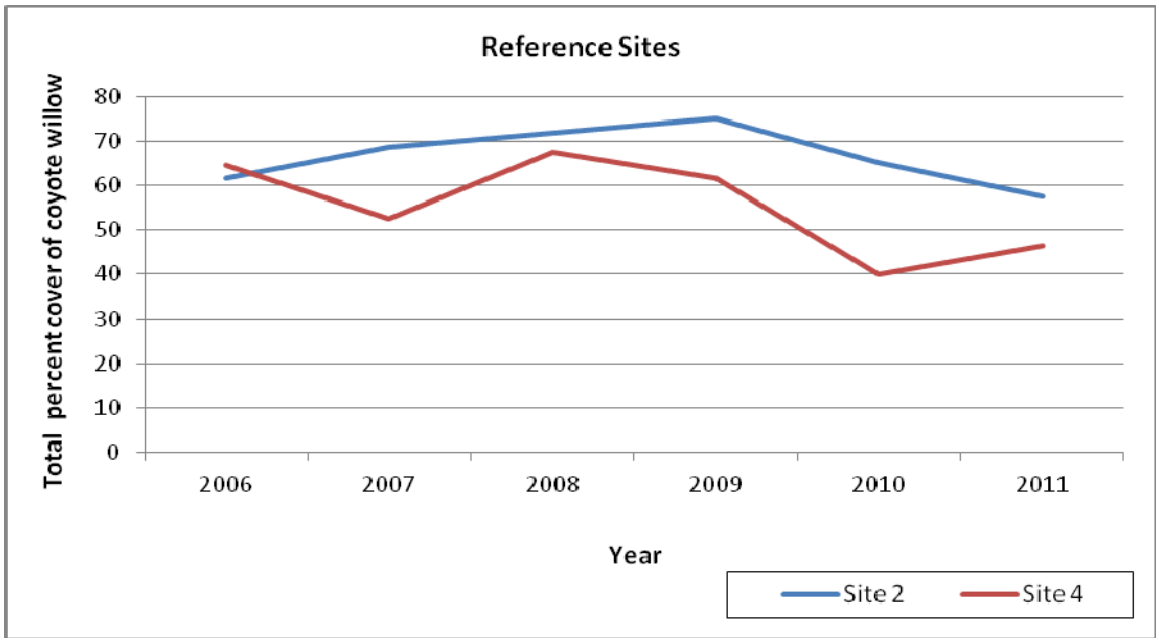


Figure 24.—Total percent overstory cover of coyote willow in transects within Reference Sites 2 and 4 from 2006 to 2011.

Table 21. —Statistical comparisons of total overstory cover and stem density between years in Reference Sites 2 and 4; Alpha=0.05.

	Total overstory cover	Total stem density
Site 2		
06 vs 07	06=07 P=0.200[1]	06=07 P=0.160[1]
07 vs 08	07=08 P=0.680[1]	07<08 P=0.004[2]
08 vs 09	08=09 P=0.594[1]	08>09 P=0.001[1]
09 vs 10	09=10 P=0.104[1]	09=10 P=0.251[1]
10 vs 11	09=10 P=0.156[1]	10>11 P=0.021[1]
06 vs 11	06=11 P=0.676[1]	06=11 P=0.814[1]
Site 4		
06 vs 07	06=07 P=0.406[1]	06=07 P=0.742[1]
07 vs 08	07=08 P=0.315[1]	07<08 P=0.020[1]
08 vs 09	08=09 P=0.609[2]	08>09 P=0.003[1]
09 vs 10	09=10 P=0.078[1]	09=10 P=0.530[1]
10 vs 11	10=11 P=0.240[1]	10=11 P=0.060[1]
06 vs 11	06>11 P=0.032[1]	06=11 P=0.079[1]

[1] Paired t-test; [2]Signed rank test
Highlighted boxes indicate a significant difference at the 95 percent confidence level.

TABLE 22.— Overall canopy cover of reference transects within Reference Sites 2 and 4 from 2006 to 2011.

Percent canopy cover											
Site 2						Site 4					
2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
63.3	72.1	63.5	88.40	81.50	67.7	*	72.9	62.2	81.8	55.50	38.2

*too windy to get an accurate reading

Table 23.— The average number of coyote willow stems per meter squared in transects within Reference Sites 2 and 4 from 2006 to 2011.

Average # of stems/m^2						
Shrub species	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Site 2						
Coyote willow	32.1	36.1	58.1	38.5	44.6	31.0
Thin leaf alder	0	0	0	0	0.1	0.1
Total shrub	32.1	36.1	58.1	38.5	44.7	31.1
Site 4						
Coyote willow	21.0	19.5	49.0	29.4	26.2	35.0

The majority of willow stems that were counted within transects originated from one base with many shoots. Therefore the increase in stem counts in 2008 was more related to resprouting of old plants than to regeneration of new plants. Evidence of beaver damage was prevalent along this section of the Rio Grande, and in 2007 it was noted that transects were heavily browsed by beaver in Site 4. This would explain an increase in the number of stems – in the form of resprouts- the following year. The hydrology within Reference sites was clearly favorable for

the growth of willow, which was the only overstory species present at these sites. Site 2 was located along a sandbar and often experienced flooding. Site 4 was characterized by side channels and depressions, which provided a source of available water. The combination of beaver browsing in 2007 and high discharges in 2008 (Figure 6) likely contributed to the significant increase in willow stem density in the Reference sites that year.

In 2009, heavy beaver damage was again noted and discharge rates were again high (Figure 6). However, willow stem counts returned to values documented in years prior to 2008. It was observed that many of the bases from which shoots of willow plants emerged had reached heights above 25 cm in 2009. In this situation, only one stem was counted since protocol for stem density involved tallying only individual stems that branched below 25 cm. So although there may have been many stems arising from one base, only one stem was counted. Factors that caused the increases in willow base heights may have been repeated beaver browsing that led to resprouting of shoots at continually higher points on the plant and/or scouring floods that lowered the ground level. The increases in willow base heights would have affected stem density by decreasing the number of stems measured below 25 cm.

In 2010, stem density was on an increasing trend in Site 2, but continued to gradually decrease in Site 4. Results were opposite in 2011, with a significant decrease in stem density in Site 2 and a barely insignificant (P=0.060) increase in stem density in Site 4. Recent beaver browsing was noted in Site 4 in 2010, which not only affected stem density but was also likely the cause for a decrease in canopy cover this year. In 2011, recent beaver activity was only noted in one of two transects, which may have been why both density and overstory cover increased slightly. Willow in Site 4 probably experience the greatest impacts from beaver of all sites monitored over the study period. Continuous and heavy browsing has most likely affected growth and development of willow at this site, which provided practical reference data since beaver populations are so high in the area. Evidence of effects from beaver can be seen in photos from Photo Station 4 (Appendix E), which show a change to a two-tiered community (starting in about 2008) with taller willow further from the river where beaver damage was limited. Decreases in stem density and overstory cover in Site 2 in 2011 may have been due to low river discharges (Figure 6) that limited overbank flows onto the sandbar.

