UPPER VERDE RIVER
TAMARISK REMOVAL PROJECT

FINAL REPORT

for the

ARIZONA WATER PROTECTION FUND COMMISSION

Contract #07-149WPF

Submitted by

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This Final Report is written to fulfill contractual requisites of the three-year Grant Award Contract number 07-149WPF "Control of Tamarisk on 12 Miles of the Upper Verde River" awarded April 4, 2007 by the Arizona Water Protection Fund Commission. This final report is submitted to fulfill all criteria as per Task 6 – final reporting.

This project was principally funded by Arizona Water Protection Fund Commission, with collaborative contributions from Rocky Mountain Research Station – Flagstaff, Arizona, and the Prescott National Forest. The views or findings presented in this report are the Grantee's and do not necessarily represent those of the Commission, the Arizona Department of Water Resources, or collaborators.

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1. EXECUTIVE SUMMARY

In 2007 the Arizona Water Protection Fund issued a three-year grant to EcoResults Institute to administer tamarisk removal on the upper most 12 miles of the Upper Verde River on Forest Service lands. The objectives of the project were to reduce stands of tamarisk in the headwaters of the Verde River to protect ecosystem values; to implement comprehensive monitoring studies to document results; and, to conduct a public outreach program to inform a broad audience of the program and its befits.

EcoResults employed skilled technicians seasonally from the National Park Service's Lake Mead Exotic Plant Team and Coconino Rural Environment Corps to do the work. Tamarisk stands were recorded by GPS, treated and then visited a second and third season to make sure any resprouting found was retreated. The project was professionally monitored at eighteen permanent transects to determine change in species diversity and at eighty photo sites to determine treatment effectiveness.

The river experienced major floods during each of the three years of treatment, which caused significant erosion and change to portions of the river bottom. Of the 9,884 live tamarisk stems documented on 80 study sites at the start of the project, only 118 live stems appeared after final treatment, for a 98.7% stem eradication rate. Permanent transect vegetation monitoring showed the only change in plant diversity was the almost total elimination of tamarisk.

The outreach program involved presentations to and assistance from over a hundred students of junior high, high school, and university ages. Many professional and news articles were published about this project. Several ranchers and public agencies were also involved with the project, and a brochure was produced and made available at agency offices in the region.

Recommendations are for land managers to follow up with minor periodic herbicide application to resprouting tamarisk stems, and to expand treatment upstream to the headwaters and downstream to the remaining 21 miles of the Upper Verde River.

The success of this project exemplifies how private organizations can assist land management agencies to achieve land restoration goals for the long-term benefit of Arizona's communities. Pioneer taramisk removal on the Y-D Ranch and Verde River Ranch inspired the project. This project was a cooperative undertaking led by EcoResults Institute (www.ecoresults.org) and the Arizona Water Protection Fund Commission, with technical assistance from the U.S. Forest Service Prescott National Forest and Rocky Mountain Research Station, Flagstaff, Arizona.

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3. INTRODUCTION

This report summarizes a three-year project funded through a grant contract with the Arizona Water Protection Fund to control tamarisk on 12 miles of the Upper Verde River. This project was administered by the non-profit EcoResults Institute, and is the first proactive effort to control the expansion of tamarisk on the Upper Verde River.

Site Background and History

The Verde River is located in central Arizona and flows southeasterly 170 miles from its headwaters to its confluence with the Salt River. The Upper Verde River reach is identified as that section from the headwaters located near Paulden, Arizona to Tapco, west of Camp Verde. The Verde River is of vital importance to the growing communities of the Verde Valley and the Phoenix metropolitan area, and contains multiple resource values of great significance to the future quality of life of many Arizonans. In 2006 the Verde River was listed as one of the ten most endangered rivers in America by American Rivers, the leading river conservation organization American Rivers. The Upper Verde River is presently under consideration for Wild and Scenic River designation.

Prior to 1980, woody vegetation was scant on the upper Verde River. Changes in grazing management in 1980 resulted in extensive stands of many woody species. Vegetation surveys of the upper Verde River by the Rocky Mountain Research Station (Medina and Long in press), indicate that density of mature tamarisk was low (<20%), but recent floods (i.e. 2004-05) induced severe channel disturbance and extensive stands of saplings (<2") are now found throughout the corridor.

The treatment area of this project is limited to the first 11.65 miles administered by the Prescott National Forest (PNF) (12.4 river miles, including a 0.75 mile section of private land). The treatment area begins at the PNF property boundary (3 miles east of Sullivan Dam) and extends to the confluence of the Verde River and Tri-Canyons (where Hell Canyon joins the Verde River). The 0.75 mile section of private land at mile 4 of the treatment area, known as the Rio Verde Ranch, is exempt from this project. These private lands were treated for tamarisk in 2005 and re-treated in 2007 to ensure compatibility with this project and are sponsored by the Upper Verde River Adaptive Management Partnership (UVRAMP). The project treated lands between the walls of the river canyon, estimated to average 305 feet in width by 61,500 feet in length for a total area of about 430 acres. River elevation ranges from 4180 at the upstream end to 3960 feet at the downstream end. Figure 1 illustrates the location of the whole project area and Figure 2 shows the location of this area within the whole Verde River watershed.

Maps

Figure 1. Map of the location of the treatment area on the Upper Verde River.

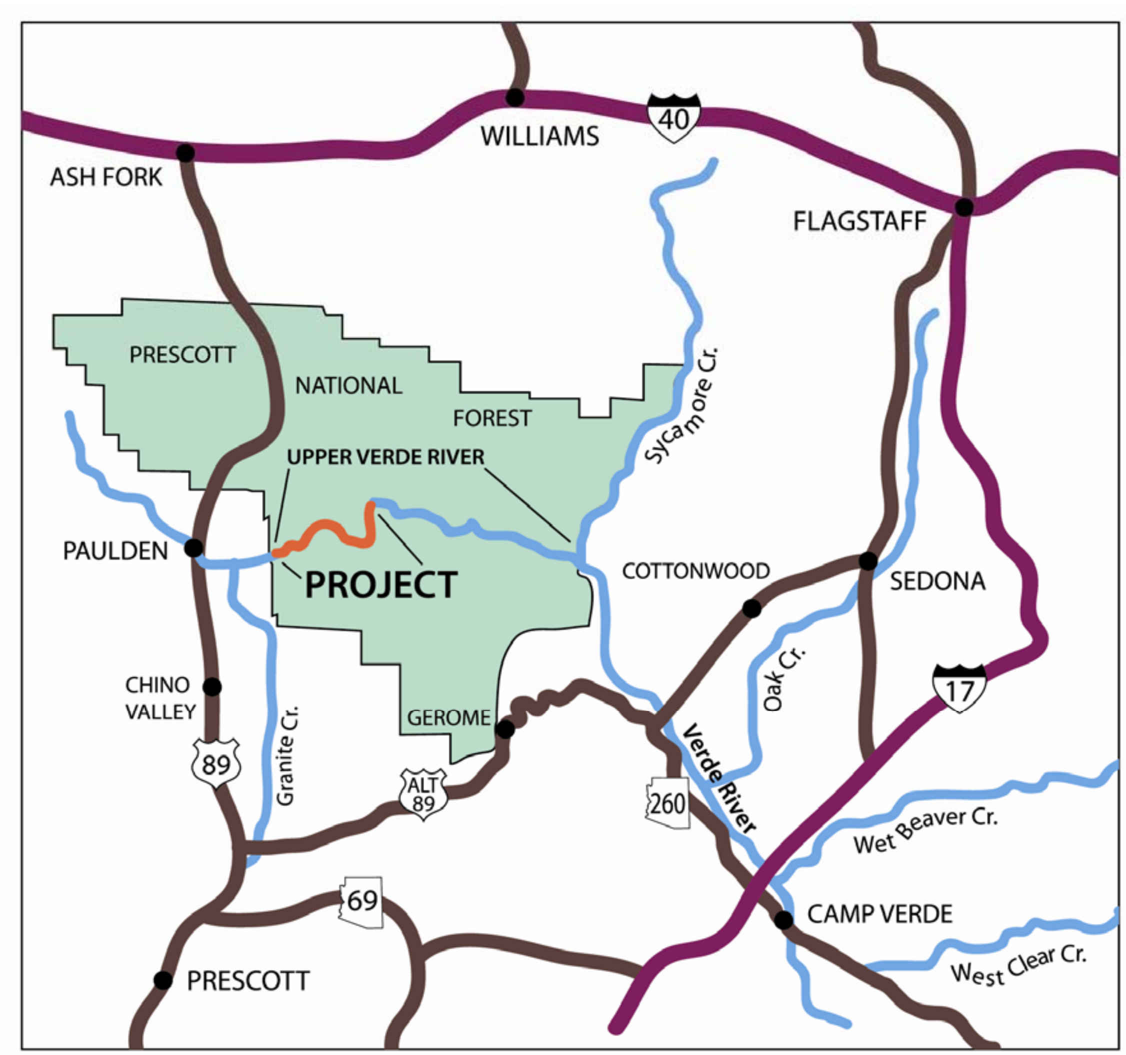
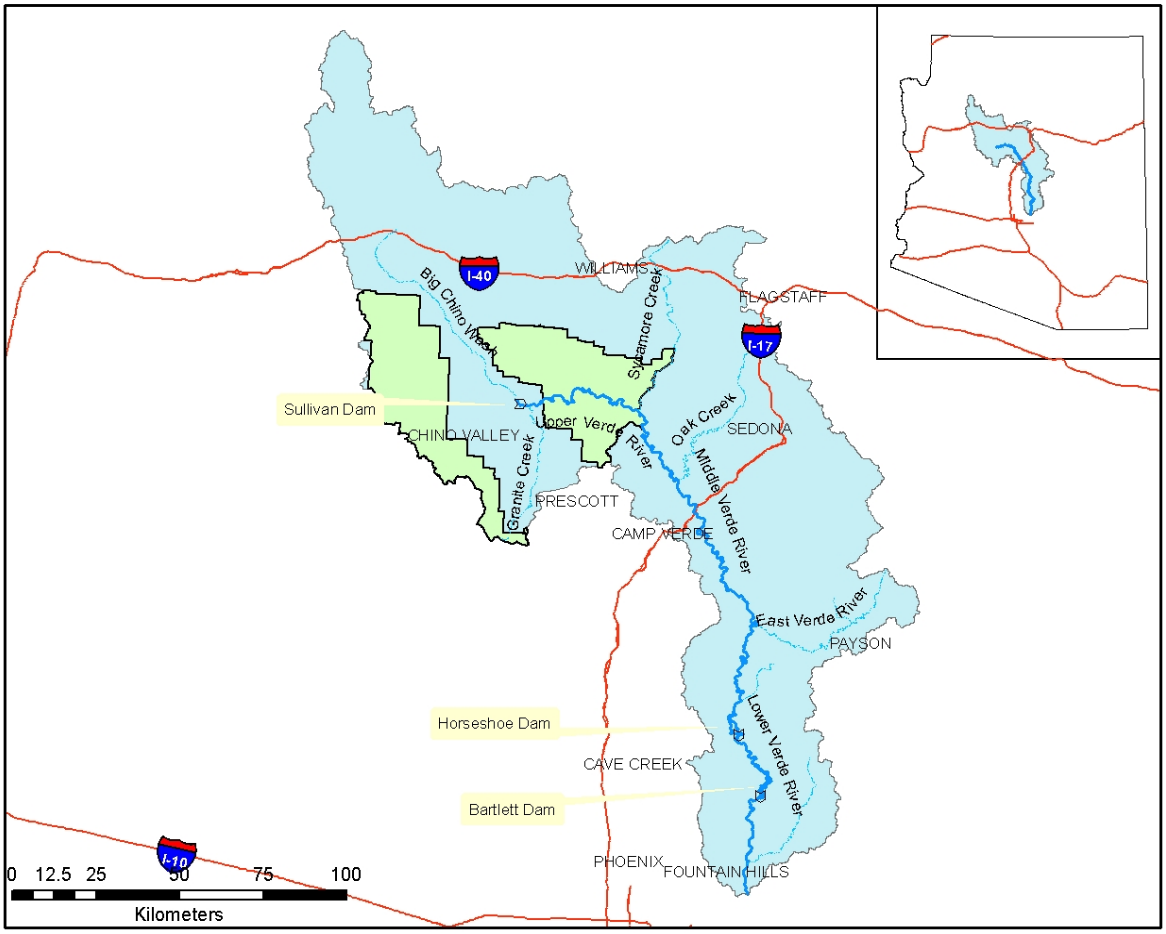
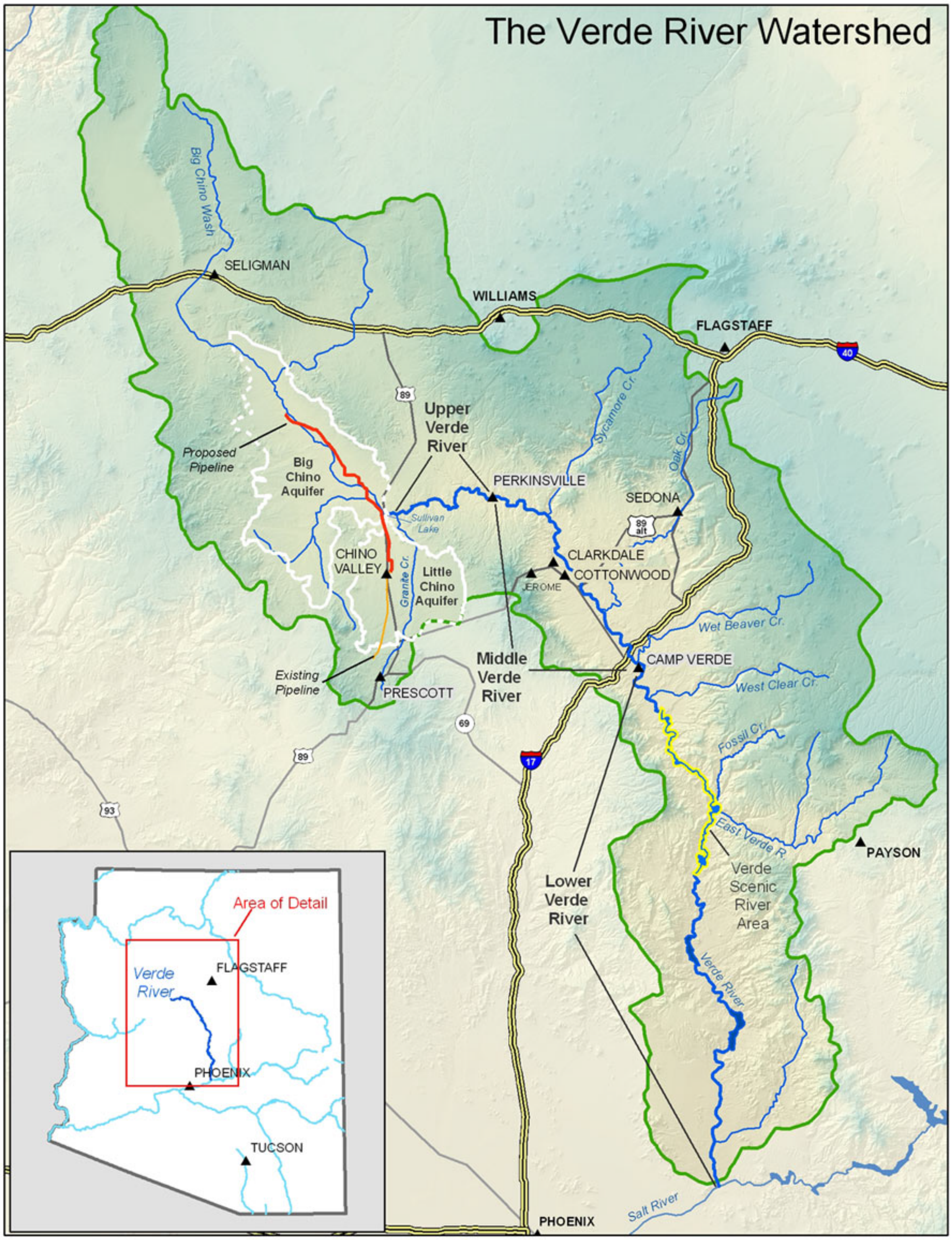


