Final Report: Monitoring Saltcedar (*Tamarix*) Biological Control (*Diorhabda carinulata*) Insectary Establishment in Dinosaur National Monument 2005 - 2010

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INTRODUCTION

The non-native invasive shrub, saltcedar (tamarisk, *Tamarix* sp.) is one of the most significant threats to aquatic and riparian ecosystems in the arid western U.S. Adverse impacts have been extensively documented over the last 40 years, including impacts on recreation, surface waters, groundwater, fire regimes, hydrology, fluvial geomorphic processes, soils, biodiversity, native plant communities, aquatic and terrestrial wildlife habitat and agricultural resources. Several agencies (USDI-BOR and USDA-ARS among them) have cooperated in field evaluation of biological control of saltcedar since 1999, using a host-specific leaf beetle (*Diorhabda carinulata*, formerly *D. elongata*) in several western states. In early 2004 the Colorado Department of Agriculture issued a call for proposed insectary sites. These sites would receive the initial releases of *D. carinulata* and would serve as future collection sites for re-distribution of the beetles. The sites chosen as appropriate for these initial releases were in Adams County, Bonny Lake State Park, Horsethief Canyon, and Echo Park in Dinosaur National Monument. In late July 2005 the USDA was granted a permit to establish several insectary sites in each of 13 western states, including the four sites selected in Colorado.

As part of the release permit release sites were required to establish a monitoring plan that would, at a minimum, document the establishment and spread of the beetle, monitor tamarisk defoliation, size and mortality, and measure any changes in the surrounding plant community (USDA-APHIS 2005). We also developed additional monitoring protocols in cooperation with Dinosaur National Monument. Monitoring was to have been performed on an at least annual basis for 5 years following release.

This research project was initiated to establish a monitoring program for *D. carinulata* releases in Dinosaur National Monument. The study began in August 2005 to collect baseline data prior *D. carinulata* release at the Echo Park site in May 2006, and concluded in September 2011. This project has focused on more detailed estimates of *D. carinulata* densities, defoliation levels, tree die-back and impacts on surrounding vegetation at one of the initial release sites. In addition to the work reported here, the National Park Service initiated an additional monitoring program in 2008. That effort focused on patterns of *D. carinulata* spread and defoliation throughout the entire river corridor within the Monument (Williams 2011).

METHODS

Site Description

Echo Park, Dinosaur National Monument, is at the junction of the Yampa River (the last major free-flowing tributary of the Colorado River) and the Green River, which is regulated upstream by Flaming Gorge Reservoir. Fremont cottonwood (*P. deltoides* ssp. *wislizenii*), coyote willow (*Salix exigua*), and boxelder (*Acer negundo*) are native woody species that co-occur with saltcedar at this site. Two releases of 5,000 *D. carinulata* adults were made in late May 2006. These releases were made at the confluence of the rivers (at Green River mile 225), and approximately 0.5 km below the Echo Park boat launch. 4 weeks later a second release of 4,000 beetles was made adjacent to the boat launch. In the spring of 2007 we made two additional releases: the first at river mile 236.5 below Lower Disaster Falls (10,000 adults) and a second (30,000 adults) at mile 226.3. All releases were made in dense, vigorously growing stands of *Tamarix*.

Top: National Park Service personnel release *D. carinulata* in May, 2006 at the Echo Park release.

Bottom: National Park Service and Colorado Department of Agriculture personnel release beetles near Lower Disaster Falls, May, 2007.

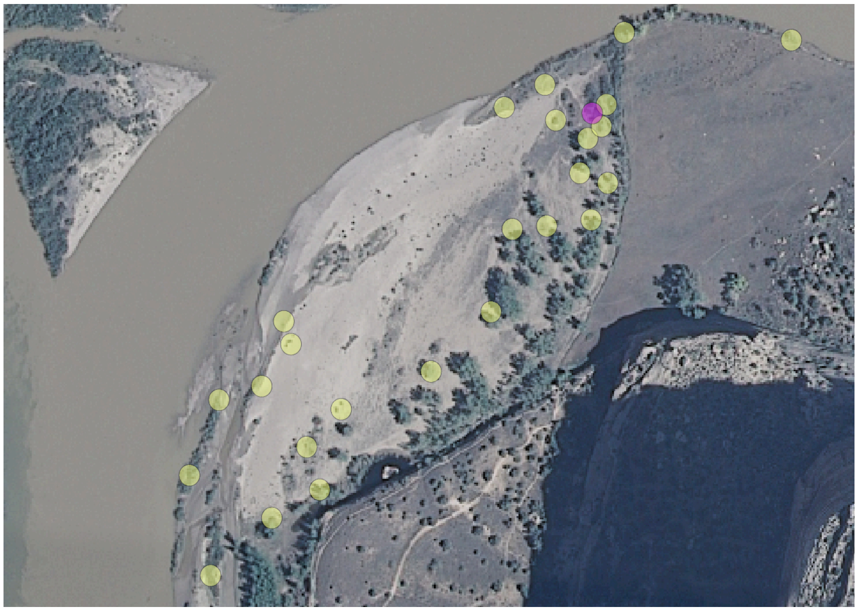


Figure 1: Aerial image of the study site. The monitoring trees are indicated by yellow circles. Release point is in pink. Image courtesy USGS National Map Seamless Server. URL: http://seamless.usgs.gov/index.php

Selection and assessment of Tamarix

On August 10, 2005, prior to the release of *D. carinulata*, we selected and tagged 25 tamarisk trees at the confluence release site and determined the initial size and condition of the trees (see Figure 1 for tree locations and Appendix 1 for GPS coordinates). Baseline assessment of selected study trees included measurements of height of the tallest green shoot, maximum width (green shoot to green shoot) and width perpendicular to maximum. Additionally, in each year subsequent to releasing *D. carinulata* tree health and reproductive condition were assessed every two weeks throughout the growing season. Tree health and condition were assessed by making visual estimates of the percent of the tree with green, senescent yellow, or dead foliage, as well as the percent of the tree consisting of dead wood. Yellow foliage includes damage by the non-native leafhopper *Opsius stactogallus*. The reproductive status of each tree was also documented. Reproductive status was indicated by the presence or absence of flower buds, open flowers, and/or seeds. Photographs were taken of each tree to document its initial size and condition prior to the establishment of and defoliation by leaf beetles. Photographs were taken again in 2010 to illustrate the impact of *D. carinulata* on the study trees.