Conclusions and Recommendations

In summary, saltcedar was removed from Treatment Sites 1 and 3 in 2008 and from Treatment Site 5 in 2010 after two years of baseline data had been collected in each site. Analyses of post-treatment data identified possible effects from saltcedar control in Treatment Sites 1, 3, and 5.

In Site 1, native grasses continued to be the dominant herbaceous life-form after saltcedar was removed, which indicated that disturbance at the site did not appear to cause a measurable increase in weedy species. Total overstory cover of coyote willow increased from 26.0 percent to 38.1 percent over the monitoring period, which was most likely due to a release in the growth of willow following saltcedar removal. During this same time period, total cover of saltcedar decreased from 7.5 percent to 2.0 percent. Saltcedar density increased from 20 stems/25m^2 in 2006 to 34.5 stems/25m^2 in 2009, which was due to resprouting as a result of treatment, but by

2010 resprouts had decreased to 22.0 stems/25m^2. The decrease in saltcedar stem density in 2010 was likely due to follow-up herbicide treatment to saltcedar foliage in August 2009. Increases in the number and height of saltcedar in treatment transects were observed in 2011.

In Site 3, total herbaceous plant cover decreased significantly from 65.5 percent prior to saltcedar control to 8.9 percent post-treatment in 2011, while total litter cover increased significantly from 32.0 percent to 73.7 percent during the same period. These changes in herbaceous plant and litter cover were most likely related to saltcedar removal. Saltcedar was hand cut and the plant material was left on site as litter. The high litter cover had a detrimental effect by inhibiting the growth of understory herbaceous species. The proportion of native plants that made up the vegetation was greater than the proportion of introduced plants. This outcome indicated that treatment did not result in an increase in introduced weedy species at the site. There was an increase in saltcedar total cover in the herbaceous layer due to resprouting the first two years after treatment (Table D-2), but by 2011 saltcedar cover was low (1.3 percent). Both overstory cover and density decreased statistically in the treated sites in 2008 (Table 9). These results suggest that saltcedar removal decreased shrub cover, which is logical because saltcedar was a relatively large component of the overstory at this site prior to treatment. Total overstory cover has been on a gradual upward trend post-treatment due to increasing cover of coyote willow. The total cover of overstory saltcedar decreased from 23.1 percent in 2007 to 1.5 percent in 2011, with saltcedar resprouts covering an average of 1.3 percent in the herbaceous layer. There was a relatively large decrease in saltcedar density to 16.5 stems/25m^2 in 2010, which was probably due to a follow-up herbicide application to saltcedar foliage in August 2009. Saltcedar density again increased to 34.0 stems/25m^2 in 2011.

In Treatment Site 5, post-treatment data was collected for the first year in 2010. The invasive species perennial pepperweed and Canada thistle showed relatively large increases in cover after treatment. These herbaceous species should be observed closely to determine if they continue to spread, in which case control may be necessary. Saltcedar should also be monitored closely at this site since there was a fair amount of resprouting following removal. In 2011, the number of saltcedar stems per 25 m^2 more than doubled. The total cover of bare ground significantly increased post-treatment, however herbaceous plant and litter cover remained statistically equal. Stem density significantly decreased following treatment, which was not surprising since Site 5 was a dense stand of saltcedar prior to removal. Regardless, there was a release in coyote willow in the absence of a saltcedar canopy, which may indicate potential for this species at this site.

Saltcedar densities recorded in treatment transects in Sites 1, 3, and 5 post-treatment indicated that saltcedar resprouted at a relatively high rate following removal. In August 2009, a foliar herbicide application was used as follow-up treatment at these sites and monitoring in 2010 showed that saltcedar stem densities were on a decreasing trend. Increases in saltcedar stem densities in 2011 at these sites suggest that another herbicide treatment may be necessary.

In Reference Sites 2 and 4, stem density of coyote willow increased significantly in 2008 but returned to initial levels in 2009. These results probably suggest that hydrologic conditions in 2008 were conducive to willow productivity at these sites. It was also likely that intensive browsing by beaver stimulated resprouting of willow stems. The large increase in stem density in 2008 should be taken into consideration when using data for comparison purposes over time. In 2009, it was observed that many of the bases from which shoots of willow plants emerged had

reached heights above 25 cm. In this situation, only one stem was counted since protocol for stem density involved tallying only individual stems that branched below 25 cm. This caused the total number of stems to decrease. This condition persisted in 2010. Beaver browsing continued to be intensive throughout the project area from 2009 to 2011 and appeared to be impacting growth of willow at some of the monitoring sites. An enclosure in Treatment Site 1 that was installed around 2004 to protect planted cottonwood saplings demonstrated effects from browsing. Willow that were enclosed in the fencing and inaccessible to beaver were much taller and more robust than those outside that were continually browsed (Figure 25).

Reclamation recommends that vegetation monitoring continue at the established sites to document effects and success of saltcedar treatment within the OVRA. Adaptive management strategies can be applied with vital information provided through monitoring. Based on the results of the sampling effort thus far, some issues that may be important to monitor over time include:

1) long-term inhibition of herbaceous species due to saltcedar material that was left on site after cutting (e.g. Treatment Site 3)
2) reestablishment of willow and other native woody species in the absence of saltcedar
3) resprouting rates of treated saltcedar
4) invasion of other troublesome species following saltcedar removal.

Figure 25.—Enclosed coyote willow are visibly taller (center back of photo) than surrounding willow because the enclosure prohibits beaver browsing.

Literature Cited

USDI - BLM, August 2006. Treatment of Saltcedar (Tamarix sp) and Other Invasive Non-Native Vegetation in Orilla Verde Recreation Area. NM-220-05-054.