Figure 2. Map of the entire Verde River Watershed



I-40
I-17
I-10
WILLIAMS
FLAGSTAFF
Big Chino Wash
Sycamore Creek
Sullivan Dam
Upper Verde River
CHINO VALLEY
Granite Creek
Oak Creek
SEDONA
Middle Verde River
PRESCOTT
CAMP VERDE
East Verde River
PAYSON
Horseshoe Dam
Lower Verde River
CAVE CREEK
Bartlett Dam
PHOENIX
FOUNTAIN HILLS
0 12.5 25 50 75 100
Kilometers


The Verde River Watershed
Big Chino Wash
SELIGMAN
WILLIAMS
FLAGSTAFF
40
89
Upper
Verde
River
Proposed
Pipeline
Big
Chino
Aquifer
Sycamore Cr.
Oak Cr.
PERKINSVILLE
SEDONA
89
alt
Sullivan
Lake
CHINO
VALLEY
Granite Cr.
Little
Chino
Aquifer
CLARKDALE
COTTONWOOD
JEROME
Wet Beaver Cr.
Existing
Pipeline
PRESCOTT
Middle
Verde
River
CAMP VERDE
West Clear Cr.
69
89
17
Fossil Cr.
93
East Verde R.
PAYSON
Verde
Scenic
River
Area
Lower
Verde
River
Area of Detail
Verde
River
FLAGSTAFF
PHOENIX
TUCSON
Verde River
Salt River
PHOENIX

Statement of the Problem

Tamarisk is the main invasive species adversely affecting riparian areas in Arizona and the Southwestern United States. The vegetation of the Verde River has been monitored by the Rocky Mountain Research Station since 1996. Tamarisk is one of the key invasive plants whose population and distribution has increased after each major flood. Tamarisk has been present within the riverine corridor for several decades, but recent catastrophic floods of 1993 and 2004 caused widespread stream bank disturbance facilitating the widespread of many young plants. According to research used by the Rocky Mountain Research Station tamarisk poses a major threat to the Verde River ecosystems by altering the (1) hydrologic regime, (2) native plant community dynamics, (3) soil productivity, (4) aquatic ecosystems, (5) and native species diversity. The spread of young plants throughout the riparian corridor is seen as a principal threat to critical habitat for Threatened and Endangered species of native fishes like the spikedace (Meda fulgida). Invading tamarisk can alter and replace vital aquatic plants like sedge and rush communities, thereby making stream banks unstable and susceptible to high erosion rates from floods. Stands of trees can cause vertical accretion to form levees and increase channel degradation to the extent that the floodplain is dewatered. These levees inevitably result in greater flooding damage, and flushing of fine sediments downstream. The thicker tree cover and rougher channel bottoms restrict travel corridors and recreation use. Tamarisk stands can also reduce and impair water quality for recreation and for downriver community water needs. Though riparian areas account for < 2% of land area in the Southwest, over 65% of wildlife depend on these riparian areas - thus tamarisk invasion poses a major threat to wildlife and plant diversity and population viability.

Treatment of tamarisk by the Forest Service was held up for many years due to the inability to use herbicides on Forest lands. The completion of an Environmental Impact Statement in December of 2004 (Integrated treatment of noxious and invasive weeds on the Coconino, Kiabab, and Prescott National Forests in Coconino, Gila, and Yavapai Counties, Arizona) opened the door for moving ahead with this treatment project.

Project Goals and Objectives

1. Reduce the stands of tamarisk in the headwaters of the Upper Verde River for the purpose of enhancing the native riparian plant communities, protecting critical habitat for wildlife and threatened and endangered native fishes, increasing ecosystem productivity, stabilizing channel conditions and sustaining and enhancing the economic and recreational benefits to users of the Verde River.

   This goal is to be achieved by manually cutting and treating with herbicide all known tamarisk stands outside of the aquatic habitat on 12 contiguous miles of the Upper Verde River floodplain on Prescott National Forest lands. Treatment will affect about 430 acres of floodplain with an approximate total tree density of 60,000 stems.

2. Implement a comprehensive monitoring process to evaluate the mortality and success of treatments over a 3-year period. The monitoring will include permanent and temporary vegetation plots where pre and post treatment measurements will be taken across the monitoring period of 3 years.

3. Conduct public outreach efforts highlighting the benefits and success of river habitat restoration. Outreach will be to multiple publics including middle and high schools, local and regional publics, resource managers and professional organizations. Outreach will include brochures, classroom and on-site educational presentations, on-site wildlife habitat development, and publication of research findings.

4. PROJECT METHODS

Following is a summary of procedures described in the three work plans for this project: the Task #3 Monitoring Plan, Task #4 Tamarisk Treatment Plan, and Task #5 Public Outreach Plan.

Treatment Methods

The cut and spray method was used for treatment. For this method woody stems of over two inches in diameter are cut off close to the ground by chainsaw. Where significant dirt from flooding accumulates on stands, hand digging tools are used to remove this debris before treatment. Cut stems are stacked away from the base of the plants and, where feasible, are stacked on terrace areas above the floodplain to provide shelter for wildlife such as quail and small mammals. Cut stem bases are then spayed from a fine-tipped backpack sprayer. Stems of under two inches are not cut but spayed on about a foot length of bark near ground level.

The water-based Garlon 4 herbicide is used on plants away from the waters edge. For plants within about ten feet of the waters edge the more expensive oil-based Habitat (Ecomazapr 2 SL) herbicide is used.

Treatment sites are then revisited on the second and third years, where only herbicide need be applied to resprouting stems on the few stands which do not die from initial treatment. Treatments are planned for the fall and spring when temperatures are warm enough for stem growth, but cool enough that herbicide does not volatilize.

Monitoring Methods

Monitoring consisted of 1) GPS mapping of tamarisk stands and treatment areas, 2) annual reading of 80 photopoint sites, and 3) annual reading of 18 permanent monitoring stations.

1) Mapping: Initial mapping in the summer of 2007 using a GPS unit showed 392 tamarisk stands in the twelve-mile treatment area. Crews conducting treatment used GPS units to map stands they encountered and treated. Color aerial photo maps were then printed out for annual reports to AWPF showing areas treated and giving total acreages treated.

2) Photopoint sites: 80 Photopoint sites were randomly selected as a 20% sample of the 392 total tamarisk stands inventoried in the twelve mile treatment area. Rebar stakes, aluminum tags, and flagging were placed at each site. At each site the number of woody stems over one inch in diameter were counted, GPS coordinates recorded, and photographs taken of the stand from the stake. Each year photosites were revisited, rephotographed, and information documented on treatment status and number of stems found.

3) Permanent Monitoring Stations: 18 existing permanent vegetation monitoring stations installed by the Rocky Mountain Research Station in collaboration with Prescott National Forest were selected for use for this project. These transects were measured in the summer of 2006, then reread by a botanist in the summers of 2007, 2008, and 2009. A permanent marker has been established for each transect site. To read each station a 40 meter tape is stretched along the waterline of each side of the river and 0.1 meter square microplots are read for each meter of the tape. A 5 meter-wide belt transect is then read along the tape to record data on woody species. Finally, up to 18 photographs are taken from corners and sides of the tapes, including upstream and downstream views. Data collected and analyzed includes: plant species present, ground cover and plant cover by species, and woody plant density, height and stem diameter.

Public Outreach Methods

Public awareness and education was accomplished by producing and initial brochure for classroom use, conducting classroom presentations at the local middle/high school and Northern Arizona University, involving youth in on-the-ground conservation activities, giving professional papers, having a local newspaper article published, and distributing a final project brochure to Forest Service and BLM offices around Arizona for public display.

5. PROJECT RESULTS

The following describes the results of this three-year project including results of tamarisk eradication efforts, vegetation monitoring results, and results from public outreach efforts.

Implementation of tamarisk eradication

The 2004 Environmental Impact Statement which authorized tamarisk removal with herbicide required Forest Service personnel be on site at all times when work was being done. As no Prescott National Forest personnel were available for this work, the USDA Rocky Mountain Research Station staff worked with the Prescott National Forest to supervise work. Tamarisk eradication work was contracted out by EcoResults to the USDI National Park Service's Lake Mead Exotic Plant Management Team (LMEPMT). The LMEPMT maintains a large federal crew of skilled sawyers and certified herbicide applicators experienced in this type of work.

The LMEPMT worked on this project for a ten-day period each fall and spring between the fall of 2007 and spring of 2010. Treatment work was limited to the first weeks of fall and first weeks of spring when air temperatures were cool enough not to vaporize the herbicide spray, yet warm enough for plant growth, so the plants would transport the herbicide to the roots, and so crews could tell which plants were living. For the fall 2008 and spring 2009 periods the Coconino Rural Environment Corps (CREC) was contracted to work with the EMPM crew to provide additional manpower needed to complete full initial treatment of the project area.

This 12 mile portion of the upper Verde River has steep canyon walls, so access was limited to six points. Overnight camps were made at four of the points during the project. Typical round-trip walking distances with equipment from camps and vehicles averaged 2.5 miles.

Monitoring Data

This section on monitoring is primarily authored by Al Medina, researcher with the Rocky Mountain Research Station, using data and analysis done by biologist Tyler Johnson.

VEGETATION TREATMENT DATA

A comprehensive GPS inventory done in 2007 showed that of the 430 acres of canyon bottom 296 acres (69%) were considered to be grossly infected with tamarisk, of which actual tamarisk plant cover equaled 28.45 acres (6.6%). Russian olive, Siberian elm and Russian Knapweed were also found and treated by crews (totaling 0.80 acres).

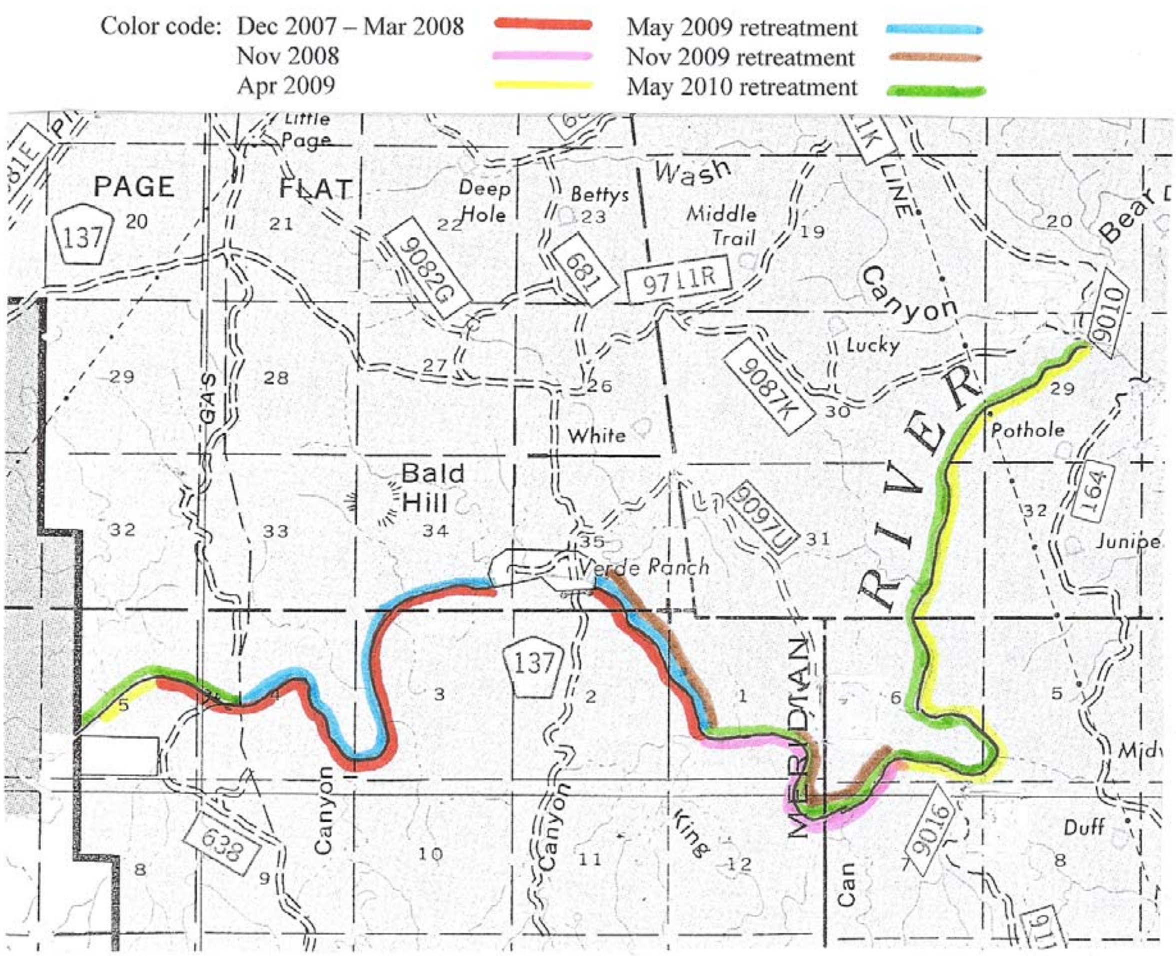
The whole 11.65 miles of river received at least an initial cutting and treatment and one follow up second year retreatment.

- During the first fall 2007-spring 2008 treatment year 5.35 miles or 46% of tamarisk eradication was completed on the project area. An LMEPMT crew of 27 persons worked an eight-day period in the fall, and a crew of 20 persons worked an eight-day period in the spring to do this work.
- During the second treatment year (fall 2008-spring 2009) the remaining 54% of tamarisk eradication was completed on the project area, and 6.3 miles or 54% of the project area received retreatment. To do this work a combined crew of 31 persons with LMEPMT and CREC worked eight-day periods in the fall and in April, and small crew of four men continued work for five days in May.
- During the third treatment year (fall 2009-spring 2010) 8.5 miles or 68% of the project area received retreatment. A crew of 5 men with LMEPMT working eight-day periods in fall and spring were able to do this 8.5 mile retreatment.

Total pre-dilution herbicide use for the three years was 76.55 gallons of Garlon 4, and 4.32 gallons of Habitat.

Figure 3 provides a visual record of when treatments were done on each section of river. In total 1168 ten-hour person-days were employed for treatment on the project.

Figure 3. Map showing areas and dates of treatment.