Diorhabda carinulata density

The presence and status of *D. carinulata* were monitored every two weeks, beginning in June 2006. The number of eggs and egg masses, 1st, 2nd, and 3rd instar larvae and adult beetles were recorded for each marked tree. We used two methods for determining *D. carinulata* abundance on the trees. First, we made a detailed count of all *D. carinulata* found on a random sample of 12 shoots from each tree. Four green shoots were randomly selected in each quadrant of the tree on each sampling date, the length measured and the number of eggs, 1st, 2nd, 3rd and adult instars were recorded. This measurement provides an accurate assessment of beetle densities per unit foliage length at the site, but we soon discovered that this precision left us unable to detect low numbers of beetles. To address this low sensitivity, we also used a 2-minute visual search of each marked tree and recorded the number and life stage of all *D. carinulata* as above. Two observers made such counts for each sample, and the mean value for *D. carinulata* was recorded. Adjacent trees were also examined and any beetle life stage(s) present were recorded. In late August 2006 and early September 2007 we also surveyed the Echo Park area by walking from Mitten Park to approximately 2.5 miles up the Yampa River from the confluence to look for the presence of *D. carinulata* or *D. carinulata* feeding damage.

Understory vegetation

We performed annual assessments of the composition and diversity of vegetation associated with the study trees in two 1m x 1m plots underneath each marked tree. The percent cover of bare soil, litter and each individual plant species were recorded within each plot. In addition to monitoring herbaceous understory vegetation we also noted potential changes in woody vegetation. The number of stems and percent cover of young woody plants ≤ 1m in height occurring in the understory plots were also recorded in order to track the potential replacement of tamarisk by native woody species.

Arthropods associated with Tamarix and other woody species

Arthropods are important food sources in terrestrial and aquatic food webs, and understanding what influences patterns of diversity and abundance of these species is essential for developing informed management practices in natural systems. Of particular importance is determining what impact non-native species such as tamarisk have on arthropod abundance and diversity, and what impact control strategies for tamarisk (such as biological control) have on arthropod abundance and food web structure.

Beginning in 2008 we used a beat sampling technique to quantify the abundance and diversity of arthropods associated with tamarisk, cottonwood and willow. On each monitoring date we sampled arthropods from each of 10 trees of each species. Since tamarisk blooms for an extended period and could attract arthropods not associated with the flowers of cottonwood or willow, we did not sample flowering branches. We collected the arthropods by haphazardly selecting a branch from 1 tree, enclosing the terminal 37 cm of the end into a specially designed plastic box and knocking it vigorously to dislodge insects. The combined arthropods were then funneled into a vial of 70% ethanol. Samples were returned to CSU for identification and quantification. We used the program EstimateS (Colwell 2005) to perform sample- and individual based rarefaction. This technique re-samples the data set and estimates the number of species found as a function of either the number of samples or individuals collected. This enables us to determine if we are nearing a saturation point (we have found nearly all species that are present) or if we have only found a portion of species present in the system.

Results

Diorhabda population estimates

a) Population trends through time: The first release of 5,000 *D. carinulata* was made at the Echo Park study site on May 24, 2006. Surprisingly, in subsequent visits that year we did not find a single adult, egg or larva on the release or adjacent trees. However, we did recover small to moderate numbers of adults and larvae on 9 of the 25 marked release trees. *D. carinulata* densities were low in the year of release, with the average number of beetles found per tree, all stages and over all sample dates = 1.3, and the maximum found per tree = 132, both estimated from the timed censuses (Figure 2). Almost all beetles were found on marked trees approximately 300 meters down river from the release site.

Defoliated *Tamarix*, September 2007. Top: Mitten Park, approximately 1 mile below the lower Echo Park release site. Bottom: just upriver from Echo Park release.

In 2007, beetles appeared on the same 8 trees that we had found them on the previous year but at substantially higher numbers. Marked trees held an average 10.13 beetles over all sample dates for the season. In September 2007 NPS personnel reported large populations of *D. carinulata* at several sites