Appendix A

Data Collection Form

Orilla Verde Recreation Area
Saltcedar Removal Vegetation Monitoring

Date:	
Observers:	
Site ID:	
Height class verification:	
Transect #:	
Waypoints:	
Photo #s:	
Densiometer readings:	

Plot #	Life Form*	Species Code	% Cover	Stem count**	Plot #	Life Form	Species Code	% Cover	Stem count

*H=Herbaceous and woody seedlings S=shrubs and saplings (<20 ft) T=tree (>20 ft) **Woody spp. Only

Appendix B

Waypoints for Transect and Photo Station Locations

Datum NAD83
Zone 13

Transect points

Site	Transect	Point	X	Y
1	1	A	433773	4021290
1	1	B	433746	4021280
1	2	A	433768	4021297
1	2	B	433741	4021304
1	3	A	433706	4021303
1	3	B	433683	4021305
1	4	A	433642	4021263
1	4	B	433622	4021286
2	1	A	431400	4018834
2	1	B	431380	4018817
2	2	A	431380	4018817
2	2	B	431370	4018800
3	1	A	433344	4021108
3	1	B	433338	4021092
3	2	A	433284	4021040
3	2	B	433259	4021031
3	3	A	433262	4021042
3	3	B	433241	4021025
3	4	A	433236	4021019
3	4	B	433217	4021008
4	1	A	431537	4019100
4	1	B	431528	4019070
4	2	A	431524	4019051
4	2	B	431518	4019025
5	1	A	433051	4020878
5	1	B	433034	4020858
5	2	A	432845	4020593
5	2	B	432834	4020576

Photo Stations

Photo Station	x	y	Notes
PS1	433703	4021312	1 photo upstream; 1 photo downstream
PS2	431431	4018844	1 photo downstream
PS3	433189	4020958	No marker; taken from rock next to elm, across river on downstream end of polygon
PS4	431571	4019053	Taken at culvert from road post w/ reflectors
PS5-1	433002	4020829	Fence post west side of road near transect 1
PS5-2	432875	4020596	Big rock upslope from transect 2, east side of road, upstream side of polygon

Appendix C

Common and Scientific Names of Plants
Detected in Treatment and Reference Transects

Code	Scientific name	Common name	Lifeform*
Trees/shrubs			
ALIN	*Alnus incana ssp tenuifolia*	Thinleaf alder	NS
ARTR	*Artemisia tridentata*	Big sagebrush	NS
FOPU	*Forestiera pubescens*	New Mexico olive	NS
JUMO	*Juniperus monosperma*	Oneseed juniper	NS
POAN	*Populus angustifolia*	Narrowleaf cottonwood	NS
PODE	*Populus deltoides*	Cottonwood	NS
SAEX	*Salix exigua*	Coyote willow	NS
TARA	*Tamarix ramosissima*	Saltcedar	IS
ULPU	*Ulmus pumila*	Siberian elm	IS
Grasses			
AGGI	*Agrostis gigantea*	Redtop	IG
BRIN	*Bromus inermis*	Smooth brome	IG
BRJA	*Bromus japonicus*	Japanese brome	IG
BRTE	*Bromus tectorum*	Cheatgrass	IG
CAEM	*Carex emoryi*	Sedge	NG
ELCA	*Elymus canadensis*	Canada wildrye	NG
ELTR	*Elymus trachycaulus*	Slender wheatgrass	NG
FEAR	*Festuca arundinacea*	Tall fescue	IG
HOJU	*Hordeum jubatum*	Barley foxtail	NG
MUAS	*Muhlenbergia asperifolia*	Alkali muhly	NG
MURA	*Muhlenbergia racemosa*	Marsh muhly	NG
PACA	*Panicum capillare*	Witchgrass	NG
PHAR	*Phalaris arundinacea*	Canary reedgrass	NG
POPR	*Poa pratensis*	Kentucky bluegrass	NG
SPCR	*Sporobolus cryptandrus*	Sand dropseed	NG
Forbs			
ACMI	*Achillea millefolium*	Common yarrow	NF
AGPA	*Agastache pallidiflora ssp neomexicana*	New Mexico giant hyssop	NF
AMAR	*Ambrosia artemisifolia*	Annual ragweed	NF
APCA	*Apocynum cannabinum*	Clasping-leaf dogbane	NF
ARAN	*Argentina anserina*	Silverweed cinquefoil	NF
ARCA	*Artemisia carruthii*	Carruth's sagewort	NF
ARFR	*Artemisia frigida*	Fringed sage	NF
ARLU	*Artemisia ludoviciana*	White sagebrush	NF
ASIN	*Asclepias incarnata*	Swamp milkweed	NF
ATPR	*Atriplex prostrata*	Triangle orache	NF
CHLI	*Chrysothamnus linifolius*	Spearleaf rabbitbrush	NF
CHSE	*Chamaesyce serpyllifolia*	Thymeleaf spurge	NF
CHAL	*Chenopodium album*	Lambsquarters	IF
CIAR	*Cirsium arvense*	Canada thistle	IF
CIMA	*Cicuta maculata*	Spotted water hemlock	NF
CIVU	*Cirsium vulgare*	Bull thistle	IF
CLLI	*Clematis ligusticifolia*	Virgin's bower	NF
COCA	*Conyza canadensis*	Horseweed	NF

Code	Scientific name	Common name	Lifeform*
CYOF	*Cynoglossum officianale*	Houndstongue	IF
DIFU	*Dipsacus fullonum*	Teasel	IF
EPCI	*Epilobium ciliatum*	Fringed willowherb	NF
ERSP	*Erigeron flagellaris*	Trailing fleabane	NF
EQAR	*Equisetum arvense*	Field horsetail	NF
EQLA	*Equisetum laevigatum*	Smooth scouringrush	NF
GLLE	*Glycyrrhiza lepidota*	Wild licorice	NF
GRSQ	*Grindelia squarrosa*	Curlycup gumweed	NF
HEAU	*Helenium autumnale*	Mountain sneezeweed	NF
HESP	*Heterotheca* sp,	Goldenaster	NF
LASE	*Lactuca serriola*	Prickly lettuce	IF
LELA	*Lepidium latifolium*	Perrenial pepperweed	IF
LEVU	*Leucanthemum vulgare*	Oxeye daisy	IF
LYAS	*Lycopus asper*	Rough bugleweed	NF
MEAL	*Melilotus albus*	White sweetclover	IF
MEOF	*Melilotus officianalis*	Yellow sweetclover	IF
MEAR	*Mentha arvensis*	Wild mint	NF
OEEL	*Oenothera elata*	Hooker's evening primrose	NF
OPSP	*Opuntia* sp.	Pricklypear cactus	NF
PAVI	*Parthenocissus vitacea*	Woodbine	NF
PLLA	*Plantago lanceolata*	Narrowleaf plantain	IF
PLMA	*Plantago major*	Common plantain	IF
PONO	*Potentilla norvegica*	Norwegian cinquefoil	NF
PSST	*Pseudognaphalium stramineum*	Cottonbatting cudweed	NF
RUCR	*Rumex crispis*	Curly dock	IF
SOCA	*Solidago canadensis*	Canada goldenrod	NF
SOAR	*Sonchus arvensis*	Field sowthistle	IF
SYLAG	*Symphyotrichum laeve var. geyeri*	Geyer's aster	NF
SYLAH	*Symphyotrichum lanceolatum ssp. hesperium*	White-panicle aster	NF
TAOF	*Taraxacum officinale*	Dandelion	IF
TRPO	*Tragopogon porrifolius*	Salsify	IF
TRPR	*Trifolium pratense*	Red clover	IF
VETH	*Verbascum thapsus*	Mullein	IF

*IS=Introduced shrub; NS=Native shrub; IG=Introduced grass; NG=Native grass; IF=Introduced forb; NF=Native forb

Appendix D

Total percent herbaceous cover by plant species, lifeform, and cover type
Sites 1-5
2006 to 2011.