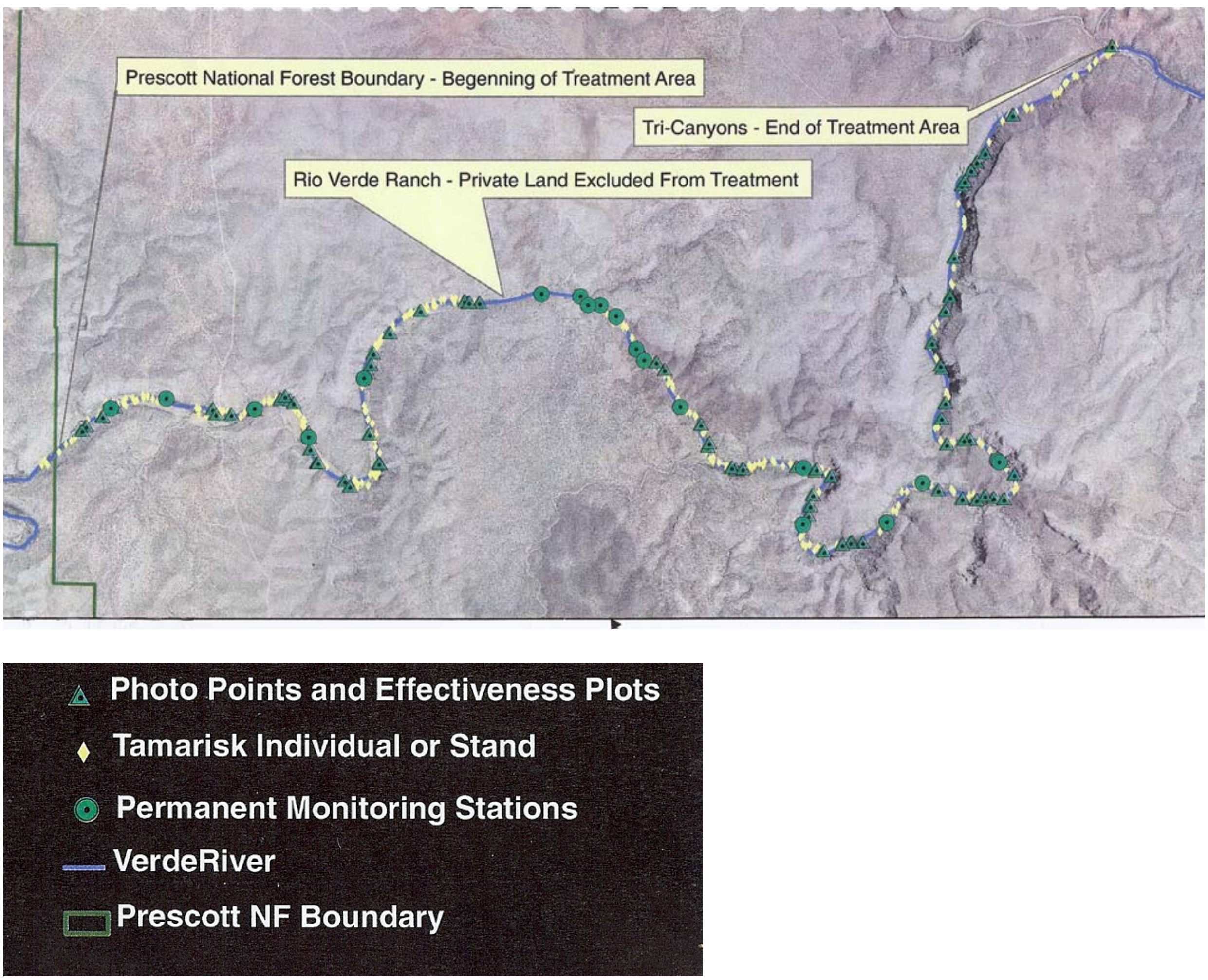
TOTAL TREATMENT RESPONSE

The 80 randomly selected photopoint sites over the 12 miles of the project are the basis upon which treatment success is based. These 80 sites represent a 20% sample of the 392 tamarisk stands (9884 stems) which were inventoried on the project area before treatment started. The 18 permanent vegetation transects are the basis upon which vegetation diversity changes are based.

Final project monitoring in May of 2010 showed that the tamarisk treatment was very effective as the total number of tamarisk stems was reduced by 98.7% over the three-year period, based on an initial 2007 live stem count of 9884 and a final 2010 live stem count of 118.

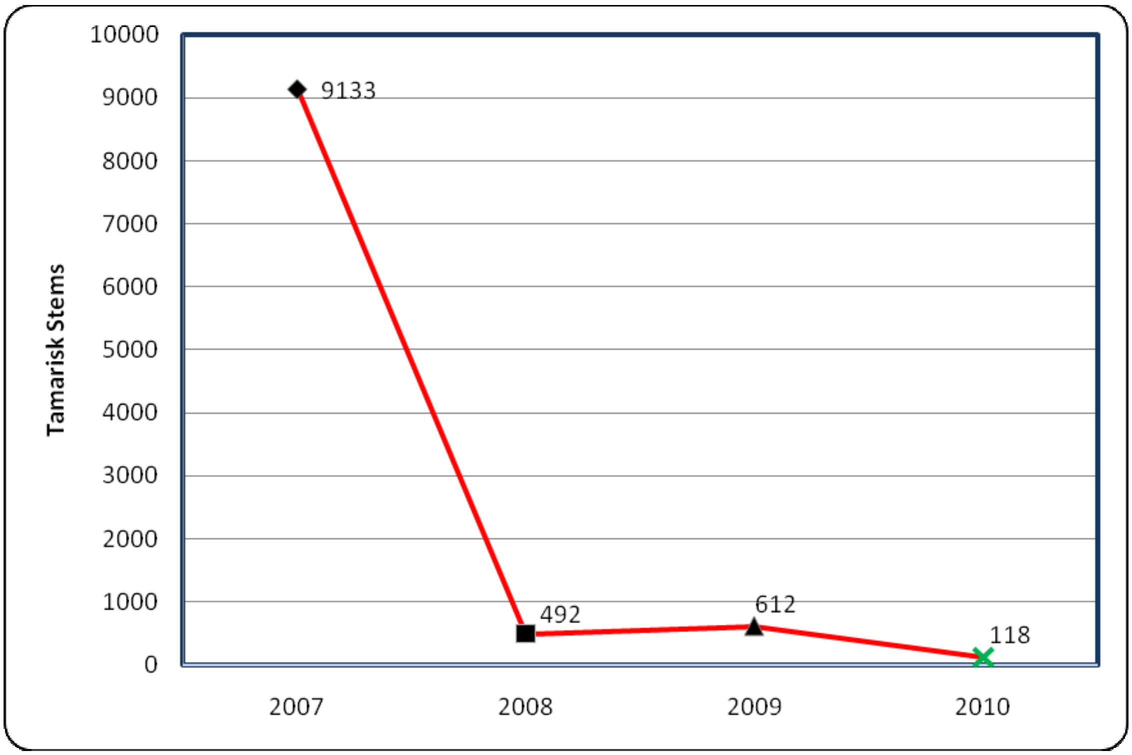
There were major floods on the river in each of the three years which resulted in major riverbed scouring. Thirteen of the 80 photopoint site tamarisk stands (16%) are now gone, with no sign of where they were rooted. Twenty four of the 80 sites (30%) had one or more healthy green resprouted shoots showing. Of note is that nine of the 80 stands (11.3%) that were observed as completely dead in the fall 2009 survey now have new living shoots coming from root bases.

Figure 4. Map showing tamarisk stands, 80 photopoints and 18 permanent monitoring stations.



Of he total number of tamarisk stems in the treatment area nearly 95 percent were treated between 2007 and 2008 (Figure 5). At the end of the second treatment year (2009), 612 stems remained. This number accounted for additional young plants that established since the initial inventory in 2007. At the end of the last treatment year (April 2010), only 118 treated plants exhibited sprouting growth and were classified as live. However, it requires several months to *identify re-sprayed plants as dead, so the actual percent success may be greater than 98.7 percent of the original stand inventory. Young plants can continue to establish from seed stock that may remain within the treatment area or from upstream sources emanating from State (Arizona Game and Fish) and private (e.g. The Nature Conservancy) lands where stands have been identified.*

Figure 5. The total number of inventoried stems was reduced by 98.7 percent across the 3-year treatment period.



In general the herbaceous vegetation of the upper Verde River within the treatment area was dominated by grasses and forbs that are native, perennial, and wetland obligate species (Table 1 & 2). This was true at the beginning of the treatment of tamarisk (2007 pre-treatment monitoring) and was true after the treatment was completed (2009 post-treatment monitoring). During the treatment of tamarisk the woody plant community was also quasi-stable and dominated by native plants. Most native woody plants had stable stem densities at the 18 permanent monitoring stations, and a few even increased in stem density, e.g. coyote willow (Figure 14). The stem density of tamarisk on the 80 monitored sites, meanwhile, increased from 2007 to 2008, most likely due to stumps re-sprouting after treatment (i.e. turning one large stem into many small re-sprouts). The stem density of tamarisk on the 80 monitored sites *decreased from 2008 to 2009 with the completion of treatment and re-treatment of many re-sprouted stems. The average post-treatment tamarisk stem density is little more than half (54%) of the average pre-treatment stem density. On the other hand, overall stem density for the entire project area was likely several times greater (est. 100-150k stems), since the 80 monitored sites represented only about 10 percent of the entire population. This reduction took place while the herbaceous and woody plant communities were largely stable and remained dominated by largely native riparian obligate plants that grow perennially.*

One interesting difference from the pre- to post-treatment monitoring was the average importance value of soil and litter. Soil dominated the abiotic environment in 2007 and 2008, but litter increased significantly from 2008 to 2009 to become the most common abiotic cover type (Figure 19). There are no obvious reasons for this change, aside from the possible transport of litter debris that was freed from tamarisk stands or heavier-than-usual growth of annual plants. No attempt is made to identify the source of litter when monitoring takes place so it is not possible to tell a posteriori what the source of the litter was. There is no obvious rationale that can be deduced from the vegetative data since very little changed from 2007 to 2009. This is a positive consequence because the project was intended to affect the presence of tamarisk, while sustaining other biological values, and seemingly this was attained.

TREATMENT RESPONSE OF SELECTED SITES

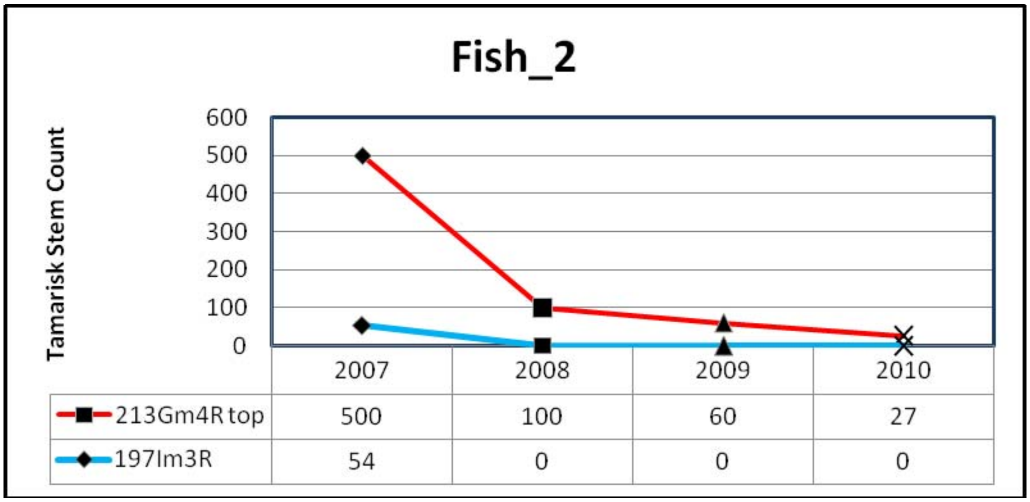
Instead of displaying and discussing in detail each station or treatment plot across all years we have chosen to discuss 7 permanent monitoring stations that had a tamarisk treatment plot within 100 meters of the center of the monitoring station. We chose to discuss this information to make sense of how the permanent monitoring stations co-varied with tamarisk stem density at treatment locations. When reviewing the efficacy of tamarisk removal and the long-term trajectory of the permanent monitoring stations it is essential to remember that this monitoring was not designed to show causality (i.e. we have no way of demonstrating that removing tamarisk caused any change in the riparian system), rather any co-variance is likely correlative. Each station consisted of two transects (one on each on each side of the river)and since the tamarisk treatment plots were selected at random (i.e. independent of the side of the river) we averaged the vegetative attributes from the two transects at each station into one value for each station. We then discuss vegetative changes as a whole based on the tamarisk treatment plot and average station data for each year.

Eighteen permanent vegetation transects were used to monitor changes in vegetation response across the three-year treatment period. Seven of these transects contained tamarisk and are used to monitor treatment response at the site level. The remaining eleven transects were absent of tamarisk and did not acquire tamarisk during the treatment period. Figures 6 through 12 illustrate the changes in stem counts between 2007 and 2010. In all cases, except for site Fish_2, stem counts were reduced by 100 percent. Stem counts after the first year (2007) are resprouts of treated stumps, and not established plants, hence, the high counts. Resprouting is a physiological response of tamarisk to overcome the stress from the herbicide. Actual mortality may be prolonged, depending on many factors, including the plants root system, water availability, amount of herbicide translocated, etc.

Station Fish_2

Site Fish_2 contained a very large group of tamarisk that required extensive excavation and removal of debris to expose the base roots. This station was added to the long-term vegetation monitoring scheme on the upper Verde River in 2006 and was established to co-occur with fish monitoring plots, thus the name. Like Station 4 this site also had two tamarisk photopoint sites within 100m. One of the photopoint sites had 54 stems in 2007 and was killed in 2008 and had no re-sprouts in 2009. The other had 500 stems in 2007, was reduced to 100 stems in 2008, and had 60 stems in 2009 (Figure 6). Fish_2 had the second highest stem density of tamarisk of the 7 selected stations across all years. This station also had a fairly robust native woody plant community largely dominated by seep willow, velvet ash, and willow species. The proportion of native species importance value increased from 2007 to 2009, although only slightly (65% in 2007 to 69% in 2009. Overall, the proportion of importance value accounted for by non-vegetative elements decreased over time from 57.5% in 2007 to 43.5% in 2009. Much like the other stations litter came to dominate the non-vegetative elements in 2009 while soil was the dominant in 2007.

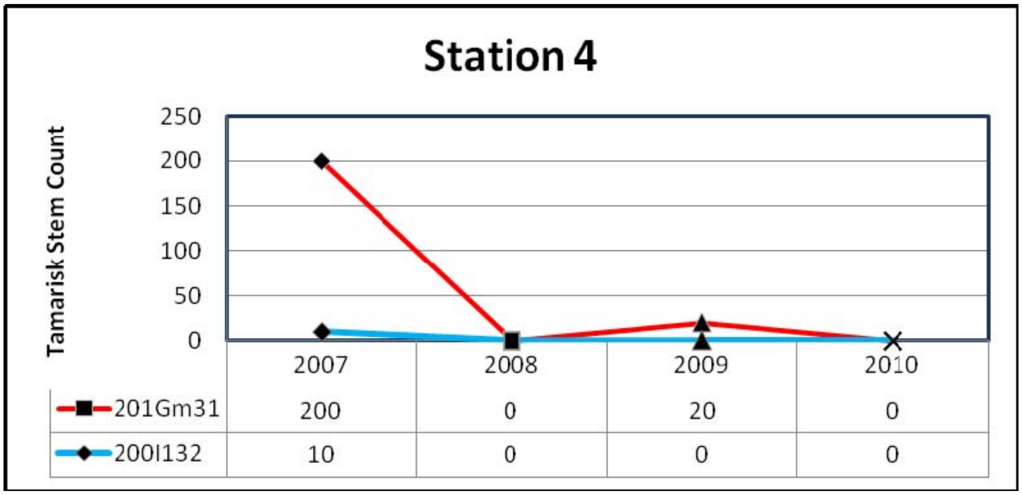
Figure 6. Tamarisk was reduced by 95% and 100%, respectively, on a very large group.



Station 4

There were two tamarisk photopoint sites within 100m of Station 4. The first had 10 tamarisk stems in 2007, which were reduced to 0 in 2008 and remained at 0 for 2009. The other site however, had 200 stems in 2007, a figure reduced to 0 in 2008, but sustained an increase in tamarisk stem density in 2009 back to 20 stems (Figure 7). The number of stems in 2009 is 10% of the stem count in 2007. Station 4 also showed a decrease in stem density for most native trees (Table 2) from 2007 to 2009. Native plants accounted for 81% of the importance value in 2007, a figure reduced to 71% by 2009. The proportion of non-vegetative elements also decreased by 10% from 2007 to 2009. The ground cover of Station 4 like the others was dominated by soil in 2007 but was dominated by litter in 2009 (22.4% soil in 2007 vs. 21.98% litter in 2009 – Table 3).