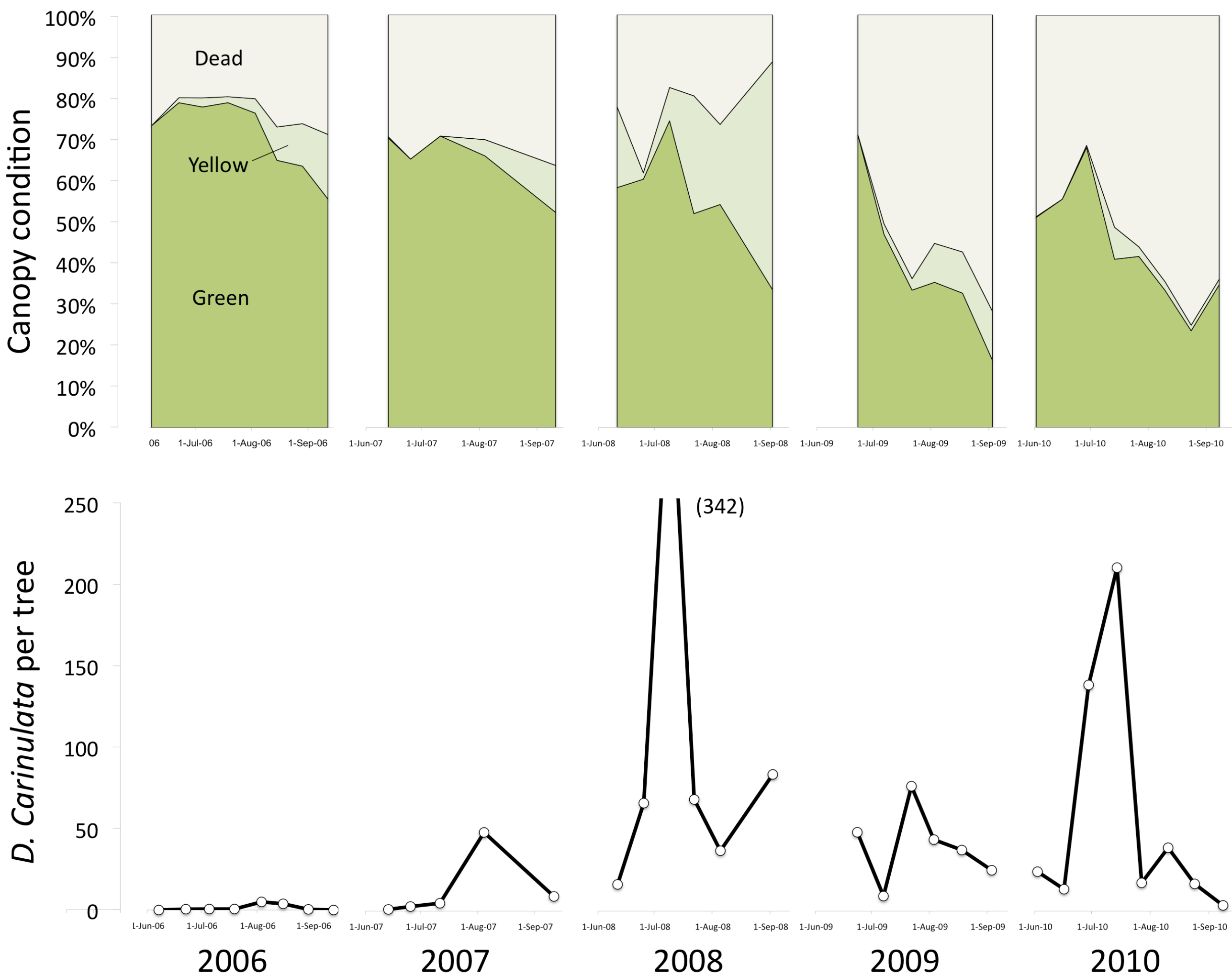


Figure 2: Canopy health and *D. carinulata* abundance from timed counts through time. Yellow foliage includes both *Opsius* damage and foliage newly damaged by *D. carinulata*. Change in canopy condition does not include overall change in tree volume.

along the river (see Williams 2011 for details). On September 3, we performed a walking survey of the Yampa and Green rivers from Box Elder Park, 2 miles up river from the confluence release site to Mitten Park at river mile 223, 1 mile down river from one of the 2006 release sites. Within this 4 mile stretch there were several areas of extensive defoliation and populations of beetles were present, though scattered, throughout this section of the rivers.

In 2008 *D. carinulata* populations were much larger than in 2007. By the end of the season all marked trees contained beetles. We observed a season average of 91.4 beetles per tree with the peak population density of 342 beetles per tree on July 9. In 2009 and

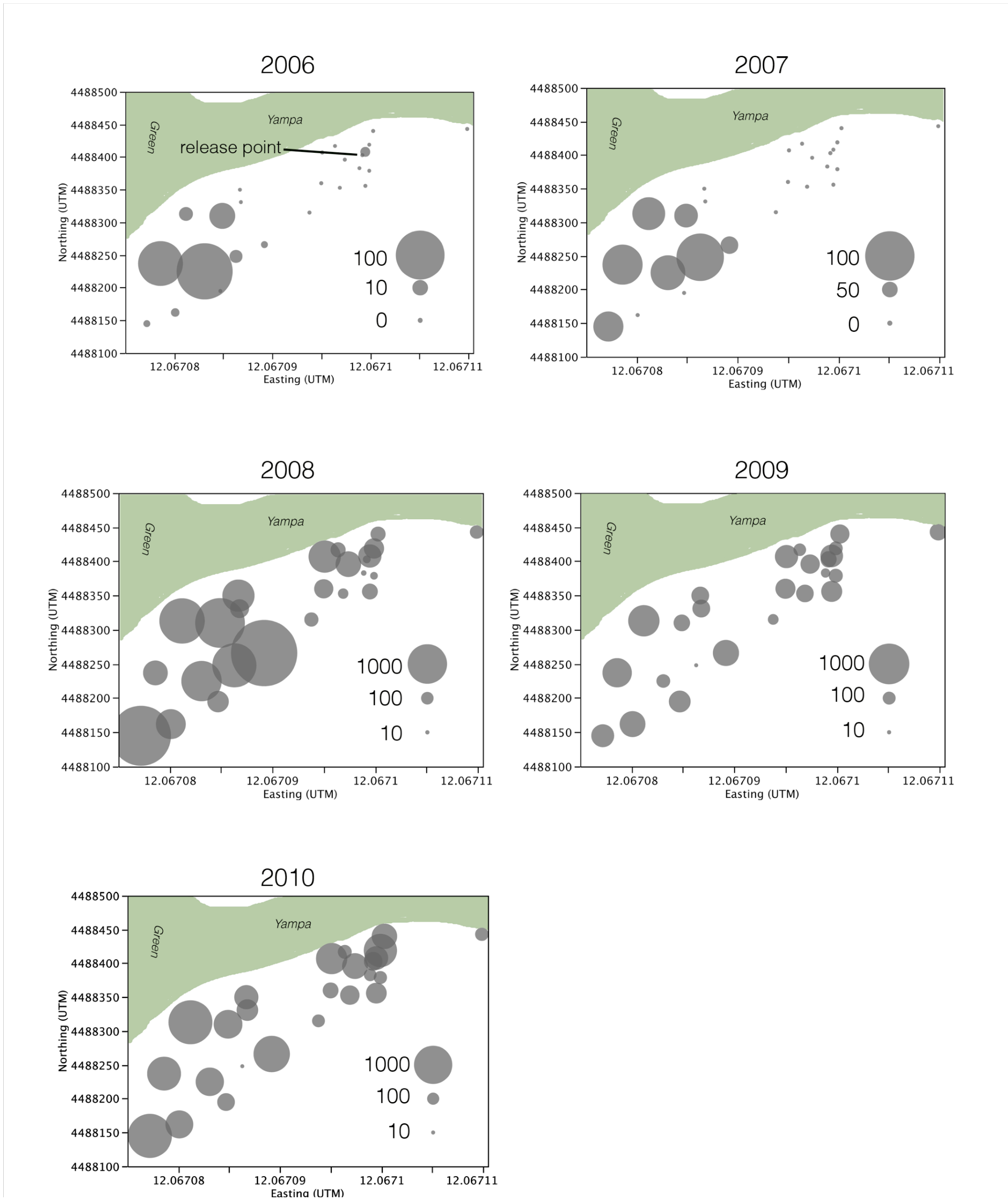


Figure 3: Abundance of *D. carinulata* on focal trees, 2006 – 2010. Each point represents a study tree, and the size of the point is proportional to the season total number of beetles found. Beetles first appeared 300 meters down river from the release site. These trees were on average healthier than un-colonized trees. By the end of 2008 all trees had been colonized.