TABLE D-1.— Total percent herbaceous cover by plant species, life-form, and cover type in treatment and reference transects within Treatment Site 1 from 2006 to 2011.

Site 1 - Total percent herbaceous cover												
	2006		2007		2008		2009		2010		2011	
	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.
Shrub seedlings												
Coyote willow	0.6	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
New Mexico olive	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.0	5.0	0.3	1.0	0.3
Native shrubs	0.6	0.0	0.0	0.0	0.2	0.4	0.2	0.0	5.0	0.3	1.0	0.3
Saltcedar	0.0	0.1	0.0	0.0	1.5	0.0	1.5	0.0	0.0	0.0	0.0	0.0
Introduced shrubs	0.0	0.1	0.0	0.0	1.5	0.0	1.5	0.0	0.0	0.0	0.0	0.0
Graminoids												
Sedge	0.0	2.1	0.0	8.6	0.0	16.5	0.0	15.7	0.0	15.2	0.0	13.0
Canada wildrye	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Slender wheatgrass	9.5	2.6	47.0	19.6	39.0	25.0	37.0	32.7	36.9	21.0	31.7	27.2
Alkali muhly	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Canary reedgrass	0.0	0.0	0.0	0.2	0.0	0.3	0.0	2.3	0.0	4.2	0.0	4.3
Kentucky bluegrass	0.0	0.4	0.0	23.5	0.0	0.0	0.0	4.2	1.0	9.5	0.0	0.0
Barley foxtail	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Native grasses	9.5	5.2	47.0	53.5	39.0	41.9	37.0	54.9	37.9	50.4	31.7	44.5
Japanese brome	0.6	0.1	0.5	0.0	2.0	0.0	15.7	0.0	4.7	0.0	3.3	0.0
Cheatgrass	3.5	0.0	7.2	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Redtop	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.8	0.0	26.0	0.0	10.5
Tall fescue	0.0	0.0	0.0	7.8	0.0	8.5	0.0	4.0	0.0	2.0	0.0	3.5
Introduced grasses	4.1	0.1	7.7	7.8	3.2	8.5	15.7	19.8	4.7	28.0	3.3	14.0
Forbs												
Annual ragweed	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.1	0.0	0.2	0.0	1.6
Dogbane	0.0	2.4	0.0	0.2	0.0	1.2	0.0	0.6	0.0	0.4	0.0	1.6
Silverweed cinquefoil	0.0	0.3	0.0	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Carruth's sagewort	0.0	0.0	0.0	0.1	0.0	0.8	0.0	2.1	0.0	0.3	0.0	1.3
Spearleaf rabbitbrush	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Canadian horseweed	0.2	0.9	5.0	6.1	0.0	0.0	1.3	4.8	0.5	0.2	0.0	0.0
Smooth scouringrush	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Field horsetail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Mountain sneezeweed	0.0	0.0	0.0	0.1	0.0	1.5	0.0	0.1	0.0	0.0	0.0	0.0
Wild mint	0.0	1.1	0.0	0.0	0.0	1.1	0.0	0.1	0.0	0.1	0.0	0.0
Woodbine	0.2	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1
Hooker's evening primrose	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.1	0.0	0.0	0.0	0.0
Cottonbatting cudweed	0.0	0.0	0.0	0.1	0.0	0.0	0.0	1.2	0.0	0.1	0.0	0.1
Geyer's aster	0.0	0.0	0.0	0.1	0.0	0.1	0.0	1.5	0.0	0.8	0.0	1.4
Thymeleaf spurge	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Common yarrow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.5	0.0	0.0
Fringed sage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Rough bugleweed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Norwegian cinquefoil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
White-panicle aster	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.2
Canada goldenrod	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Frindged willowherb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Unknown forb	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0

Native forbs	0.4	4.8	7.0	7.5	0.0	8.7	1.4	11.1	0.5	3.2	0.3	7.4
Canada thistle	3.3	2.6	0.7	3.2	2.0	2.8	8.2	1.4	7.4	2.1	3.7	0.9
Bull thistle	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0
Houndstongue	0.2	0.0	1.0	0.0	1.7	0.0	1.4	0.0	1.6	0.2	1.9	1.2
Perennial pepperweed	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
White sweetclover	0.0	0.0	0.0	4.4	0.1	0.0	0.0	0.0	0.0	0.7	0.0	0.1
Narrowleaf plantain	0.0	0.0	0.6	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Curly dock	0.0	0.0	0.1	0.0	0.2	0.0	0.2	0.0	0.0	0.0	0.1	0.0
Red clover	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Mullein	0.0	0.0	6.8	0.3	6.7	0.1	0.4	0.1	0.0	2.0	0.0	0.0
Field sowthistle	0.0	0.0	0.0	0.0	0.0	1.6	1.5	1.0	1.8	0.1	0.1	0.2
Common plantain	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1
Teasel	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	1.5
Prickly lettuce	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Introduced forbs	4.1	2.8	9.4	8.7	10.7	4.8	11.8	2.6	13.0	5.1	6.6	4.0
Total vegetative cover	18.7	13.0	71.1	77.5	54.6	64.3	67.6	88.4	61.1	87.0	42.9	70.2
Basal area of shrubs	8.2	15.6	3.3	1.0	2.5	7.0	1.0	3.5	2.3	5.2	1.0	1.0
Litter	62.5	43.1	22.6	14.5	37.9	26.2	24.9	7.5	31.0	7.5	39.3	27.7
Bare	10.6	28.3	3.0	7.0	5.0	2.5	6.5	0.6	5.6	0.3	16.8	1.1
Total herbaceous cover	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table D-2. —Total percent herbaceous cover by plant species, life-form, and cover type in treatment and reference transects within Treatment Site 3 from 2006 to 2011.