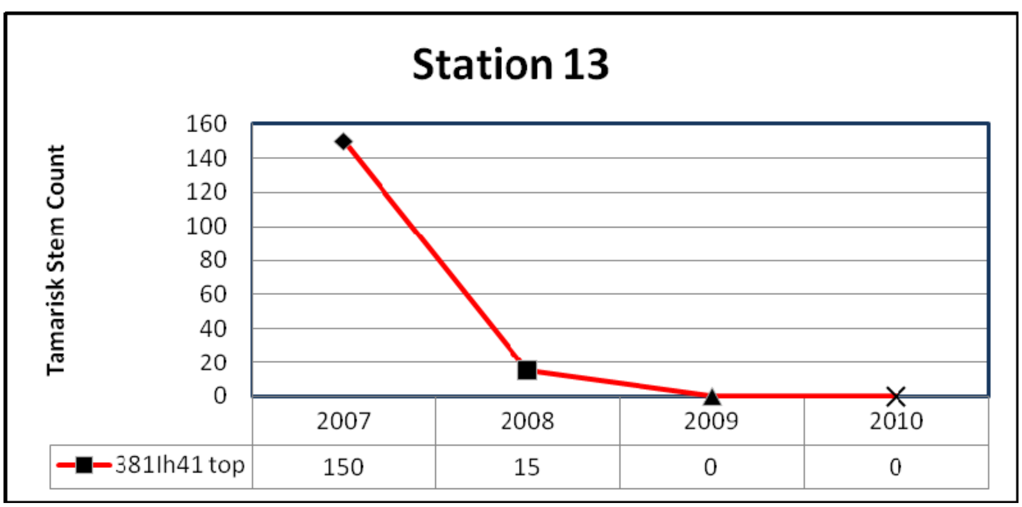
Figure 7. This site exhibited typical resprouting after a year, but was killed following a second herbicide treatment.



Station 13

The density of tamarisk at the tamarisk photopoint site located within 100 meters of Station 13 had 150 tamarisk stems in 2007, 15 tamarisk stems in 2008 and no stems in 2009 (Figure 8). During the same period the proportion of introduced to native proportion of importance value increased from 30% introduced in 2007 to 40% in 2009. The proportion of importance value accounted for by non-vegetative cover was 41.5% in 2007 and was 46% in 2009. The primary non-vegetative element (soil, litter, rock, and gravel) switched from soil having the highest proportion of importance value in 2007 (24.6%) to litter dominating the category in 2009 (23.6%) (Table 3). At station 13 the woody plant community was largely dominated by willow species in 2007 and remained so in 2009.

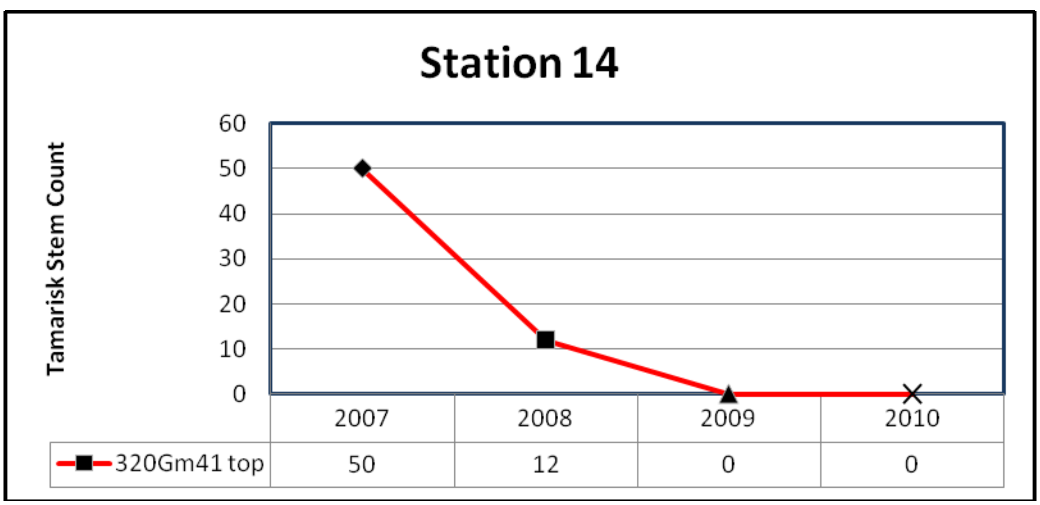
Figure 8. This site illustrates the typical response to cutting and herbicide treatment.



Station 14

The tamarisk photopoint site within 100m of station 14 had 50 tamarisk stems in 2007, 12 in 2008 and none in 2009 (Figure 9). Station 14 had a dense woody plant community in 2007 and was little changed by 2009, with the exception of a decrease in tamarisk stem density. The woody plants associated with station 14 were characterized by dense growth of seep willow, velvet ash, and willow species. Another exotic tree, Siberian elm, was present in all years and increased in stem density in 2009. While the woody plant community remained dominated by native tree species, the herbaceous plant community changed from being dominated by native plant proportion of importance value to introduced proportion of importance value . The proportions of these importance vales were exactly reversed during the monitoring period; the proportion of native plant proportion of importance value in 2007 was 61%, while at the end of the monitoring period the proportion of introduced proportion of importance value was 61% . While the proportions of native and introduced proportion of importance value changed dramatically, the proportion of non-vegetative proportion of importance value remained nearly the same from 2007 to 2009 at station 14. Non-vegetative proportion of importance value was 44.5% in 2007 and was 46% in 2009. Like Station 13, the dominant non-vegetative element at Station 14 was soil in 2007(23.6%) and litter in 2009 (24.3%) (Table 3).

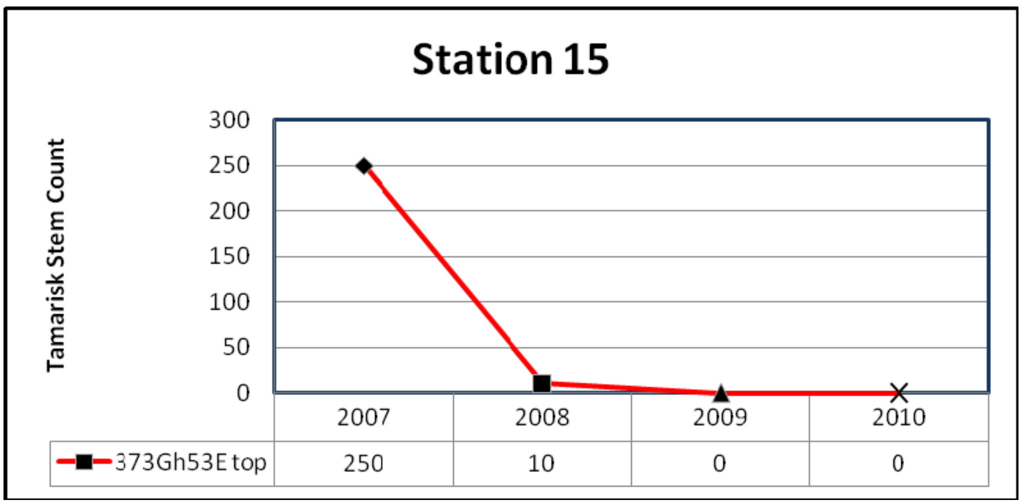
Figure 9. This site contained a large tree that was successfully treated despite a 20 percent resprout rate.



Station 15

During the monitoring period, Station 15 had a fairly noticeable increase in the proportion of native plant proportion of importance value to that of introduced plant proportion of importance value. Native plants accounted for 76% of the total plant proportion of importance value in 2007 and accounted for 88% in 2009 (Figure 10). While the proportion of introduced *plant proportion of importance value decreased, the non-vegetative portion of the herbaceous community in 2007 was very similar to that found in 2009. The non-vegetative elements of the understory community accounted for 43.5% of the total proportion of importance value in 2007 and accounted for 44.5% in 2009. Like most stations, the dominant non-vegetative element changed from soil dominance in 2007 to litter dominance in 2009 (Table 3). Station 15 was lightly wooded relative to the other stations. The woody plant community, such as it was, did remain stable from year to year with a slight increase in native woody plant density, coupled with a decrease in tamarisk stem density. At the tamarisk monitoring station within 100m of Station 15 the initial count of 250 tamarisk stems was decreased to 10 in 2008, and none in 2009.*

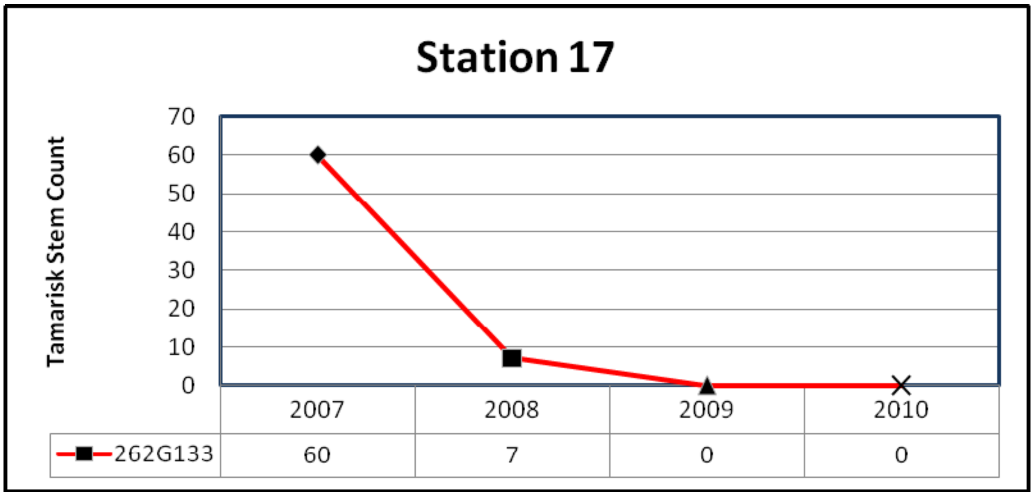
Figure 10. The large stem count on this site was effectively reduced by the first treatment.



Station 17

At the tamarisk photopoint site within 100m of Station 17 the 60 tamarisk stems counted in 2007 were reduced to seven in 2008 and none in 2009 (Figure 11). During the same period the native woody plant community remained stable and was largely dominated by native trees. The herbaceous community was dominated by native plant proportion of importance value in 2007, but was reduced by 2009 (82% native in 2007 to 66% native in 2009. However, an examination of the total proportion of importance value for Station 17 (including non-vegetative elements) shows that native vegetation (51.5%) is still dominant in 2009 with non-vegetative elements accounting for 38%, a figure not much different from the 2007 monitoring which showed non-vegetative elements accounting for 37.5%. In 2007 soil was the dominant non-vegetative element at 19.7%, but like many of the other stations litter had come to dominate in 2009 with 24.1% (Table 3).

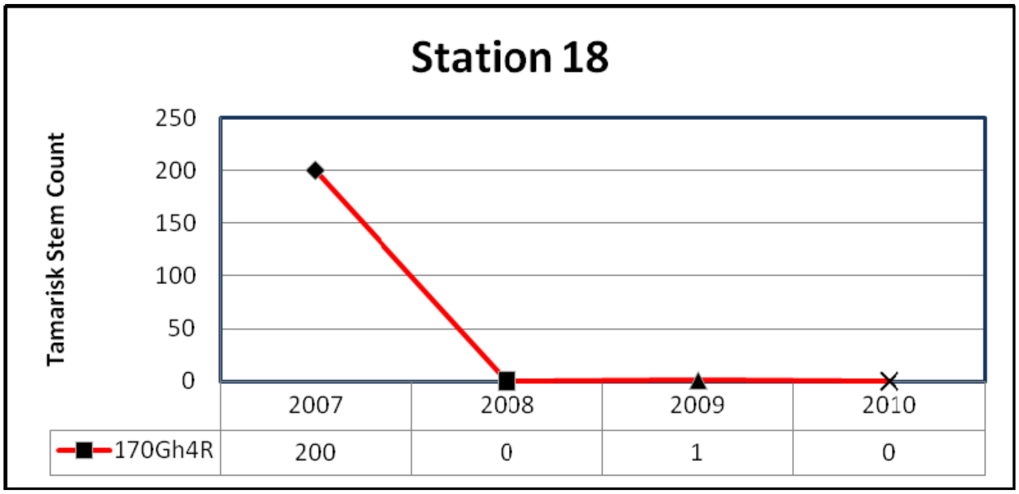
Figure 11. This stand responded well to the first treatment of cutting and herbicide, followed by a second herbicide application.



Station 18

Station 18 had one of the largest tamarisk infestations of any permanent monitoring station. However, only one of the randomly selected tamarisk photopoint sites was located within 100m of station 18. This tamarisk photopoint site had 200 stems in 2007, none in 2008, and 1 stem in 2009 (Figure 12). With an overall reduction in tamarisk stem density, the woody plant community at Station 18 increased in native tree stem density, especially velvet ash, which increased in stem density every year. The proportion of native plants decreased slightly from 85% proportion of importance value in 2007 to 76% proportion of importance value in 2009. The proportion of non-vegetative proportion of importance value changed from 51.5% in 2007 to 43% in 2009. Station 18 followed most stations by changing from dominance of soil in 2007 (23.8% in 2007) to litter (23.4 in 2009). Station 18 was fairly unique in having a large proportion of non-vegetative proportion of importance value accounted for by rock in 2007, although this proportion only lasted one year (Table 3).

Figure 12. This large group was killed by a single application of cutting and herbicide.



Figures 6-12 illustrate typical responses to treatments. Resprouting is noted within a year, which is retreated with herbicide. A second treatment may not be necessary in some cases, as the plant may be incurring a slow physiological death, but re-spraying insures mortality. It is difficult to predict whether resprouts are a response to the herbicide or simply regrowth of an unsprayed stem. While some plants or group complexes may be effectively killed by a single treatment of cutting and herbicide, there is no way of knowing if the plant is dead unless you have subsequent visits in a second or third year. This especially true of groups that have been heavily covered-up by river debris and or overburdened by sediment deposits, and or are intermixed with other down woody vegetation.

RESPONSE OF WOODY PLANTS

A principal reason for monitoring vegetation on permanent transects was to assess the response of associated vegetation to the tamarisk removal treatments. Twenty species of woody plants were found on the eighteen vegetation transects. Their relative abundance at the start of treatment is noted in Figure 13. Tamarisk (TARA) was present in high numbers. Seepwillow (BASA4), a common plant found in the channel and floodplain, was also abundant. Comparatively, willows (SAEX, SAGO, SALA) and Arizona ash (FRVE2) were only moderately abundant. The complete list of plants and their respective plant codes are noted in Table 2. In short, the removal of tamarisk yielded no significant increase in woody plant density for most species, with the exception in decrease in six facultative upland species. Potential shifts in plant composition may occur in later years after the channel adjusts to local absence of tamarisk stands, especially the larger complexes.

The post-treatment relative difference in stem counts for the same twenty plants in Figure 13 are illustrated in Figure 14. Note the absence of tamarisk (TARA), as well as six other species, including Amorpha fruticosa (AMFR), Brickellia californica (BRCA3), Garrya wrightii (GAWR3), Juniperus osteosperma (JUOS), Robinia neomexicana (RONE), and Salix laevigata (SALA3). With the exception of Salix laevigata, the remaining plants are facultative upland species. These plants were either lost to flood erosion from adjacent terraces or streambanks or were abandoned by shifts in position of the main channel. Floods are the most common cause of channel changes and concomitant shifts in plant composition.