2010 beetles were again found on all marked trees with season average densities of 40.5 and 68.9, respectively. In 2011 we were only able to visit the site once, on July 19. At this time there were an average of 20.8 beetles per tree. This is lower than the numbers found in mid July the previous 3 years.

There appears to have been a boom-bust pattern of *D. carinulata* densities from 2008 – 2011 where very large populations in one year were followed by lower populations in the next. This could be driven by over-exploitation of the trees at high densities, followed by migration of the second-generation adults to non-defoliated trees. It is also possible that this is driven by weather differences between years, or it could be random population fluctuations.

b) Patterns within the site: In the first two years after release *D. carinulata* were only found on 10 of the 25 marked trees (Figure 3). In both these years adults and larvae appeared on trees that were down river from the release site and tended to be isolated from other tamarisk. Tree health may also have influenced this: There was a significant relationship between beetle density and the proportion of a tree's canopy that was green in the first year of our survey (before *D. carinulata* had had any effect on the trees). On average 78% of the tree canopy was green for trees with *D. carinulata* compared to 66% for those without ($P > 0.005$). However, by the end of 2008 (when populations were an order of magnitude greater than in 2007) *D. carinulata* densities were essentially randomly or evenly distributed across all marked trees.

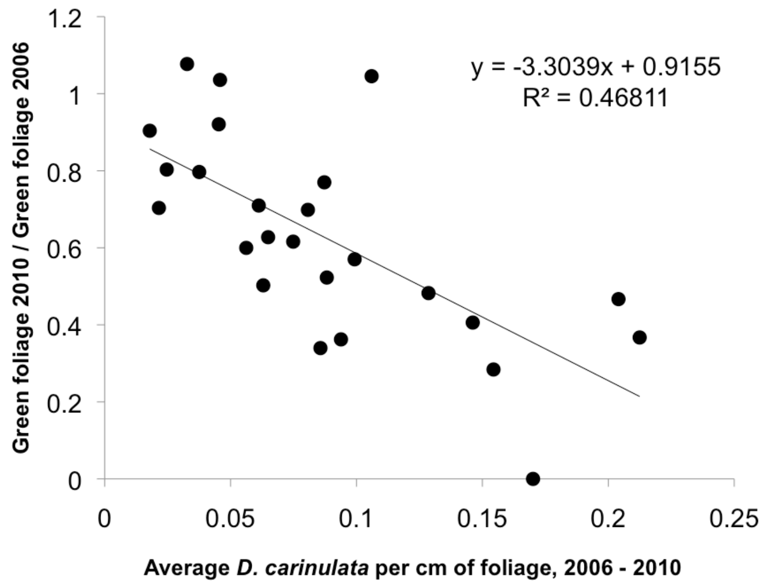


Figure 4. Relationship between average *D. carinulata* density over 5 years and the relative change in the amount of green foliage. Trees with more beetles had a greater reduction in health.

Defoliation levels

Increasing populations of the beetles resulted in a decrease in the amount of tree canopy classified as green, both within a season and between seasons (Figure 2). By the end of 2008

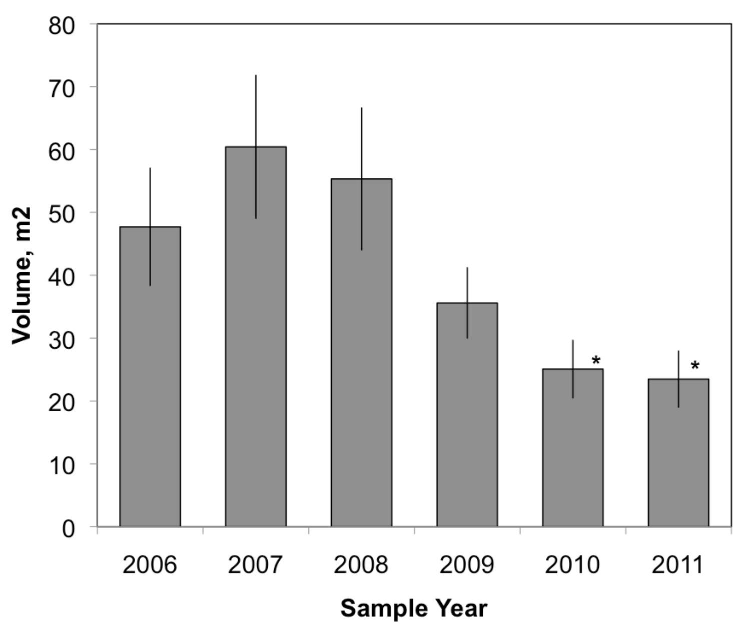


Figure 5. Change in tree volume through time. Average volume was significantly smaller in 2010 and 2011 than in 2006.

marked trees retained on average only 30% green and healthy foliage by the end of August. Similar levels were also seen in 2009 and 2010. Starting in 2009, early estimates of tree health taken at the end of May or the beginning of June (before beetles became abundant) showed that trees were starting the season with a smaller live canopy than they had for the seasons 2006 – 2008. There was a significant negative relationship between the average number of *D. carinulata* found on a tree over all years, and the change in the amount of foliage that was classified as green from 2006 to 2010 ($P < 0.0002$, Figure 4).

Tree Size

Each year in July we measured the total volume of the focal trees. Trees increased in volume between 2006 and 2007, but thereafter began to decrease in size. By 2011, trees were on average 51% smaller than when we began measuring them (Figure 5). Because our measurements were from edge to edge of the canopy this estimate of tree size does not take into account that a substantial portion of the canopy was no longer living – on average 60% at the beginning of the 2010 season. When these data are combined tree canopies were on average ca. 40% of their initial values. As with measures of tree health, there was a significant relationship between average number of *D. carinulata* and greater reductions in size from 2006 – 2011.

Photographs of the study trees were taken in 2006, prior to any defoliation by beetles, and again in 2010. The photos in the Appendix illustrate changes in tree size (volume of foliage) and condition due to the impact of feeding by *D. carinulata* over 4 years. In contrast, the trees at other release sites where *D. carinulata* has not established continue to increase in size through time.