Site 3 - Total percent herbaceous cover												
	2006		2007		2008		2009		2010		2011	
	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.	Treat.	Ref.
Shrub seedlings												
Cottonwood	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coyote willow	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Mexico olive	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.4	0.0	0.3
Oneseed juniper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Big sagebrush	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Native shrubs	0.0	0.3	0.0	0.1	0.0	0.1	0.0	0.3	0.0	0.4	0.0	0.4
Saltcedar	0.1	0.0	0.0	0.0	6.3	0.0	6.3	0.0	0.4	0.0	1.3	0.0
Siberian elm	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Introduced shrubs	0.1	0.0	0.1	0.0	6.3	0.0	6.3	0.0	0.4	0.0	1.3	0.0
Graminoids												
Sedge	0.0	3.3	0.0	7.4	0.2	11.0	0.0	12.1	0.1	9.1	0.1	13.5
Canada wildrye	0.0	0.0	0.1	0.4	0.0	1.8	0.0	0.0	0.1	0.0	0.0	0.0
Slender wheatgrass	0.2	0.0	3.0	3.4	1.9	4.9	2.0	9.0	0.1	0.0	0.4	0.0
Alkali muhly	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.3	0.0	0.0	0.0	0.0
Marsh muhly	0.0	0.0	0.1	0.4	1.0	0.1	0.0	0.0	0.0	0.8	0.0	0.0
Canary reedgrass	0.0	1.0	0.0	3.0	0.0	3.3	0.0	3.6	0.0	8.0	0.0	4.4
Kentucky bluegrass	0.2	0.0	3.8	0.0	3.4	0.8	0.5	0.0	0.1	0.1	0.1	0.7
Sand dropseed	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.1	0.4	0.2	0.8
Native grasses	0.4	4.3	7.3	14.7	6.6	22.1	2.5	25.0	0.5	18.4	0.8	19.4
Redtop	0.0	0.7	0.0	10.4	1.4	11.9	0.5	4.4	0.5	3.4	0.5	6.2
Smooth brome	0.1	0.8	0.0	4.6	2.2	7.8	0.5	4.9	1.5	7.7	1.8	7.8
Japanese brome	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cheatgrass	0.6	0.0	40.4	1.2	0.5	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Introduced grasses	0.7	1.5	43.4	16.2	4.1	19.7	1.0	9.3	2.0	11.4	2.3	14.0
Forbs												
Common yarrow	0.1	0.0	1.6	0.0	2.4	0.0	2.0	0.0	1.5	0.0	0.0	0.0
Dogbane	0.0	0.2	0.0	0.1	0.0	0.4	0.0	0.7	0.0	0.1	0.0	1.5
Silverweed cinquefoil	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Carruth's sagewort	0.0	0.0	2.2	0.0	2.9	1.3	4.7	0.5	7.2	1.0	3.6	1.6
White sagebrush	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.3	0.0	0.2	0.0	0.5
Swamp milkweed	0.0	1.5	0.0	0.5	0.4	0.3	0.0	0.7	0.1	0.7	0.0	0.7
Spearleaf rabbitbrush	0.0	0.0	0.5	0.0	2.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Canadian horseweed	0.2	0.2	1.5	0.5	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
Field horsetail	0.0	0.1	0.0	0.0	0.0	0.7	0.0	1.8	0.0	0.1	0.0	0.0
Smooth scouringrush	0.6	0.6	0.9	0.4	1.1	0.5	0.2	0.0	0.6	0.6	0.7	0.5
Curlycup gumweed	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rough bugleweed	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Wild mint	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Woodbine	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.2
Hooker's evening primrose	0.0	0.0	1.9	0.0	0.0	0.0	0.1	0.0	0.4	0.0	0.0	0.0
Pricklypear cactus	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cottonbatting cudweed	0.0	0.8	0.0	0.3	0.0	0.0	0.0	1.0	0.0	0.4	0.0	0.1
White-panicle aster	0.0	0.1	0.0	2.0	0.0	2.2	0.0	0.3	0.0	0.0	0.0	0.0

Geyer's aster	0.0	0.0	0.1	0.4	0.0	0.1	0.0	0.0	0.0	2.8	0.0	4.7
Trailing fleabane	0.0	0.0	0.0	0.0	0.0	0.2	0.0	2.5	0.0	2.0	0.0	0.1
Thymeleaf spurge	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Goldenaster	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Virgen's bower	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Unknown forb	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
Native forbs	1.0	3.5	9.0	4.2	8.8	7.0	7.1	7.8	9.9	8.5	4.3	10.0
Canada thistle	0.0	0.6	0.0	1.8	0.0	1.0	0.2	0.9	0.1	1.7	0.0	2.6
Houndstongue	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Perennial pepperweed	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
White sweetclover	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Narrowleaf plantain	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Dandelion	0.0	0.0	0.1	0.3	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.2
Red clover	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mullein	1.1	0.0	5.5	1.4	0.3	0.6	0.1	0.1	0.1	0.1	0.0	0.0
Common plantain	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.0	0.2	0.0	0.1
Field sowthistle	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.5	0.0	0.6
Prickly lettuce	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Teasel	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.1	0.0	0.1	0.0
Oxeye daisy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.2
Bull thistle	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Yellow sweetclover	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Introduced forbs	1.3	0.7	5.7	5.1	0.5	1.8	0.8	1.6	0.4	2.9	0.2	3.7
Total vegetative cover	3.5	10.3	65.5	40.3	26.3	50.7	17.7	44.0	13.2	41.6	8.9	47.5
Basal area of shrubs	13.3	14.8	13.5	7.5	3.5	1.5	2.5	0.0	1.0	1.0	0.0	0.0
Litter	58.2	36.2	18.5	37.7	59.8	39.9	63.2	51.2	66.8	51.2	73.7	45.0
Bare	25.0	38.7	2.5	14.5	10.4	7.9	16.6	4.8	19.0	6.2	17.4	7.5
Total herbaceous cover	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table D-3.— Total percent herbaceous cover by plant species, life-form, and cover type in treatment transects within Treatment Site 5 from 2008 to 2011.