Most plants retained their initial abundance, but an increase in Juniperus osteosperma (JUOS) is noted. This is likely due to a shift in the main channel to a position against upland terraces where Utah juniper prevails. Utah juniper is a common woody component in the floodplain as well, being a long term resident in comparison to the younger obligate riparian species.

The effects of seasonal (summer and winter) floods are notable. The combination of floods and the current high density of cottonwoods and willows create multiple channels with eroded bedload material accumulating as windrows or levees behind the trees. These levees essentially create a highly braided channel network that is hydrologically unstable and creates site habitat for the establishment and propagation of other woody plants. These sites are the typical location where large tamarisk stands were found. These sites are elevated 2-4 meters relative to the main channel, as the combination of dense wooded habitats and levee networks aid the degradation of the channel. The channel downcutting causes the main channel to migrate further away from its historical position and up against the terraces.

Figure 13. This graph illustrates the stem counts and relative abundance of 20 species of woody plants prior to treatment.

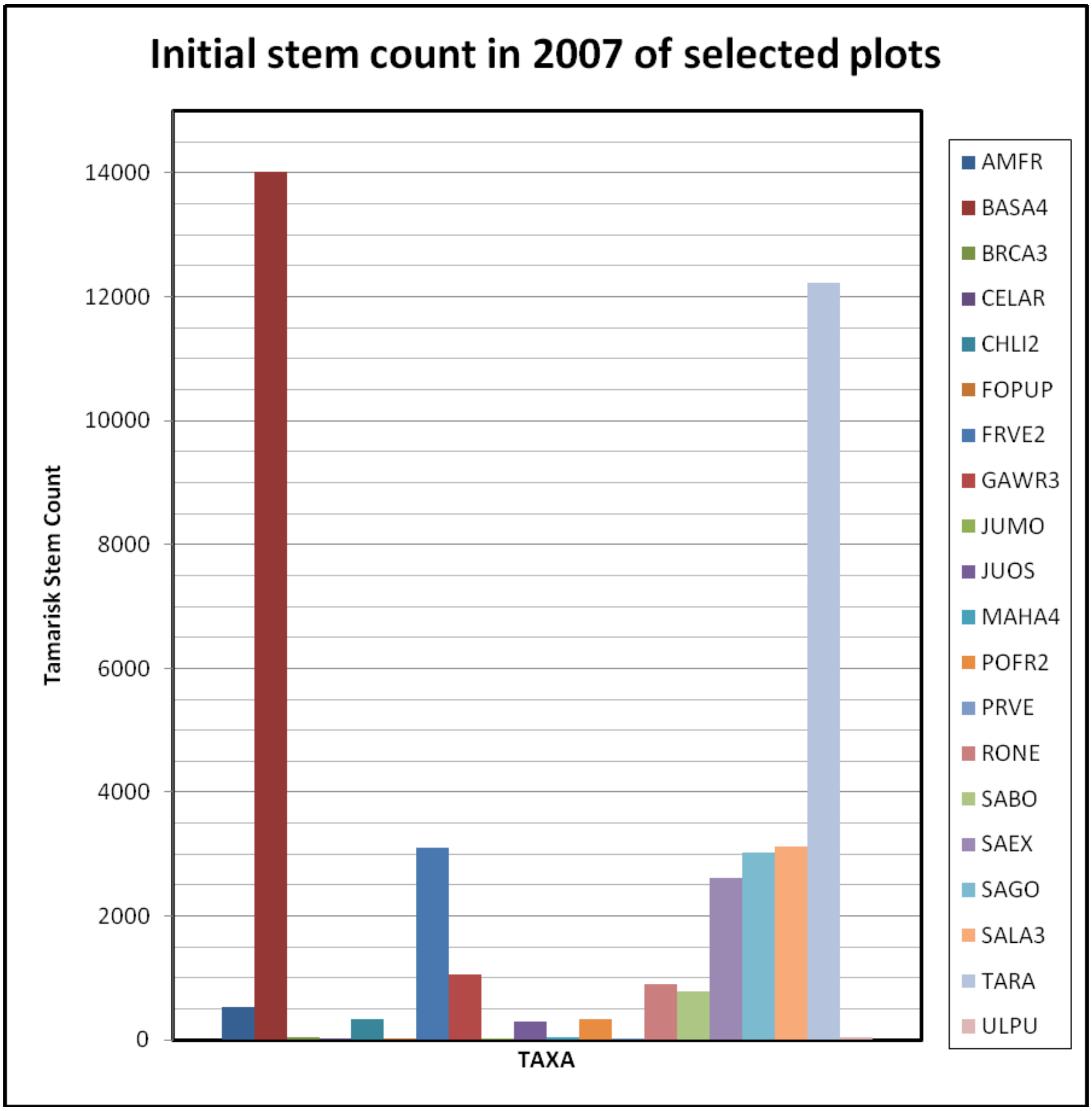
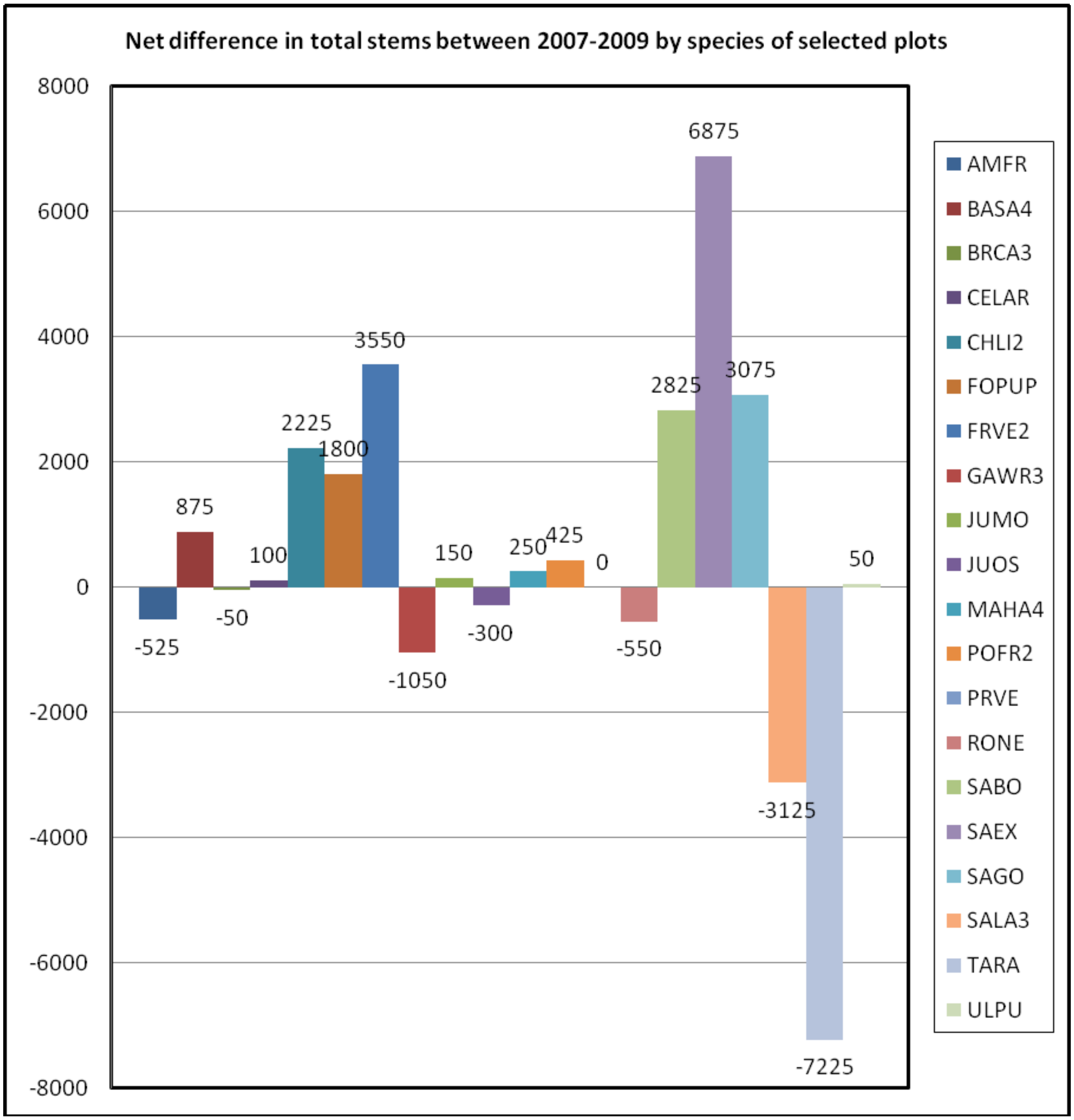


Figure 14. This graph illustrates the post treatment relative abundance of the same 20 species noted in Figure 13. Species response may be due to other factors, e.g. flooding, channel changes, besides removal of tamarisk.



RESPONSE OF HERBACEOUS PLANTS

Herbaceous plant responses were more notable than woody plants. Their relative prevalence was noted by changes in their importance value. The importance value is a relative index that takes into account cover, frequency, and constancy of each plant (Table 1). There were 105 plants found within the eighteen permanent transects over the 3-year period (Table 2). This constitutes over 50 percent of the known flora for the upper Verde River. Hence, the sites monitored exhibit very high species richness, with ample mixes of perennial and annual species of graminoids and forbs. There is no evidence that removal of tamarisk caused any shifts in plant composition.

Table 1 contains a list of the thirty most important plants within the project area. The most dominant plants as indicated by their importance value (IV) are aquatic perennial graminoids (SCPUL4, SCACO2, SCAM6, ELMA5), which are key to stabilizing streambanks, producing high quality wetland habitat, produce large quantities of forage, and mitigate bank erosion. These species can attain heights of five to six feet (Photo 1). In contrast, various non-native species (MEOF, POMO5, and CYDA) also persist throughout the project area. Common species such as Paspalum distichum (PADI6) are important pioneer graminoids that help stabilize streambanks. Differences in IV values across years are largely due to erosional effects from floods, as species are eroded or diminished in abundance from sedimentation. Overall the top two species were native perennial wetland obligate species (Cutleaf water parsnip and common three-square). Four of the top five species averaged across all years were native perennial wetland obligate species. These four species accounted for 41% of the total average cover and were present, on average, in 32% of the sampling frames. The top species, cutleaf water parsnip, was present at all stations in all years. The only introduced species in the overall top five (yellow sweet clover) was also present at all stations in all years and was in the top five in 2008 and 2009.

Native plants accounted for 69% of the vegetative cover averaged across all years, native plant diversity ranged from 54 native species in 2007 to 47 native species found in 2009, while introduced plants accounted for 30% of vegetative cover and had diversities ranging from 22 in 2009 to 29 in 2008. Figure 15 shows the average percent importance value for native and introduced plants across all 3 monitoring periods. Plants that grow perennially accounted for 75% of the vegetative cover averaged across all years while annual plants averaged 10% of vegetative cover. Average cover by perennial plants was very stable across the 3 monitoring periods, ranging from 77% in 2007 to 74% in both 2008 and 2009 (Figure 16). Across all years wetland plants averaged 81% of the vegetative cover, 64% of which was cover by obligate wetland plants and 17% was cover by facultative wetland plants. Figure 17 shows the yearly *figures for wetland plant cover. Averaged across all years, graminoids account for 49% of the total vegetative importance value, while forbs and herbs account of 47%. Figure 18 shows the yearly distribution of importance value by growth form.*

Table 2 provides a complete list of the known flora of the upper Verde River. Noted in bold are species that were found in the eighteen transects during the 3-years of monitoring. The list contains the respective plant codes/symbols for deciphering scientific names and their associated common names.

Photo 1. This photo illustrates the habitat potential properly managed wetland on private lands of the Verde River Ranch. The site is managed using cattle to suppress exotic plants and promote perennial graminoids, such sedges and rushes.

Figure 15. This graph illustrates the average importance value by nativity for all 18 permanent monitoring stations.

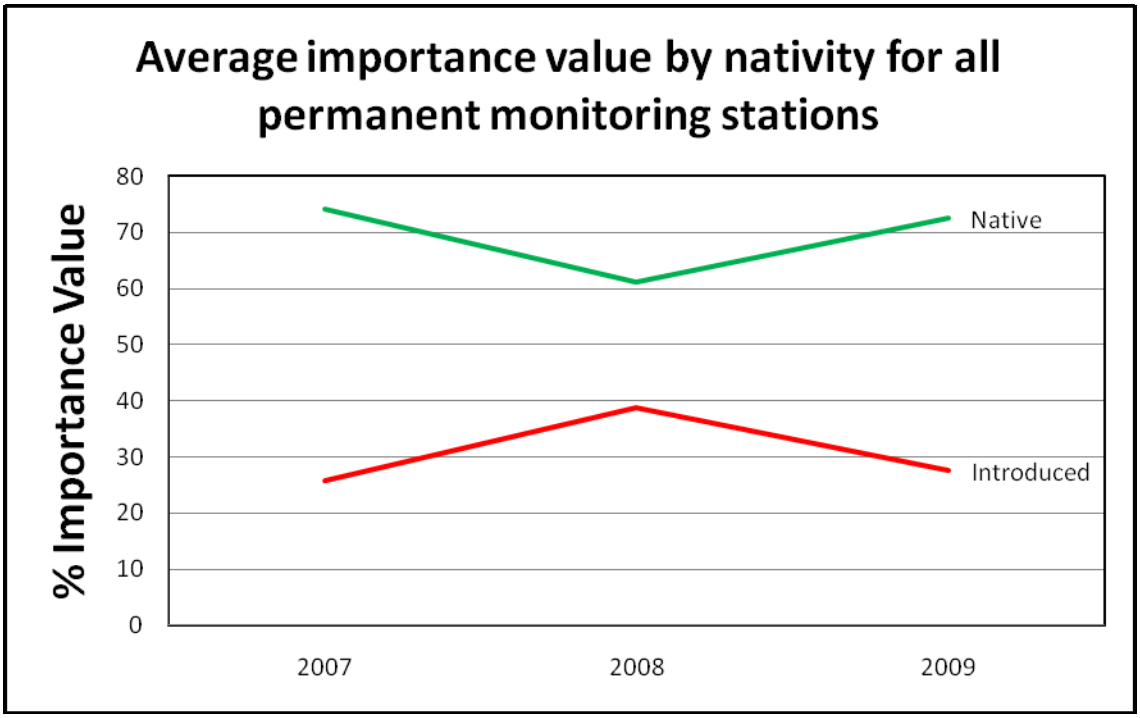


Figure 16. This graph illustrates the difference between life forms as expressed by their importance values.