Understory vegetation

By 2010, understory species richness and percent cover had both increased (Table 2). While the total percent cover of understory vegetation has fluctuated year-to-year at this site, total species richness has continued to increase for both native and exotic species. In 2006 we identified 21 taxa (ultimately identified to at least the genus level) in the understory, and by 2010 the accumulated number of taxa recorded in

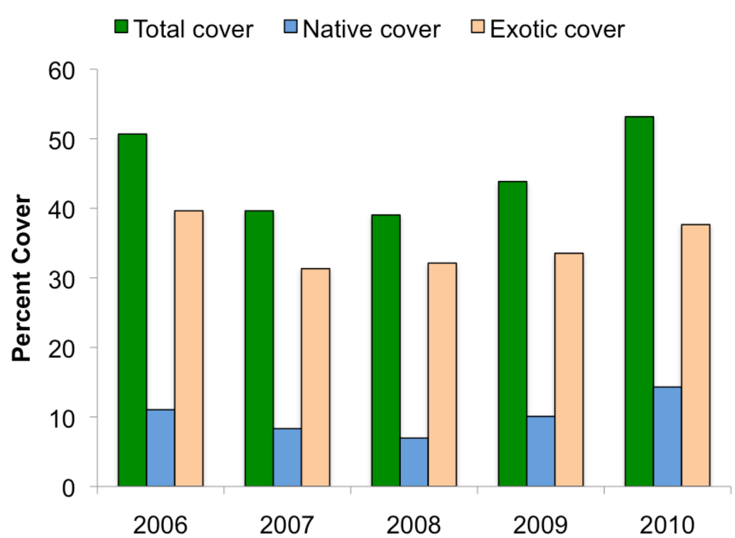
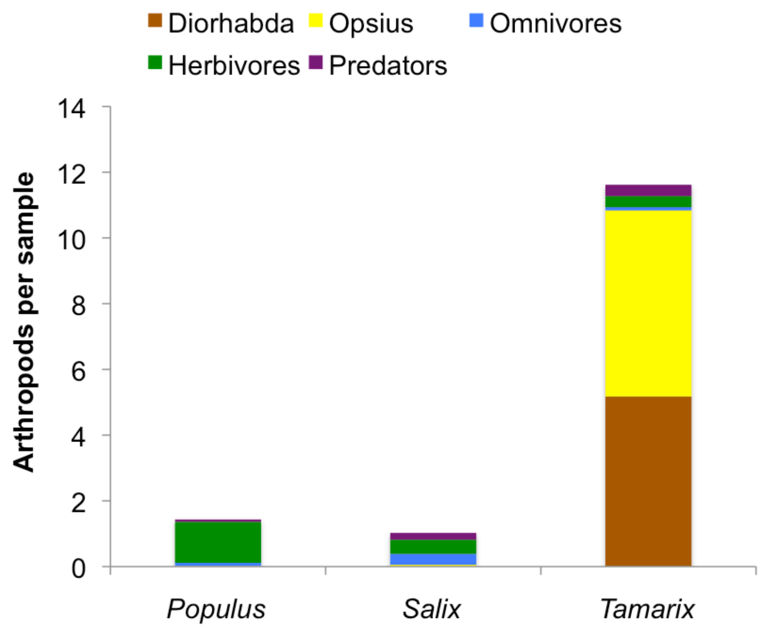


Figure 6: Percent cover of understory vegetation, 2006 – 2010.

plots under the study trees had increased to 48. The changes in plant community structure observed thus far are likely the result of year-to-year variation in temperature, precipitation regimes, overbank flows or successional dynamics within the plant community.

There is widespread concern that, as tamarisk is removed from riparian areas, other exotic weed species might take its place. The Echo Park study site is dominated by native plant species and species both native and exotic in origin tended to appear and disappear between years, perhaps due in part to propagule deposition from sources upriver and/or scouring by flood pulses and runoff. The most pervasive exotic species is cheatgrass (*Bromus tectorum*), which (depending on the year) occurred in 34-41 of 50 plots. Other exotic weeds of potential concern are Russian knapweed (*Acroptilon repens*, occurring in 6-13 plots) and perennial pepperweed (*Lepidium latifolium*, occurring in from 1 to 8 plots). However, while the occurrences and percent cover of exotic species varied from year to year we noted no marked increase in dominance of exotics over the 5 years of monitoring.



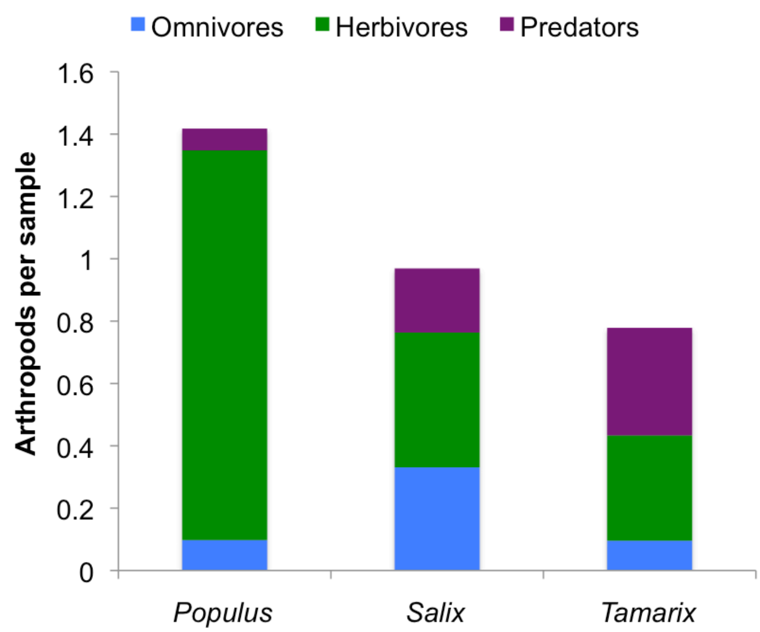


Figure 7a (top): Abundance of arthropods by feeding guild on *Populus*, *Salix* and *Tamarix*. Data are averaged over 2008 – 2010 samples.

Figure 7b (bottom): Same as in 6a, but with *D. carinulata* and *Opsius* removed from the analysis.

Percent cover of native species appears to be responding in the same manner and rate as for exotic species (Figure 6). These data indicate that so far there is no evidence that exotic, weedy vegetation is responding to the additional light and water available post- *D. carinulata* defoliation by excluding native species. So far at least, concerns that other noxious species will replace *Tamarix* if *D. carinulata* reduces the density of this species appear to be unfounded. However, it is still early in the process and as *D. carinulata* continues to reduce *Tamarix* tree size other weedy vegetation could take advantage of this space.