Site 5 - Total percent herbaceous cover				
	2008	**2009**	**2010**	**2011**
Shrub seedlings				
Coyote willow	0.2	0.0	0.0	0.0
New Mexico olive	0.1	0.1	0.0	0.2
Native shrubs	0.3	0.1	0.0	0.2
Graminoids				
Slender wheatgrass	12.3	12.4	11.6	12.5
Canada wildrye	0.0	0.1	0.0	0.0
Native grasses	12.3	12.5	11.6	12.5
Japanese brome	1.0	0.0	0.0	0.0
Cheatgrass	0.0	0.5	0.2	0.0
Introduced grasses	1.0	0.5	0.2	0.0
Forbs				
Dogbane	0.1	0.0	0.0	0.0
Virgin's bower	4.6	2	0.4	0.4
Woodbine	4.5	11.5	0.0	0.3
Triangle orache	0.0	0.0	0.4	0.0
Native forbs	9.2	13.5	0.8	0.7
Bull thistle	0.2	0.2	0.0	0.0
Houndstongue	4.6	3.1	1.9	1.8
Perennial pepperweed	4.9	4.0	11.2	7.3
Mullein	0.5	0.2	0.0	0.0
Prickly lettuce	0.2	0.2	0.0	0.2
Canada thistle	0.0	0.4	3.2	7.2
Lambsquarters	0.0	0.1	0.0	0.0
Field sowthistle	0.0	0.0	0.3	0.0
Dandelion	0.0	0.0	0.2	0.1
White sweetclover	0.0	0.0	0.1	0.0
Introduced forbs	10.4	8.2	16.9	16.6
Total vegetative cover	33.2	34.8	29.5	30.0
Basal area of shrubs	5.1	4.0	0.0	1.7
Litter	61.7	61.2	48.5	50.5
Bare	0.0	0.0	22.0	17.8
Total herbaceous cover	100.0	100.0	100.0	100.0

Table D-4.— Total percent herbaceous cover by plant species, lifeform, and cover type in transects within Reference Sites 2 and 4 from 2006 to 2011.

Total Percent Herbaceous Cover - Reference Polygons												
	Site 2						Site 4					
	2006	2007	2008	2009	2010	2011	2006	2007	2008	2009	2010	2011
Shrub seedlings												
Coyote willow	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0
Thinleaf alder	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Native shrubs	0.2	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0
Graminoids												
Sedge	5.3	10.7	11.2	17.3	16.8	13.7	16.4	16.0	15.8	19.0	28.4	21.4
Canada wildrye	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Slender wheatgrass	0.0	0.5	0.5	0.1	4.1	3.1	3.4	0.0	0.0	0.0	0.0	0.0
Canary reedgrass	0.2	1.8	3.8	2.6	5.8	7.2	2.8	4.8	3.2	6.5	12.6	15.9
Witchgrass	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kentucky bluegrass	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Native grasses	5.5	13.1	15.7	20.0	26.7	24.0	22.7	20.8	19.0	25.5	41.0	37.3
Redtop	3.7	20.3	5.5	7.7	14.5	11.7	0.0	20.8	30.7	25.7	28.5	28.7
Tall fescue	0.0	0.0	0.0	0.0	0.0	0.0	5.4	13.4	2.5	0.0	0.0	1.0
Introduced grasses	3.7	20.3	5.5	7.7	14.5	11.7	5.4	34.2	33.2	25.7	28.5	29.7
Forbs												
Dogbane	1.5	2.6	1.5	5.2	1.2	1.0	0.2	0.5	1.0	1.0	0.6	1.9
Silverweed cinquefoil	0.8	0.4	1.5	1.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carruth's sagewort	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spearleaf rabbitbrush	0.0	0.2	2.5	2.0	2.2	0.7	21.2	15.3	21.7	37.1	21.6	8.0
Canadian horseweed	0.2	0.7	0.0	2.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Field horsetail	0.2	0.1	10.4	3.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Smooth scouringrush	1.0	3.6	1.4	1.6	1.2	1.2	0.0	0.0	0.1	0.0	0.0	0.0
Wild licorice	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Mountain sneezeweed	0.0	0.2	0.2	0.6	0.8	0.6	0.0	0.0	0.1	0.1	0.1	0.0
New Mexico giant hyssop	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.5	2.1	0.0
Wild mint	0.3	0.0	0.1	0.4	0.3	0.1	0.0	0.0	1.0	1.1	0.2	0.4
Hooker's evening primrose	0.0	0.3	0.0	2.1	0.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Norwegian cinquefoil	0.7	0.0	0.6	0.7	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Cottonbatting cudweed	0.0	0.9	0.6	1.0	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0
White-panicle aster	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Geyer's aster	0.0	0.0	0.2	0.3	0.8	1.0	0.0	0.1	0.2	0.0	0.2	0.2
Swamp milkweed	0.0	0.0	0.1	0.1	0.4	0.4	0.0	0.0	0.3	0.2	0.7	1.2
Fringed willowherb	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Woodbine	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Spotted water hemlock	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2
Unknown forb	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Native forbs	4.6	9.5	19.3	21.1	9.1	6.8	21.7	15.9	24.9	40.1	25.7	11.9
Canada thistle	1.3	2.9	0.9	0.7	1.5	2.3	0.9	7.8	4.3	0.5	1.8	3.9
Bull thistle	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Prickly lettuce	0.0	0.1	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
White sweetclover	0.0	1.0	0.1	0.1	2.2	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Narrowleaf plantain	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Common plantain	0.0	0.0	0.9	0.6	6.3	8.6	0.0	0.0	0.0	0.0	0.0	0.0
Dandelion	0.0	0.3	0.1	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Red clover	0.1	0.2	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Field sowthistle	0.0	0.0	0.0	0.4	0.5	2.9	0.0	0.0	0.0	0.0	0.0	0.2
Curly dock	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Mullein	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Yellow sweetclover	0.0	0.0	0.0	0.2	4.8	2.3	0.0	0.0	0.0	0.0	0.0	0.0
Teasel	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Introduced forbs	1.4	7.4	2.3	2.3	15.5	18.7	0.9	7.8	4.3	0.7	1.8	4.1
Total vegetative cover	15.4	50.3	42.8	51.1	65.9	61.3	50.8	78.7	81.5	92.0	97.0	83.0
Basal area of shrubs	9.2	7.7	14.5	10.0	4.7	2.5	11.9	7.5	10.7	1.5	0.0	1.0
Litter	49.7	42.0	25.6	27.0	29.3	32.6	32.3	13.3	7.3	6.0	3.0	14.5
Bare	25.7	0.0	17.1	11.9	0.1	3.6	5.0	0.5	0.5	0.5	0.0	1.5
Total herbaceous cover	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Appendix E