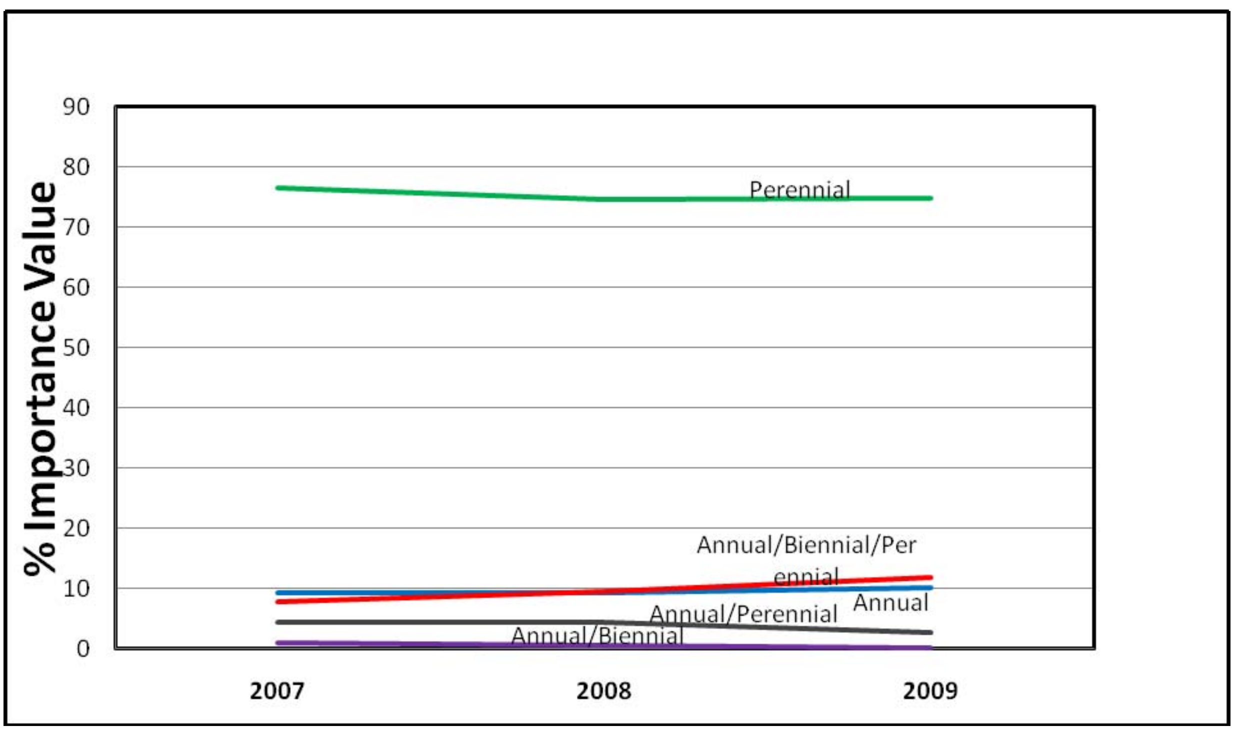


Figure 17. This graph illustrates the average importance value by wetland status for all permanent monitoring stations.

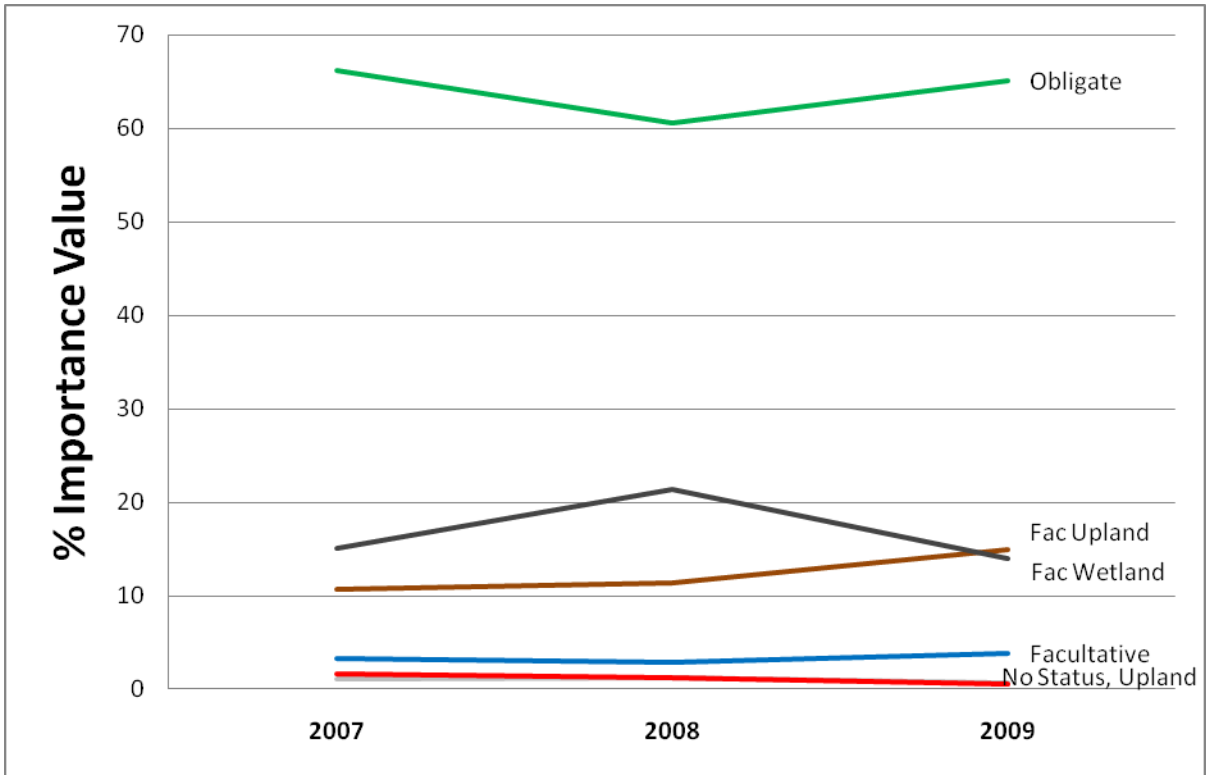


Figure 18. This graph illustrates the relationship between growth forms as expressed by their importance values. Note that not much difference exists between woody plants.

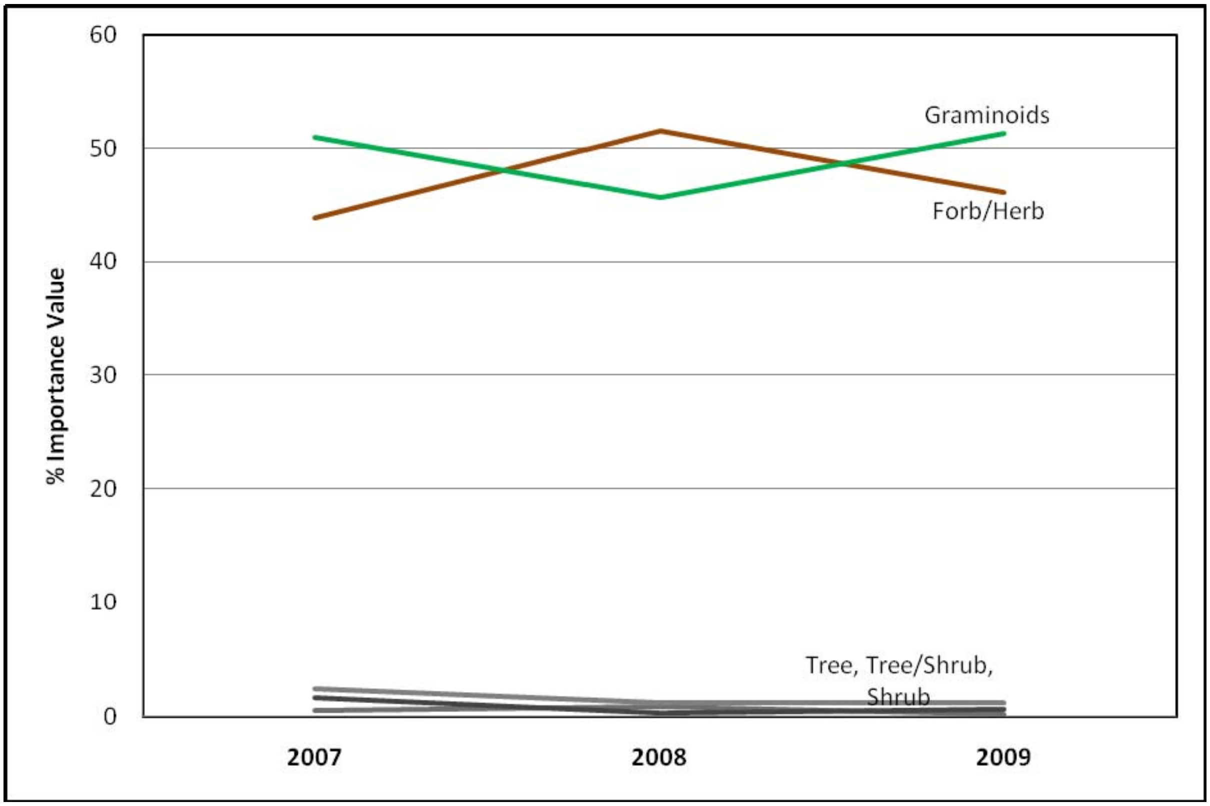


Table 1. List of the 30 most important plants on the project area as determined by the overall importance value (AVE).

GENUS	SPECIES	TAXA	07_IV	08_IV	09_IV	AVE	FORM	LIFE	NAT	WET
Berula	erecta	BEER	12.27	10.97	11.48	**11.57**	F/H	P	N	O
Schoenoplectus	pungens var longispicatus	SCPUL4	22.12	10.25	0.12	**10.83**	G	P	N	O
Meliotus	officinalis	MEOF	4.01	8.17	11.74	**7.98**	F/H	A/B/P	**I**	FU
Leersia	oryziodes	LEOR	6.39	2.52	12.49	**7.13**	G	P	N	O
Schoenoplectus	acutus var. occidentalis	SCACO2	0.03	0.99	19.99	**7.01**	G	P	N	O
Nasturtium	officinale	NAOF	6.44	10.70	1.92	**6.35**	F/H	P	**I**	O
Paspalum	distichum	PADI6	9.37	3.62	4.21	**5.73**	G	P	N	O
Polypogon	monspelienis	POMO5	4.57	6.32	4.57	**5.15**	G	A	**I**	FW
Typha	latifolia	TYLA	3.06	3.47	6.49	**4.34**	F/H	P	N	O
Schoenoplectus	americanus	SCAM6	0.00	9.99	0.00	**3.33**	G	P	N	O
Eleocharis	macrostachya	ELMA5	4.30	2.72	1.67	**2.90**	G	P	N	O
Polygonum	lapathifolium	POLA4	2.32	1.23	4.65	**2.73**	F/H	A	N	O
Cynodon	dactylon	CYDA	3.09	1.73	2.74	**2.52**	G	P	**I**	FU
Agrostis	gigantea	AGGI2	1.27	3.39	2.88	**2.51**	G	P	**I**	FW
Ambrosia	psilostachya	AMPS	2.63	1.45	2.50	**2.19**	F/H	A/P	N	F
Rumex	crispus	RUCR	0.67	3.48	1.43	**1.86**	F/H	P	**I**	FW
Equisetum	laevigatum	EQLA	1.42	1.46	1.33	**1.41**	F/H	P	N	FW
Polygonum	persicaria	POPE3	1.65	2.44	0.09	**1.39**	F/H	A/P	**I**	FW
Equisetum	arvense	EQAR	1.28	1.32	1.25	**1.28**	F/H	P	N	FW
Juncus	articus	JUARL	1.26	1.27	0.70	**1.07**	G	P	N	NO
Plantago	major	PLMA2	1.10	1.09	1.04	**1.07**	F/H	P	N	FW
Salix	exigua	SAEX	0.42	1.10	0.99	**0.84**	T/S	P	N	O
Veronica	anagallis-aquatica	VEAN2	0.92	1.33	0.06	**0.77**	F/H	B/P	N	O
Carex	spp.	CAREX	0.64	0.52	0.47	**0.55**	G	P	N	O
Mentha	spicata	MESP3	0.69	0.28	0.64	**0.54**	F/H	P	**I**	FW
Polypogon	viridis	POVI9	0.27	0.86	0.21	**0.45**	G	P	**I**	FW
Juncus	articulatus	JUAR4	0.00	0.98	0.00	**0.33**	G	P	N	O
Salix	goodingii	SAGO	0.60	0.02	0.21	**0.27**	T	P	N	O
Typha	angustifolia	TYAN	0.76	0.00	0.00	**0.25**	F/H	P	**I**	NI
Paspalum	dilatatum	PADI3	0.01	0.73	0.01	**0.25**	G	P	**I**	F

Table 2. This is the complete list of known plants occurring on the upper Verde River as determined by Alvin L. Medina between 1996-2010. Species noted in bold occurred within 18 transects monitored for this project.

CODE	GENUS	SPECIES	COMMON NAME
ACGR	*Acacia*	*greggii*	*catclaw acacia*
ACNE2	*Acer*	*negundo*	*boxelder*
AGGI2	*Agrostis*	*gigantea*	*redtop*
AGST2	*Agrostis*	*stolonifera*	*creeping bentgrass*
ALOB2	*Alnus*	*oblongifolia*	*Arizona alder*
AMPA	*Amaranthus*	*palmeri*	*carelessweed*
AMCO3	*Ambrosia*	*confertiflora*	*weakleaf burr ragweed*
AMPS	*Ambrosia*	*psilostachya*	*Cuman ragweed, western ragweed*
AMFR	*Amorpha*	*fruticosa*	*desert false indigo*
ANCA10	*Anemopsis*	*californica*	*yerba mansa*
ARLU	*Artemisia*	*ludoviciana*	*white sagebrush*
AVSA	*Avena*	*sativa*	*common oat*
BADI	*Bahia*	*dissecta*	*ragleaf bahia*
BASC5	*Bassia*	*scoparia*	*burningbush*
BASA4	*Baccharis*	*salicifolia*	*seepwillow, mule's fat*
BEER	*Berula*	*erecta*	*stalky berula, cutleaf waterparsnip*
BILA	*Bidens*	*laevis*	*smooth beggartick*
BOBA3	*Bothriochloa*	*barbinodis*	*cane bluestem*
BOCU	*Bouteloua*	*curtipendula*	*sideoats grama*
BRAR5	*Bromus*	*arvensis*	*field brome*
BRCA3	*Brickellia*	*californica*	*California brickellbush*
BRCI2	*Bromus*	*ciliatus*	*fringed brome*
BRDI3	*Bromus*	*diandrus*	*ripgut brome*
BRDIR	*Bromus*	*diandrus*	*ripgut brome*
BRRU2	*Bromus*	*rubens*	*foxtail, red brome, chess*
BRTE	*Bromus*	*tectorum*	*cheatgrass, downy brome*
CAPA47	*Calibrochoa*	*parviflora*	*seaside petunia*
CAPE42	*Carex*	*pellita*	*woolly sedge*
CAPR5	*Carex*	*praegracilis*	*clustered field sedge*
CASE	*Carex*	*senta*	*swamp carex*
CASI2	*Carex*	*simulata*	*analogue sedge, short-beaked sedge*
CAREX	*Carex*	*spp.*	*sedge*
CEDI3	*Centaurea*	*diffusa*	*diffuse knapweed*
CELAR	*Celtis*	*laevigata var. reticulata*	*netleaf hackberry*
CHAL11	*Chamaesyce*	*albomarginata*	*white margin sandmat/ rattlesnake weed*
CHLI2	*Chilopsis*	*linearis*	*desert willow*
CIVU	*Cirsium*	*vulgare*	*bull thistle*
COAR4	*Convolvulus*	*arvensis*	*European glorybind, field bindweed*
COCA5	*Conyza*	*canadensis*	*horseweed fleabane, Canadian horseweed*
CUFO	*Cucurbita*	*foetidissima*	*Missouri gourd*
CUSCU	*Cuscuta*	*spp.*	*Dodder*
CYDA	*Cynodon*	*dactylon*	*Bermudagrass*
CYES	*Cyperus*	*esculentus*	*yellow nutsedge*