In 2011, near-record runoff inundated the study site, and nearly all trees were in running water for a period of at least three weeks. Floodwaters were strong enough to uproot one of the focal trees. Understory vegetation had a predictable response: two weeks after flood waters had receded percent vegetation cover under the study trees was very nearly 0%. Within the 50 1 m x 1 m plots examined we discovered only a few seedlings. Outside of plots the most common seedlings discovered were *Populus*. Disturbances like this are a common, and natural part of unregulated riparian systems. This highlights that excessive concern with re-vegetation or weed succession within the riparian corridor of unregulated rivers is likely misguided.

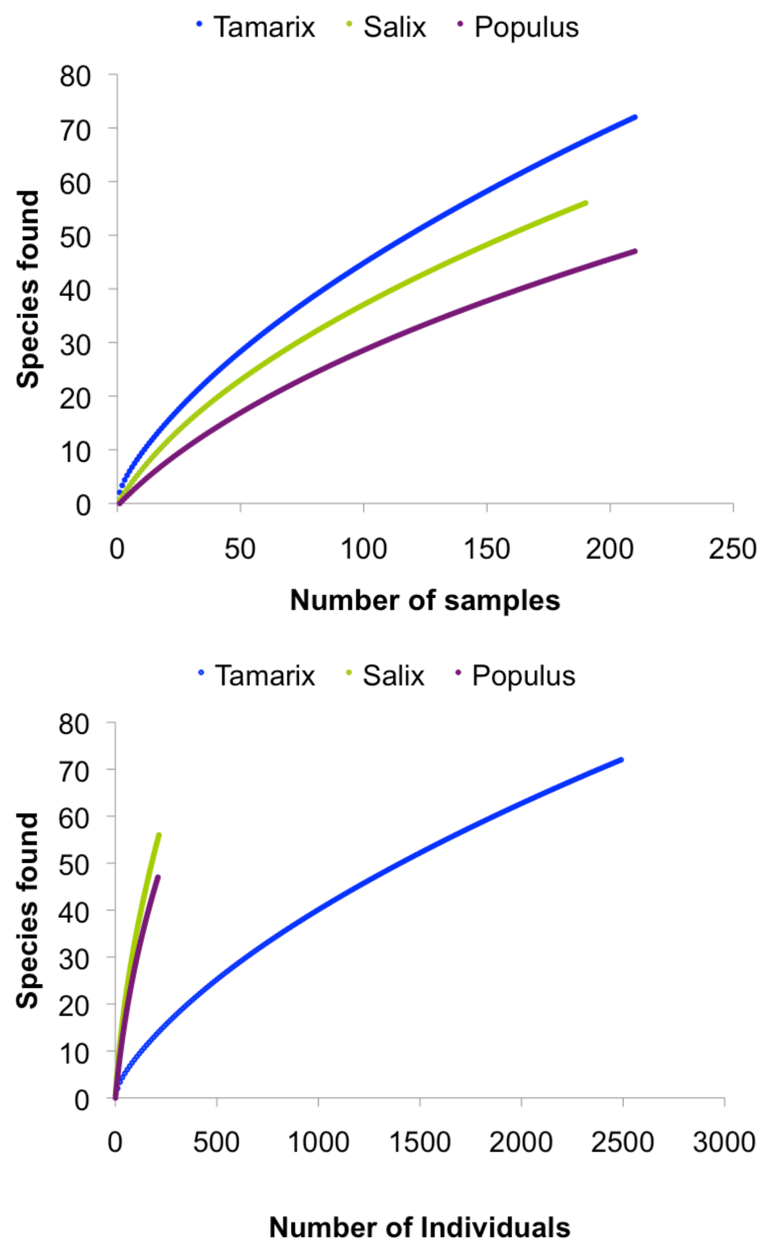


Figure 8a (top): Sampled-based rarefaction curves for the study species. A rarefaction curve estimates the number of species that would be found for a given sampling effort, and steeper slopes indicate greater diversity.

Figure 8b (bottom): Individual-based rarefaction curves estimate the number of species that would be found for a given number of individuals collected. *Tamarix* has much lower diversity than the other two species because the majority of individuals are either *Diorhabda* or *Opsius*.

Other arthropods on *Tamarix Populus* and *Salix*

Samples were collected during biweekly monitoring visits to the Echo Park study site from 2008 through 2010. *D. carinulata* has not been observed feeding on any of the plant species at the site other than on *Tamarix* and our samples are consistent with this.

On average we found more arthropods per sample on tamarisk (11.6) than on willow (1.02) or cottonwood (1.4) (Figure 7a). This was also true when examining only plant-feeding species (average per sample = 11.2, 0.5 and 1.3 for tamarisk, willow and cottonwood, respectively). However, the majority of the difference in herbivore abundance per sample between tamarisk and the other tree species is due to high densities of two arthropod species found only on tamarisk: The biological control agent *D. carinulata* and the exotic tamarisk specialist leafhopper *Opsius stactogalus*. Together, these two arthropods contributed nearly 93% of the arthropods on *Tamarix*. If these exotic arthropods are excluded, then *Populus* held more arthropods than *Salix* than *Tamarix* (Figure 7b), consistent with the notion that exotic plant species have fewer arthropods feeding on them than native plant species. There is perhaps some indication that higher numbers of arthropods on *Tamarix* resulted in a greater abundance of predatory taxa than would be expected (there are more predatory arthropods on *Tamarix* than on *Populus* or *Salix*, despite there being fewer herbivores), but this effect, if any, is slight.

Diversity: Tamarix held more species (72) than either *Populus* (47) or *Salix* (56) (Figure 8a) Sample-based rarefaction indicates that there is a slight trend for *Tamarix* to exhibit greater diversity (a steeper number of species per sample curve) than either *Salix* or *Populus*. This curve estimates the number of species that would be found for a given amount of sample effort. In contrast to this, individual-based rarefaction (Figure 8b) indicates that *Populus* and *Salix* hold substantially more diverse arthropod assemblages than *Tamarix*. The overwhelming number of *Diorhabda* and *Opsius* found in the sample greatly reduces diversity on *Tamarix*.

Summary

Diorhabda carinulata readily established in Dinosaur National Monument, spread rapidly and reached populations capable of defoliating the majority of *Tamarix* at the release site within 2 years. Other surveys (Williams 2011) found established populations of beetles miles from the initial release site 1 year after the Echo Park release. These populations may have arisen from either the 2006 Echo Park release or the 2007 Lower Disaster Falls or Lower Lodore releases. This rapid establishment and spread has been seen at other west-slope sites but has not occurred at releases east of the Continental Divide. Although populations of the beetle are now established at several Arkansas Valley sites we have not seen the explosive growth and spread of the beetles that we have in Dinosaur or along the Colorado River.