Photo Stations
June 2006 through October 2011

Site 1 - Treatment Transects

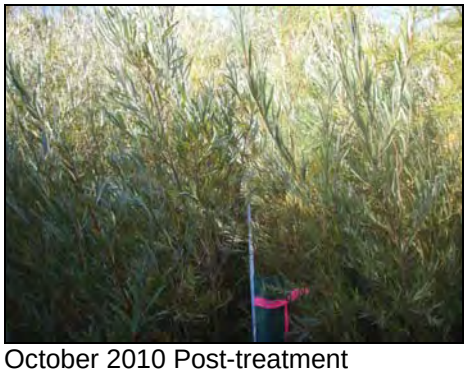
1A

June 2006 Pre-treatment

October 2007 Post-treatment

October 2008 Post-treatment

October 2009 Post-treatment


October 2010 Post-treatment

October 2011 Post-treatment

1B

June 2006 Pre-treatment

October 2007 Post-treatment

October 2008 Post-treatment

October 2009 Post-treatment

October 2010 Post-treatment

October 2011 Post-treatment

4A

June 2006 Pre-treatment

October 2007 Pre-treatment

October 2008 Post-treatment

October 2009 Post-treatment

October 2010 Post-treatment

October 2011 Post-treatment

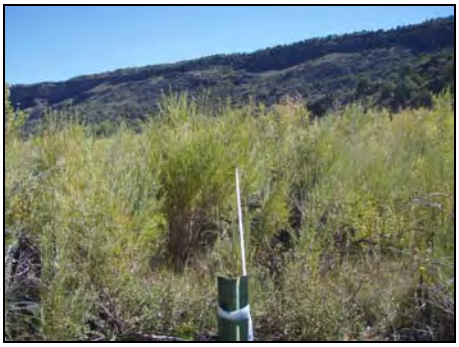
4B

June 2006 Pre-treatment

October 2007 Pre-treatment

October 2008 Post-treatment

October 2009 Post-treatment


October 2010 Post-treatment

October 2011 Post-treatment

Site 1 - Reference Transects

2A

June 2006

October 2007

October 2008

October 2009

October 2010

October 2011

2B

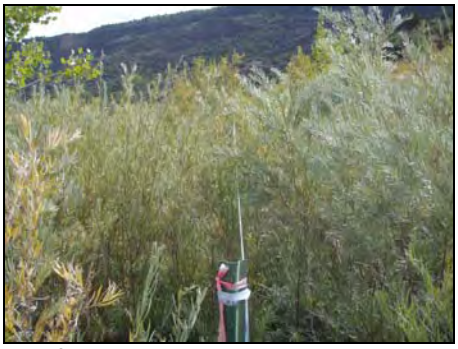
June 2006

October 2007

October 2008

October 2009

October 2010


October 2011

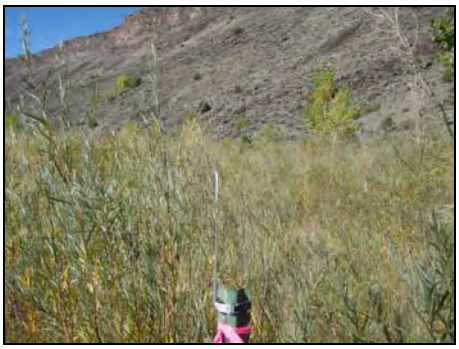
3A

June 2006

October 2007

October 2008

October 2009


October 2010

October 2011

3B

June 2006

October 2007

October 2008

October 2009

October 2010

October 2011

Site 2 – Reference Transects

1A

June 2006

October 2007

October 2008

October 2009

October 2010

October 2011

1B

June 2006

October 2007

October 2008

October 2009

October 2010

October 2011

2A

June 2006

October 2007

October 2008

October 2009

October 2010

October 2011

2B

June 2006

October 2007

October 2008

October 2009

October 2010

October 2011

Site 3 – Treatment Transects

2A

June 2006 Pre-treatment

October 2007 Pre-treatment

October 2008 Post-treatment

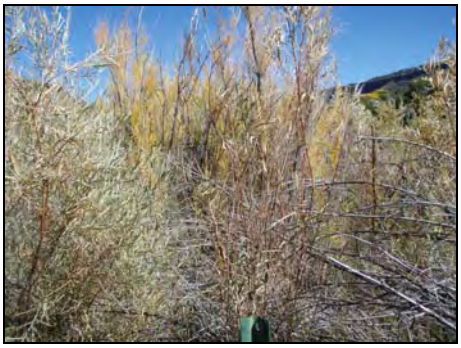
October 2009 Post-treatment

October 2010 Post-treatment

October 2011 Post-treatment

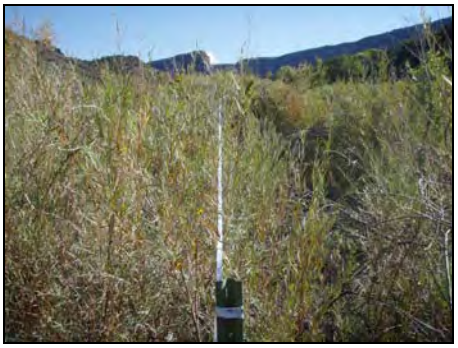
2B

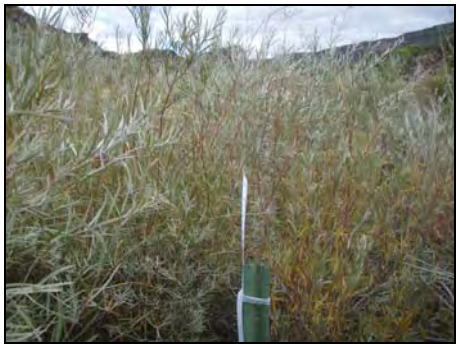
June 2006 Pre-treatment


October 2007 Pre-treatment

October 2008 Post-treatment

October 2009 Post-treatment


October 2010 Post-treatment


October 2011 Post-treatment

4A

June 2006 Pre-treatment

October 2007 Pre-treatment

October 2008 Post-treatment

October 2009 Post-treatment

October 2010 Post-treatment

October 2011 Post-treatment

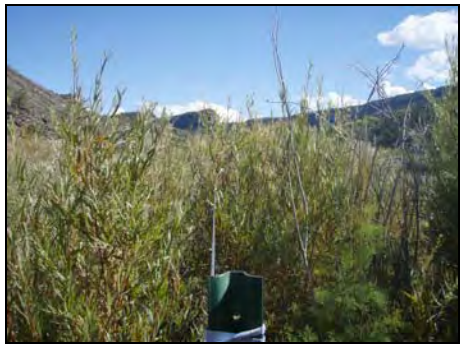
4B

June 2006 Pre-treatment

October 2007 Pre-treatment

October 2008 Post-treatment

October 2009 Post-treatment

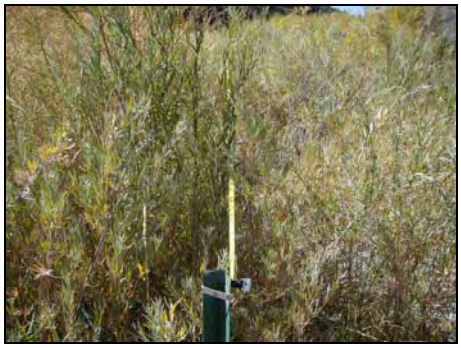

October 2010 Post-treatment

October 2011 Post-treatment