CYNI2	Cyperus	niger	black flatsedge
CYPER	Cyperus	spp.	flatsedge
DAGL	Dactylis	glomerata	orchardgrass
DAWR2	Datura	wrightii	jimsonweed, sacred thornapple
DECA18	Deschampsia	caespitosa	tufted hairgrass
DISP	Distichlis	spicata	inland saltgrass
ECCR	Echinochloa	crus-galli	barnyardgrass
ELAN	Elaeagnus	angustifolia	Russian olive
ELCA4	Elymus	canadensis	Canada wildrye
ELEOC	Eleocharis	spp.	spike rush
ELMA5	Eleocharis	macrostachya	pale spike rush
ELPA	Eleocharis	pachycarpa	black sand spikerush
ELPA3	Eleocharis	palustris	common spikerush
ELPA4	Eleocharis	parishii	Parish's spikerush
ELQU2	Eleocharis	quinqueflora	fewflower spikerush
ELEL5	Elymus	elymoides	bottlebrush squirreltail, wildrye sp.
ELGL	Elymus	glaucus	blue wildrye
EPCI	Epilobium	ciliatum	hairy willowherb, fringed willowherb
EQAR	Equisetum	arvense	field horsetail
EQLA	Equisetum	laevigatum	smooth horsetail
ERCI6	Erodium	cicutarium	redstem stork's bill, filaree
ERDI4	Erigeron	divergens	spreading fleabane
ERIN	Eragrostis	intermedia	plains lovegrass
ERUM	Eriogonum	umbellatum	sulphur-flower buckwheat
ERIOG	Eriogonum	spp.	Buckwheat
FOPU2	Forestiera	pubescens	stretchberry
FOPUP	Forestiera	pubescens var pubescens	stretchberry
FRVE2	Fraxinus	velutina	velvet ash
GADI2	Gayophytum	diffusum	spreading groundsmoke
GAMO5	Gaura	mollis	velvetweed, gaura, little-primrose sp.
GAWR3	Garrya	Wrightii	Wright’s silktassel
GLSP	Glossepetalon	spinescens	spiny greasebush
GRNUA	Grindelia	nuda	gumweed sp.
GUSA2	Gutierrezia	sarothrae	broom snakeweed
HEAN3	Helianthus	annuus	common sunflower
HESU3	Heterotheca	subaxillaris	camphorweed
HOJU	Hordeum	jubatum	foxtail barley
HOMUL	Hordeum	murinum ssp. leporinum	leporinum barley
HOLE	Hordeum	leporinum	leporinum barley
HYVE2	Hydrocotyle	verticillata	whorled marshpennywort
JUAR4	Juncus	articulatus	jointed rush
JUARL	Juncus	articus	Baltic rush, wiregrass
JUEF	Juncus	effusus	Common Rush
JUMA	Juglans	major	Arizona Walnut
JUME4	Juncus	mexicanus	Mexican rush
JUNCU	Juncus	spp.	rush
JUMO	Juniperus	monosperma	oneseed juniper

JUNE	*Juncus*	*nevadensis*	*Sierra rush*
JUTE	*Juncus*	*tenuis*	*poverty rush*
JUTO	*Juncus*	*torreyi*	*Torrey's / bur rush*
JUXI	*Juncus*	*xiphoides*	*irisleaf rush*
JUOS	*Juniperus*	*osteosperma*	*Utah juniper*
LASE	*Lactuca*	*serriola*	*prickly lettuce*
LEOR	*Leersia*	*oryziodes*	*rice cutgrass*
LEMNA	*Lemna*	*spp.*	*duckweed*
LEGI	*Lemna*	*gibba*	*swollen duckweed*
LEPID	*Lepidium*	*spp.*	*pepperweed*
LEVA	*Lemna*	*valdiviana*	*valdivia duckweed*
LUPE5	*Ludwigia*	*peploides*	*floating primrosewillow*
LYAS	*Lycopus*	*asper*	*rough bugleweed*
LYHY3	*Lythrum*	*hyssopifolium*	*hyssop loosestrife*
LYPA	*Lycium*	*pallidum*	*pale desert thorn*
MAGR10	*Machaeranthera*	*gracilis*	*slender goldenweed*
MAHA4	*Mahonia*	*haematocarpa*	*red barberry*
MANE	*Malva*	*neglecta*	*common mallow*
MAVU	*Marrubium*	*vulgare*	*common hoarhound*
MEPO3	*Medicago*	*polymorpha*	*burclover*
MEOF	*Meliotus*	*officinalis*	*yellow sweetclover*
MEAR4	*Mentha*	*arvensis*	*wild mint*
MENTZ	*Mentzelia*	*spp.*	*Blazingstar*
MESP3	*Mentha*	*spicata*	*spearmint*
MESA	*Medicago*	*sativa*	*alfalfa*
MIAC3	*Mimosa*	*aculeaticarpa*	*catclaw mimosa*
MIGU	*Mimulus*	*guttatus*	*seep monkeyflower*
MOSQ	*Monroa*	*squarrosa*	*false buffalograss*
MUAS	*Muhlenbergia*	*asperifolia*	*scratchgrass*
NOMI	*Nolina*	*microcarpa*	*beargrass*
NAOF	*Nasturtium*	*officinale*	*watercress*
OEEL	*Oenothera*	*elata*	*Hooker's evening-primrose*
OELA	*Oenothera*	*laciniata*	*cutleaf evening-primrose*
OPUNT	*Opuntia*	*spp.*	*opuntia*
PACA6	*Panicum*	*capillare*	*common witchgrass*
PAQU2	*Parthenocissus*	*quinquefolia*	*Virginia creeper*
PASM	*Pascopyrum*	*smithii*	*western wheatgrass*
PADI3	*Paspalum*	*dilatatum*	*dallisgrass*
PADI6	*Paspalum*	*distichum*	*knotgrass*
PASPA2	*Paspalum*	*spp.*	*crowngrass*
PHAR3	*Phalaris*	*arundinaceae*	*reed canarygrass*
PHAN3	*Phaseolus*	*angustissimus*	*slimleaf bean*
PHAU7	*Phragmites*	*australis*	*common reed*
PLMA2	*Plantago*	*major*	*common / rippleseed plantain*
PLWR2	*Platanus*	*wrightii*	*Arizona sycamore*
POAV	*Polygonum*	*aviculare*	*prostrate knotweed*
PODOT	*Polanisia*	*dodecandra ssp. trachysperma*	*sandyseed clammyweed*

POFE	*Poa*	*fendleriana*	*muttongrass*
POPR	*Poa*	*pratensis*	*Kentucky bluegrass*
POPU3	*Polemonium*	*pulcherrimum*	*Jacob's-ladder*
POLA4	*Polygonum*	*lapathifolium*	*curleytop knotweed, curlytop ladysthumb*
POPE3	*Polygonum*	*persicaria*	*spotted ladysthumb*
POMO5	*Polypogon*	*monspelienis*	*rabbitfoot polypogon*
POVI9	*Polypogon*	*viridis*	*beardless rabbitsfoot grass*
POFR2	*Populus*	*fremontii*	*Fremont cottonwood*
POCR3	*Potamogeton*	*crispus*	*curly pondweed*
POGL9	*Potentilla*	*glandulosa*	*gland cinquefoil*
PORTU	*Portulaca*	*spp.*	*purslane*
PRPA2	*Proboscidea*	*parviflora*	*doubleclaw*
PRVE	*Prosopis*	*velutina*	*velvet mesquite*
PSCAC2	*Pseudognaphalium*	*canescens*	*cudweed sp.*
PSCA11	*Pseudognaphalium*	*canescens*	*cudweed sp.*
PSSP6	*Pseudoroegneria*	*spicata*	*bluebunch wheat grass*
PUST	*Purshia*	*stansburiana*	*cliffrose*
QUGA	*Quercus*	*gambelii*	*gambel oak*
QUTU2	*Quercus*	*turbinella*	*sonoran scrub oak*
RIAU	*Ribes*	*aureum*	*golden current*
RONE	*Robinia*	*neomexicana*	*New Mexican locust*
RUCR	*Rumex*	*crispus*	*curly dock*
SABO	*Salix*	*bonplandiana*	*Bonpland willow*
SAEX	*Salix*	*exigua*	*sandbar, coyote, narrowleaf willow*
SAGO	*Salix*	*goodingii*	*Gooding / black willow*
SALA3	*Salix*	*laevigata*	*red willow*
SATR12	*Salsola*	*tragus*	*prickly Russian thistle*
SAVAP	*Samolus*	*valerandi*	*water-pimpernels sp.*
SASA4	*Sapindus*	*saponaria*	*wingleaf soapberry*
SCAC3	*Schoenoplectus*	*acutus*	*tule bulrush, hardstem bulrush*
SCACO2	*Schoenoplectus*	*acutus var. occidentalis*	*hardstem bulrush*
SCAM2	*Schoenoplectus*	*americanus*	*American, chairmaker's bulrush*
SCAM6	*Schoenoplectus*	*americanus*	*American, chairmaker's bulrush*
SCPA8	*Scirpus*	*pallidus*	*cloaked bulrush*
SCPH	*Schedonorus*	*phoenix*	*tall / Alta / Kentucky fescue*
SCPU10	*Schoenoplectus*	*pungens*	*three-sqaure bulrush*
SCPUL4	*Schoenoplectus*	*pungens var. longispicatus*	*common three-square*
SCPU3	*Schoenoplectus*	*pungens*	*common three-square*
SELAG	*Selaginella*	*spp.*	*spikemoss*
SEVI4	*Setaria*	*viridis*	*green bristlegrass*
SIAL2	*Sisymbrium*	*altissimum*	*tall tumblemustard*
SOEL	*Solanum*	*elaeagnifolium*	*silverleaf nightshade; white horsenettle*
SOAS	*Sonchus*	*asper*	*spiny sowthistle*
SOOL	*Sonchus*	*oleraceus*	*common sowthistle*
SORO	*Solanum*	*rostratum*	*buffaloburr nightshade*
SPPA2	*Sphaeralcea*	*parvifolia*	*smallflower globemallow*
SPAI	*Sporobolus*	*airoides*	*alkali sacaton*

SPCR	*Sporobolus*	*cryptandrus*	*sand dropseed*
SYSU5	*Symphyotrichum*	*subulatum*	*annual saltmarsh aster*
TACH2	*Tamarix*	*chinensis*	*fivestamen tamarisk*
TARA	*Tamarix*	*ramosissima*	*tamarisk, saltcedar*
TAOF	*Taraxacum*	*officinale*	*common dandelion*
TORA2	*Toxicodendron*	*radicans*	*poison ivy*
TRDU2	*Trifolium*	*dubium*	*suckling clover*
TRRE3	*Trifolium*	*repens*	*white clover*
TRTE	*Tribulus*	*terrestris*	*punctire vine*
TYAN	*Typha*	*angustifolia*	*common / narrowleaf cattail*
TYLA	*Typha*	*latifolia*	*broadleaf cattail*
TYPHA	*Typha*	*spp.*	*cattail*
TYGL	*Typha*	*x glauca*	*cattail*
ULPU	*Ulmus*	*pumila*	*Siberian elm*
VETH	*Verbascum*	*thapsus*	*flannel / common mullein*
VEAN2	*Veronica*	*anagallis-aquatica*	*water speedwell*
VIAR2	*Vitus*	*arizonicus*	*canyon grape*
XAST	*Xanthium*	*strumarium*	*rough cockleburr*

Table 3. Average importance values for non-vegetative classes at each selected station by year.

STN	YEAR	SOIL	LITTER	ROCK	GRAVEL
FISH_2	**2007**	21.74	15.03	18.74	2.26
	2008	12.73	5.36	10.21	2.08
	2009	12.64	23.36	7.79	0
	AVE	15.7	14.59	12.25	1.45
4	**2007**	22.4	15.87	8.97	0
	2008	11.28	7.22	3.96	0.03
	2009	13.43	21.98	3.1	0
	AVE	15.7	15.02	5.35	0.01
13	**2007**	24.56	14.3	2.14	6.3
	2008	15.79	7.55	2.04	7.62
	2009	17.31	23.56	1.4	3.49
	AVE	19.22	15.14	1.86	5.8
14	**2007**	23.64	17.85	0.12	0
	2008	23.96	5.94	1.34	0
	2009	21.74	24.29	0	0
	AVE	23.12	16.03	0.49	0
15	**2007**	26.66	10.16	5.88	0.73
	2008	13.72	2.88	1.54	0.08
	2009	19.16	24.63	0.89	0
	AVE	19.85	12.56	2.77	0.27
17	**2007**	19.7	15.41	1.88	0.61
	2008	11.14	10.12	1.64	1.12
	2009	14.04	24.14	0	0
	AVE	14.96	16.56	1.17	0.57
18	**2007**	23.83	14.16	12.34	2.89
	2008	12.36	7.08	3.7	0.08
	2009	16.58	23.43	3.02	0
	AVE	17.59	14.89	6.35	0.99

RESPONSE OF NON-VEGETATIVE COVER

On average, 60% of the cover for all three years was from plant cover, the remaining cover was from non-vegetative components of the riparian community. Of that 40%, soil comprised more than half (22%) and litter comprised 15%, leaving rock and gravel to make up the remaining 3%. Figure 19 shows the average percent importance value for each of the abiotic elements for all 3 monitoring periods. Soil was the dominant component of the abiotic environment in 2007 and 2008, but litter increased significantly from 2008 to become the dominant component in 2009. Figure 20 shows the proportion of native, introduced, and non-vegetative importance value averaged across all stations each year. In 2008 the proportion of importance value accounted for by abiotic elements decreased significantly but returned to 2007 levels in 2009 (Figures 19 & 20).

Figure 19. This graph illustrates the relationships between abiotic classes as expressed by their importance value on the 18 permanent monitoring stations.