15 months after the first releases substantial late-season defoliation of *Tamarix* occurred

at the release site and at several locations up and down river. Initially, beetles colonized and defoliated the healthiest trees at the release site. By the end of 2008 however, all marked monitoring trees were colonized and at least partially defoliated. By the end of 2010 there were extensive areas of defoliated *Tamarix* throughout the monument. Williams (2011) observed that initial populations of the beetles appear on shorter, isolated *Tamarix* growing in the absence of understory vegetation. We found this same pattern at the Echo Park release and add that these trees were, on average, greener and healthier (less of the tree was categorized as "dead wood") than the un-colonized trees at the same site. *Diorhabda* spp. use a combination of plant-produced volatile compounds from damaged trees and a male-produced aggregation pheromone to locate mates (Cosse et al. 2005, 2006). Adult beetles produce dense aggregations on trees and are not evenly distributed throughout a stand. A preference for greener trees could result from these trees producing a greater amount of volatile compounds than stressed trees. Alternatively, beetles may cue in on isolated trees more readily than trees within a dense stand of *Tamarix*.

Repeated bouts of defoliation have reduced both the volume of living trees at the release site and the proportion of each tree that is living. We found a strong correlation between both the number of beetle larvae found on each tree and the amount of defoliation, and between the amount of defoliation and the reduction in tree size and health over the 4 years of monitoring. On average, trees are now less than ½ of their initial volume and start each season with a smaller proportion of healthy canopy. As of 2011 only 1 tree out of 25 has died at the release site. We expect that repeated defoliation will continue to stress *Tamarix* throughout the Monument and gradually reduce the size, and thus the impact of the trees on the riparian system.

Understory vegetation may be responding to this defoliation. From 2007 – 2010 there was an increase in the percent cover of understory vegetation under focal trees. This can be seen in the images (see Appendix 2) of tree #101: In the 2010 image what looks to be green portion of *Tamarix* is actually a large *Chrysothamnus nauseosus* individual that has increased in size as the *Tamarix* has decreased. Although percent cover of understory vegetation was increasing, we saw no evidence that *Tamarix* defoliation was favoring exotic species over native species. This result is expected, but it is reassuring that *D. carinulata* does not appear to result in the shift from one exotic species (*Tamarix*) to another.

Extensive sampling of *Populus* and *Salix* at this and other sites found no examples of the biological control agent feeding on these non-target species. These results are entirely expected and further support the results of a large number of published host specificity studies (see DeLoach et al 2003 or Moran et al 2006 for examples). Our surveys also found that, absent the intentionally introduced *D. carinulata* or the unintentionally introduced exotic *Opsius*, *Tamarix* has lower overall arthropod abundance than either of the two native trees. Although arthropod species richness was similar for all species examined, the fauna of *Tamarix* is now dominated by the two exotic insects.

The *Tamarix* biological control program at Dinosaur National Monument has been phenomenally successful so far. *Diorhabda carinulata* has established, spread, and stressed *Tamarix* throughout the Monument and has resulted in smaller and less competitive trees. We expect that this pattern will continue for the foreseeable future and hope that our baseline data will be of greater use in subsequent years. Further, the NPS is to be commended for having the foresight to fund this and other studies documenting the impacts of this program, as few other agencies have found to the funds to do this.

References cited

Colwell RK. 2005. EstimateS: Statistical estimation of species richness and shared species from samples. Version 7.5. User's Guide and application published at: http://purl.oclc.org/estimates.

Cosse AA, Bartelt RJ, Zilkowski BW, Bean DW, Petroski RJ. 2005. The aggregation pheromone of *Diorhabda elongata*, a biological control agent of saltcedar (*Tamarix* spp.): Identification of two behaviorally active components. J Chem Ecol.: 31(3) 657-670.

Cosse AA, Bartelt RJ, Zilkowski BW et al. 2006. Behaviorally active green leaf volatiles for monitoring the leaf beetle, *Diorhabda elongata*, a biocontrol agent of saltcedar, *Tamarix* spp. J. Chem. Ecol. 32(12): 2695-2708.

DeLoach CJ, Lewis PA, Herr JC, Carruthers RI, Tracy JL, Johnson, J. 2003. Host specificity of the leaf beetle, *Diorhabda elongata deserticola* (Coleoptera : Chrysomelidae) from Asia, a biological control agent for saltcedars (*Tamarix* : Tamaricaceae) in the Western United States. Biological Control 127(2) 117-147.

Moran PJ, DeLoach CJ, Dudley TL et al. 2009. Open field host selection and behavior by tamarisk beetles (*Diorhabda* spp.) (Coleoptera: Chrysomelidae) in biological control of exotic saltcedars (*Tamarix* spp.) and risks to non-target athel (*T. aphylla*) and native *Frankenia* spp. Biological Control 50(3): 243-261

Williams PA. 2011. Dinosaur National Monument northern tamarisk beetle (*Diorhabda carinulata*) biological control project: 2006–2010. Dinosaur National Monument. Dinosaur, Colorado.

USDA-APHIS 2005. Program for biological control of saltcedar (*Tamarix* spp.) in 13 Western states: environmental assessment.

TABLE 1: **Tamarisk Study Tree Locations - Dinosaur National Monument**

		(WGS84 datum)	
Tree #	**UTM E**	**UTM N**	**Notes**
101	12.0670831	4488225	
102	12.0670801	4488162	
103	12.0670772	4488145	
104	12.0670786	4488237	
105	12.0670847	4488195	
106	12.0670863	4488248	
107	12.0670849	4488310	
108	12.0670892	4488266	
109	12.0670938	4488315	
110	12.0670868	4488331	
111	12.0670951	4488407	
112	12.0670974	4488396	
113	12.0670999	4488379	
114	12.0670989	4488383	
115	12.0670992	4488403	
116	12.0670999	4488419	
117	12.0670964	4488417	
118	12.0671099	4488443	
119	12.0671003	4488440	
120	12.0670995	4488356	
122	12.0670969	4488353	
123	12.0670950	4488360	
124	12.0670867	4488350	
125	12.0670812	4488313	
126	12.0670995	4488408	Release tree

APPENDIX:

Photographic Comparisons of Tamarisk Study Trees

Unless otherwise noted, photos were taken on August 29, 2006 and July 27, 2010.