Site 3 – Reference Transects

1A

June 2006


October 2007

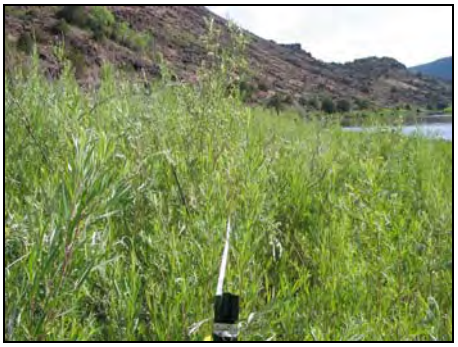
October 2008

October 2009

October 2010

October 2011

1B


June 2006

October 2007

October 2008

October 2009

October 2010

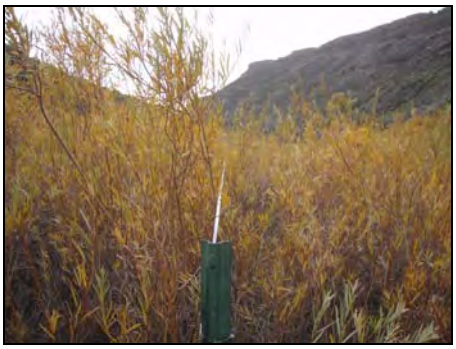
October 2011

3A

June 2006

October 2007

October 2008


October 2009

October 2010

October 2011

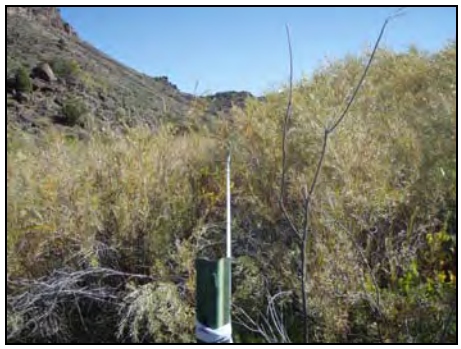
3B

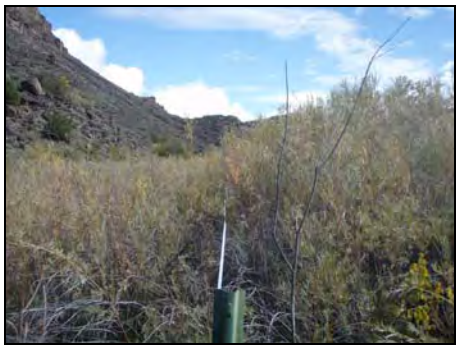
June 2006

October 2007

October 2008

October 2009


October 2010


October 2011

Site 4 – Reference Transects

1A

June 2006

October 2007

October 2008

October 2009

October 2010

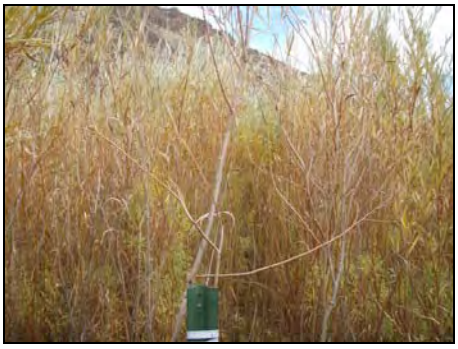
October 2011

1B

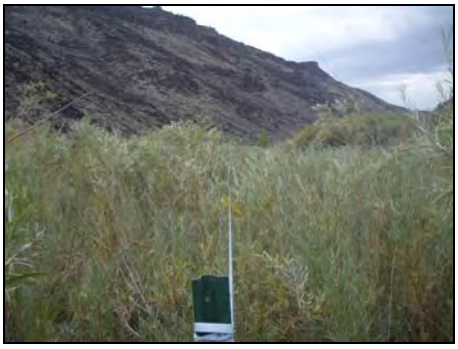
June 2006

October 2007

October 2008


October 2009

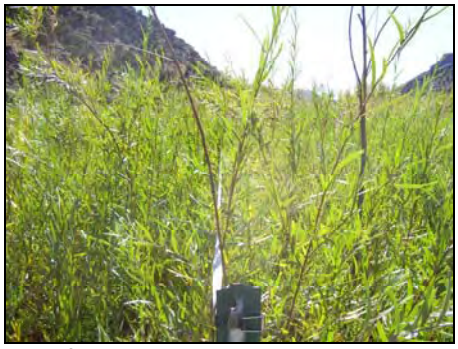
October 2010


October 2011

2A

June 2006

October 2007


October 2008

October 2009

October 2010

October 2011

2B

June 2006

October 2007

October 2008

October 2009

October 2010

October 2011

Site 5 – Treatment Transects

1A

August 2008 Pre-treatment

August 2009 Pre-treatment

October 2009 Post-treatment

October 2010 Post-treatment

October 2011 Post-treatment

1B

August 2008 Pre-treatment

August 2009 Pre-treatment

October 2009 Post-treatment

October 2010 Post-treatment

October 2011 Post-treatment

2A

August 2008 Pre-treatment

August 2009 Pre-treatment

October 2009 Post-treatment

October 2010 Post-treatment

October 2011 Post-treatment

2B

October 2008 Pre-treatment

October 2009 Pre-treatment

October 2009 Post-treatment

October 2010 Post-treatment

October 2011 Post-treatment

Photo Stations

Photo Station 1 – upstream

June 2006

October 2007

October 2008

October 2009

October 2010

October 2011

Photo Station 1 – downstream

June 2006

October 2007

October 2008

October 2009

October 2010

October 2011

Photo Station 2

June 2006

October 2007

October 2008

October 2009

October 2010

October 2011

Photo Station 3

June 2006

October 2007

October 2008

October 2009

October 2010

October 2011

Photo Station 4 – upstream

June 2006

October 2007

October 2008

October 2009

October 2010

October 2011

Photo Station 4 – across

June 2006

October 2007

October 2008

October 2009

October 2010

October 2011

Photo Station 4 – downstream

June 2006

October 2007

October 2008

October 2009

October 2010

October 2011

Photo Station 5-1

August 2008

August 2009 Pre-treatment

October 2009 Post-treatment

October 2010

October 2011

Photo Station 5-2

August 2008

August 2009 Pre-treatment

October 2009 Post-treatment

October 2010

October 2011