Tree #101

2006

2010

Tree #102

2006

2010

<u>Tree #103</u>

2006

2010

<u>Tree #104</u>

2006

2010

Tree #105

2006

2010

Tree #106

2006

September 3, 2009

Tree #107

2006

2010

Tree #108

2006

2010

<u>Tree #109</u>

2006

2010

<u>Tree #110</u>

2006

2010

Tree #111

2006

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Tree #112

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Tree #113

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<u>Tree #114</u>

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Tree #115

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Tree #116

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Tree #117

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Tree #119

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<u>Tree #120</u>

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Tree #122

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Tree #123

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Tree #124

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Tree #125

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Tree #126

2006

2010

Table 2. Understory vegetation, 2006 – 2010. Incidence is the proportion of plots (out of 50) that contained the species.

		2006		2007		2008		2009		2010	
Species	**Native / Exotic**	**Incidence**	**% cover**	**Incidence**	**% cover**	**Incidence**	**% cover**	**Incidence**	**% cover**	**Incidence**	**% cover**
Acroptilon repens	E	0.12	3.48	0.16	2.94	0.26	3.62	0.20	*4.40*	0.25	6.23
Agropyron sp.	N?	0.06	1.62	0.08	0.44	0.00	0.00	0.02	0.80	0.00	0.00
Alyssum desertorum	E	0.04	0.08	0.36	1.14	0.34	0.99	0.06	0.10	0.41	1.30
Ambrosia sp.	N	0	0	0.00	0.00	0.02	0.04	0.00	0.00	0.00	0.00
Apocynum cannabinum	N	0.02	0.04	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Artemisia tridentata	N	0	0	0.00	0.00	0.00	0.00	0.02	0.02	*0.02*	*0.09*
Asclepias sp.	N	0	0	0.02	0.10	0.02	0.10	0.02	0.16	0.05	0.00
Astragalus geyori	N	0	0	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00
Bromus inermis	E	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bromus tectorum	E	0.78	35.6	0.94	26.76	0.68	24.76	0.82	28.80	0.93	29.70
Carduus nutans	E	0	0	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Chamaesyce serpyllifolia	N	0.02	0.02	0.00	0.00	0.08	0.08	0.08	0.05	0.00	0.00
Chenopodium album	E	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Chrysothamnus nauseosus	N	0.06	0.54	0.02	0.10	0.04	0.32	0.02	0.30	0.05	0.59
Conyza canadensis	N	0	0	0.06	0.06	0.12	0.40	0.14	0.33	0.07	0.32
Unk. Mustard	?	0	0	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Descurainia sp.	N?	0	0	0.04	0.04	0.02	0.02	0.02	0.00	0.00	0.00
Distichlis spicata	N	0.16	1.7	0.16	0.38	0.20	0.84	0.00	0.00	0.02	0.23
Elymus cinereus	N	0.02	0.14	0.02	0.30	0.02	0.30	0.02	0.80	0.02	0.68
Elymus repens	?	0	0	0.00	0.00	0.06	1.72	0.12	0.27	0.07	0.93
Equisetum laevigatum	N	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.00	0.02	0.05
Gnaphalium sp.	N?	0	0	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Grindelia squarrosa	N	0.04	0.22	0.08	0.92	0.04	0.08	0.18	0.40	0.20	0.80
Helianthus sp.	N	0	0	0.00	0.00	0.02	0.04	0.00	0.00	0.00	0.00
Heterotheca villosa	N	0.28	1.9	0.44	3.08	0.32	2.02	0.50	4.49	0.59	6.30
Hordeum jubatum	N	0	0	0.00	0.00	0.00	0.00	0.02	0.20	0.00	0.00
Kochia scoparia	E	0	0	0.00	0.00	0.04	0.40	0.02	0.00	0.00	0.00
Lactuca serriola	E	0.06	0.08	0.02	0.02	0.02	0.02	0.00	0.00	0.05	0.03

Table 2 cont.		**2006**		**2007**		**2008**		**2009**		**2010**	
Species	**Native / Exotic**	**Incidence**	**% cover**	**Incidence**	**% cover**	**Incidence**	**% cover**	**Incidence**	**% cover**	**Incidence**	**% cover**
Lepidium latifolium	E	0.08	0.12	0.20	0.28	0.14	0.19	0.08	0.04	0.02	0.02
Lepidium perfoliatum	E	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Lupinus pusillus	N	0	0	0.04	0.30	0.02	0.02	0.02	0.06	0.07	0.27
Machaeranthera canescens	N	0.04	0.04	0.10	0.10	0.06	0.14	0.06	0.04	0.00	0.00
Melilotus officinalis	E	0.04	0.1	0.04	0.04	0.06	0.10	0.04	0.04	0.09	0.05
Oenothera coronopifolia	N	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.05
Mentha arvensis	N	0	0	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00
Oryzopsis hymenoides	N	0.38	4.7	0.20	0.84	0.14	0.36	0.16	0.34	0.11	0.43
Plantago major	E	0	0	0.00	0.00	0.00	0.00	0.02	0.08	0.02	0.09
Poa sp.	?	0.02	0.04	0.00	0.00	0.04	0.14	0.02	0.00	0.07	0.20
Polygonum sp.	?	0	0	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Portulaca oleracea	E	0	0	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00
Salsola iberica	E	0	0	0.00	0.00	0.06	0.06	0.02	0.00	0.05	0.03
Sisymbrium sp.	E	0	0	0.00	0.00	0.00	0.00	0.02	0.00	0.05	0.03
Solidago sp.	N	0.06	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solidago sp. #2	N	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sporobolus cryptandrus	N	0	0	0.28	1.60	0.24	2.12	0.40	2.07	0.50	4.50
Tamarix ramosissima	E	0.02	0.04	0.02	0.00	0.02	0.06	0.02	0.00	0.02	0.00
Taraxacum officinale	E	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.07
Tragopogon dubius	E	0	0	0.04	0.04	0.00	0.00	0.06	0.04	0.05	0.05
Unknown # 1	?	0.02	0.02	0.00	0.00	0.00	0.00	0.02	0.04	0.02	0.00
Unknown # 2 opposite leaves	?	0	0	0.00	0.00	0.02	0.02	0.02	0.00	0.00	0.00
Unknown #3	?	0	0	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Unknown #3 alternate leaves	?	0	0	0.00	0.00	0.02	0.04	0.00	0.00	0.00	0.00
Vulpina octoflora	N	0	0	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Verbascum thapsus	E	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.11