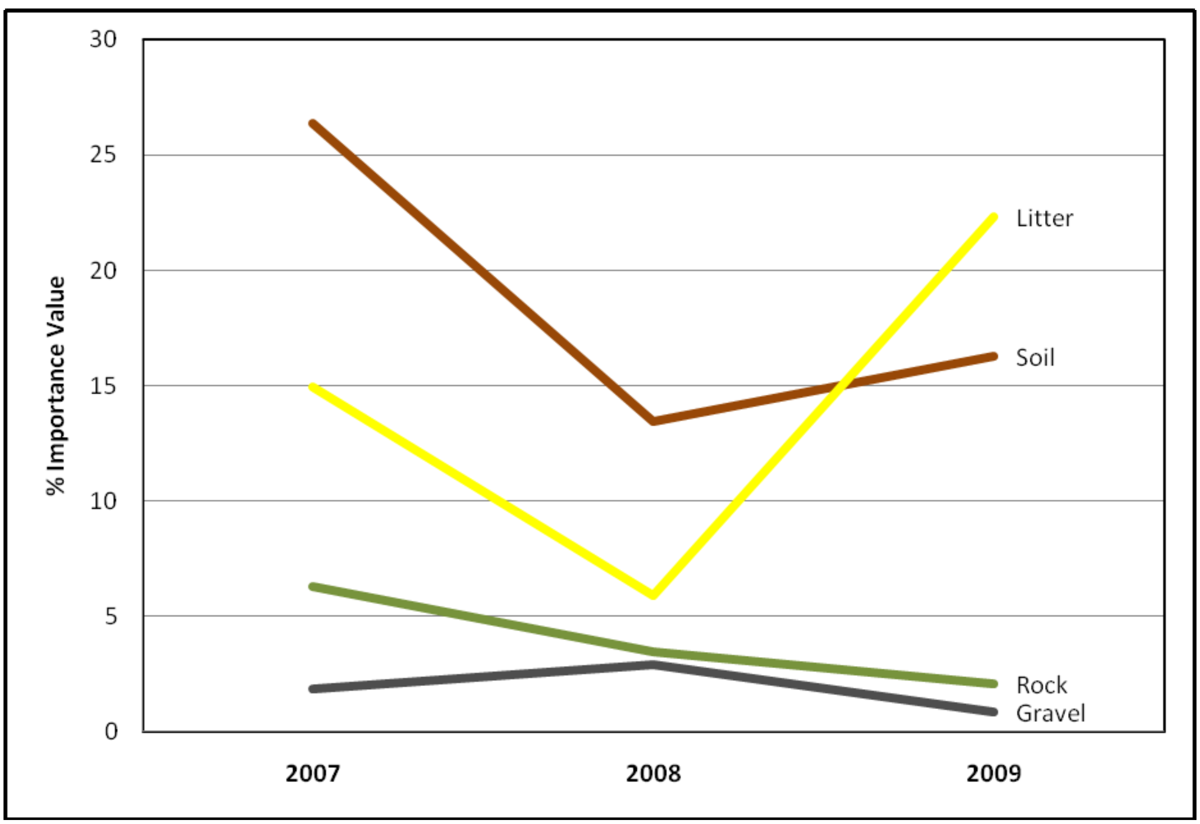
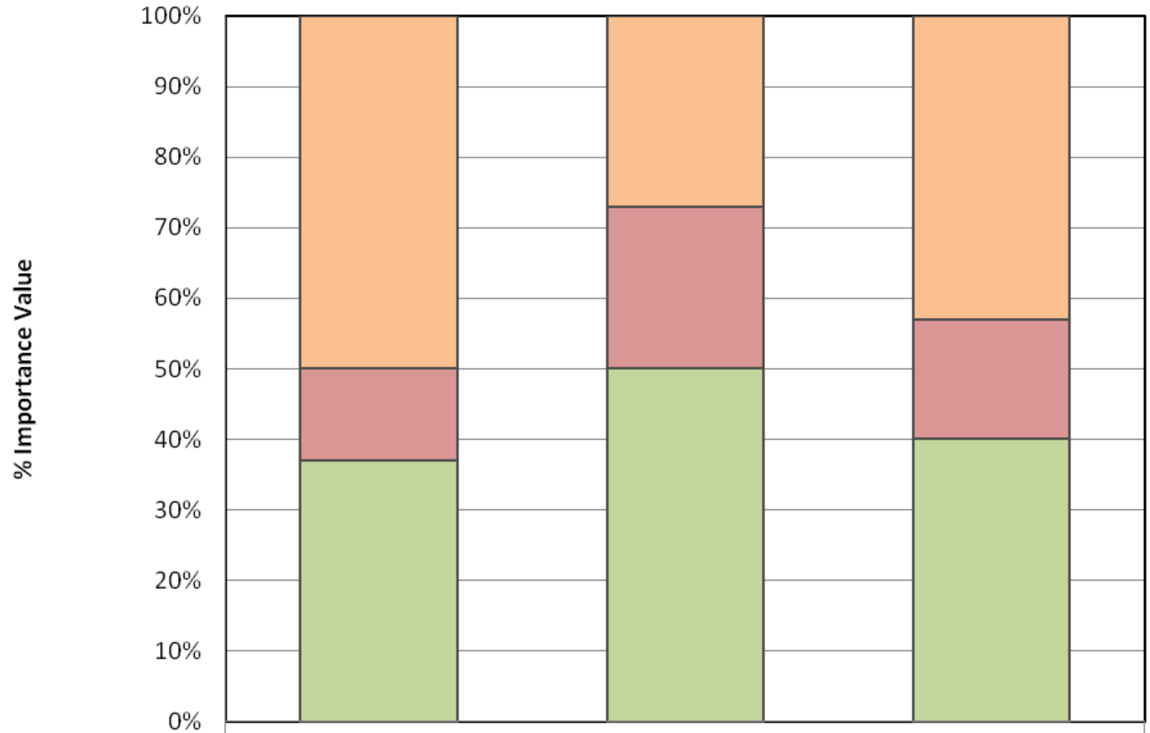


Figure 20. Average importance value of native, introduced, and non-vegetative classes at all stations by year.



	2007	2008	2009
Non-vegetative	50	27	43
Introduced	13	23	17
Native	37	50	40

Summary of Data Analyses

From the analysis of all stations and all years and the 7 stations that we analyzed in detail we were able to discern some general trends about the vegetative changes that took place during the tamarisk treatment period. Using 2007 as a baseline (pre-treatment) monitoring period and 2009 as a finished (post-treatment) monitoring period, we were able to compare the pre-and post- treatment environment. The analysis of the 7 permanent monitoring stations mirrors that of the analysis from the 18 permanent monitoring stations. Additionally, tamarisk stem densities were reduced at the tamarisk monitoring plots associated with the 7 monitoring stations as well as at all the tamarisk monitoring plots. The monitoring of the riparian vegetation alongside the upper Verde River during tamarisk removal shows that in general, the *riparian vegetative community is dominated by native grasses, forbs, shrubs and trees, most of which grow perennially and are wetland species. This community changed little from 2007 to 2009. In other words, the only thing that changed from a riverine health perspective was the reduction in tamarisk density, which was one of the principal goals of the removal project.*

DISCUSSION of MONITORING

Much of the success of this project is due to three factors: project design, highly skilled technicians, and treatment applications. The project was designed to take into account unforeseen factors and mitigate their consequences in an adaptive context. The 3-year plan to to cut and spray in year one, followed by re-spray treatments in years two and three proved to be a very effective method to locate and re-treat sprouts that would have otherwise been left to regrow into new plants. Additionally, it can be extremely difficult to inventory every tamarisk plant amidst dense stands of woody vegetation. When the population of tamarisk gets high near 20-25 percent, there is a constant expansion of many young plants that can escape detection until their growth is evident in subsequent years. We were able to treat hundreds of young plants that grew after the initial inventory, because of our 3-year treatment plan. GPS technology greatly assisted our annual surveys and improved the accuracy of acreage estimates and plant distributions. Our plan also embraced multiple options to facilitate transport of personnel and equipment to the work sites. Trucks, ATV's and helicopter were used to decrease travel time and increase actual work time and job safety.

The physical treatment process is a major factor affecting the degree of plant mortality. Highly skilled technicians were used to perform the physical and chemical treatment of very large mixed aged stands, some requiring extensive labor to prepare (Photo 2), while others are easier to access, yet require removal of debris about the basal area (Photos 3, 4). Failure to remove debris and expose the basal stems can result in high resprouting rates and require retreatment and possibly even subsequent re-excavation. A common fault of tamarisk cutting is to "crew cut" the stems at 2-3 feet and leaving stubble-stumps, rather than cutting at the root crown level or thereby. This stubble creates obstacles where flood debris gathers and causes undue bed erosion about the plant stubble. The desired outcome should be obstacle-free. Cut stems should be removed from the floodplain wherever feasible and stacked on adjacent terraces in key locations so as to create cover habitat for ground dwelling birds and other wildlife, as well as to abate erosion from terraces (Photo 5).

The herbicides, Garlon 4 Ultra and Habitat, used proved to be effective in killing tamarisk and other invasive trees, e.g. Russian olive, Siberian elm. Their careful application (specifically of Habitat) in situations near water resulted in nearly 100 percent mortality from one treatment, thereby reducing costs. The use of good quality equipment reduced down time. Here is another facet of work where professional trained technicians performed outstanding work to insure complete coverage of all visible plants.

Photo 2. This large stand of tamarisk required a crew of 30+ and took nearly 4 days to treat.

Photo 3. This young tamarisk is considerably easier to access and treat, yet requires removal of the basal debris.

Photo 4. Extensive preparation of tamarisk plants may be required before cutting and spraying with herbicide.

Photo 5. Cut brush should be stacked on adjacent terraces to create habitat for wildlife.

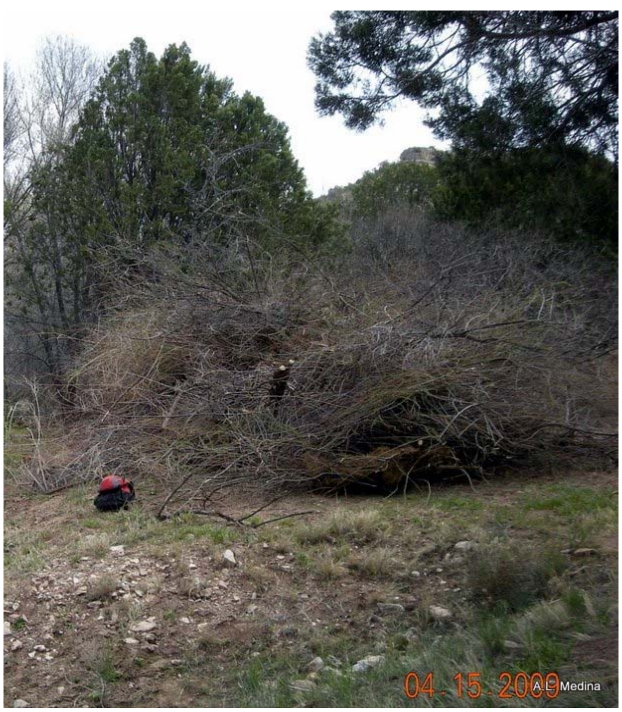
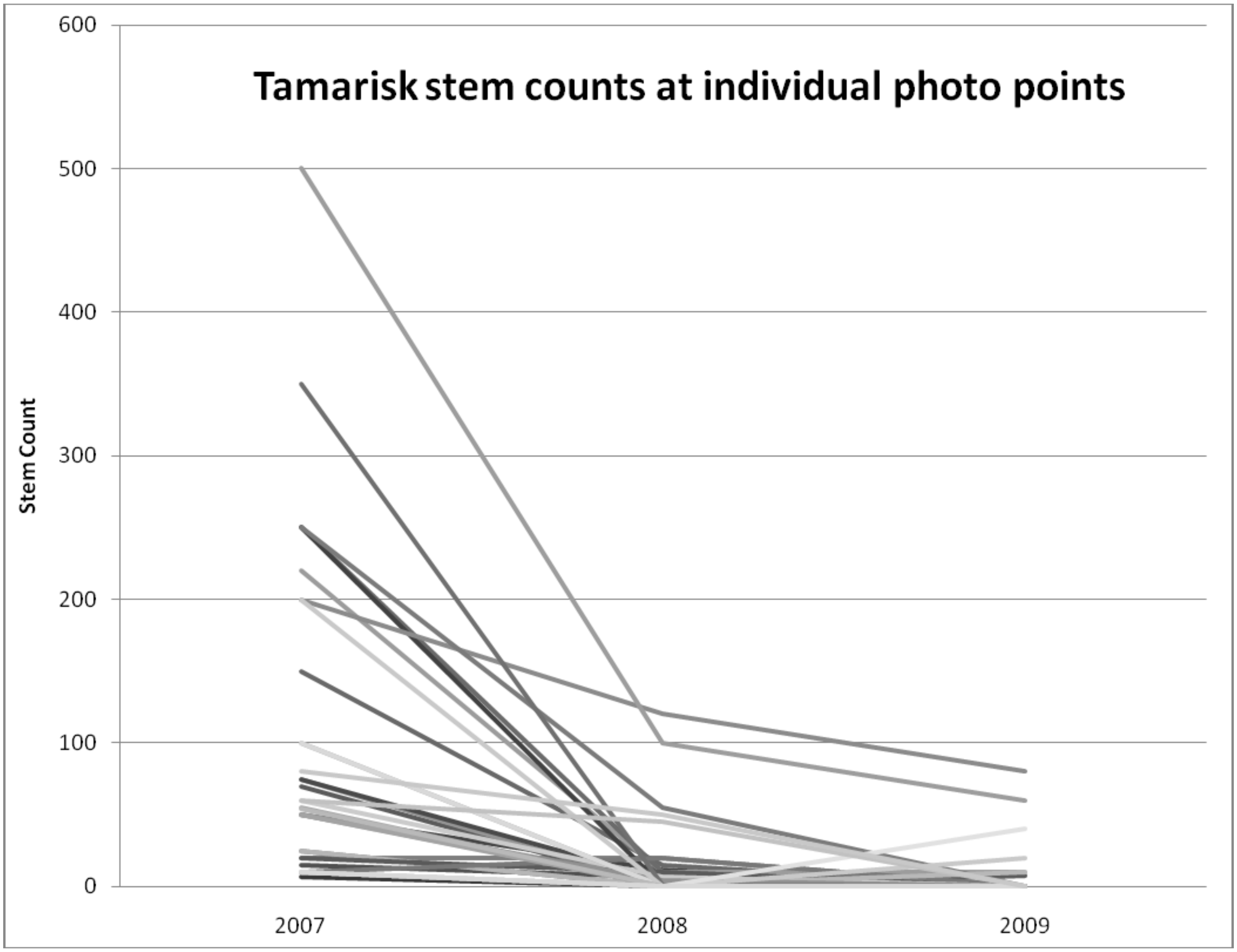


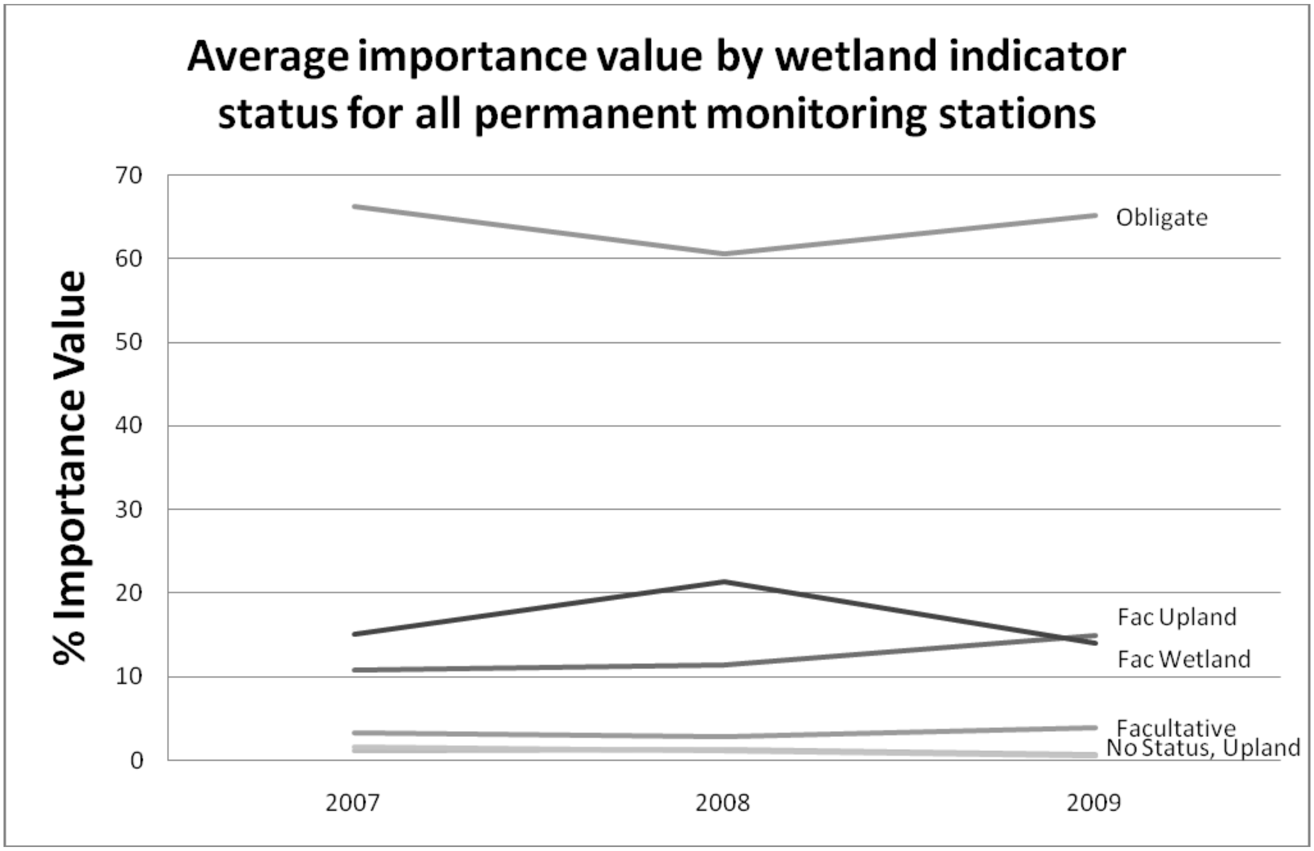
Photo 6. Some tamarisk stands are very dense with old growth and require removal of cut brush away from the work area.

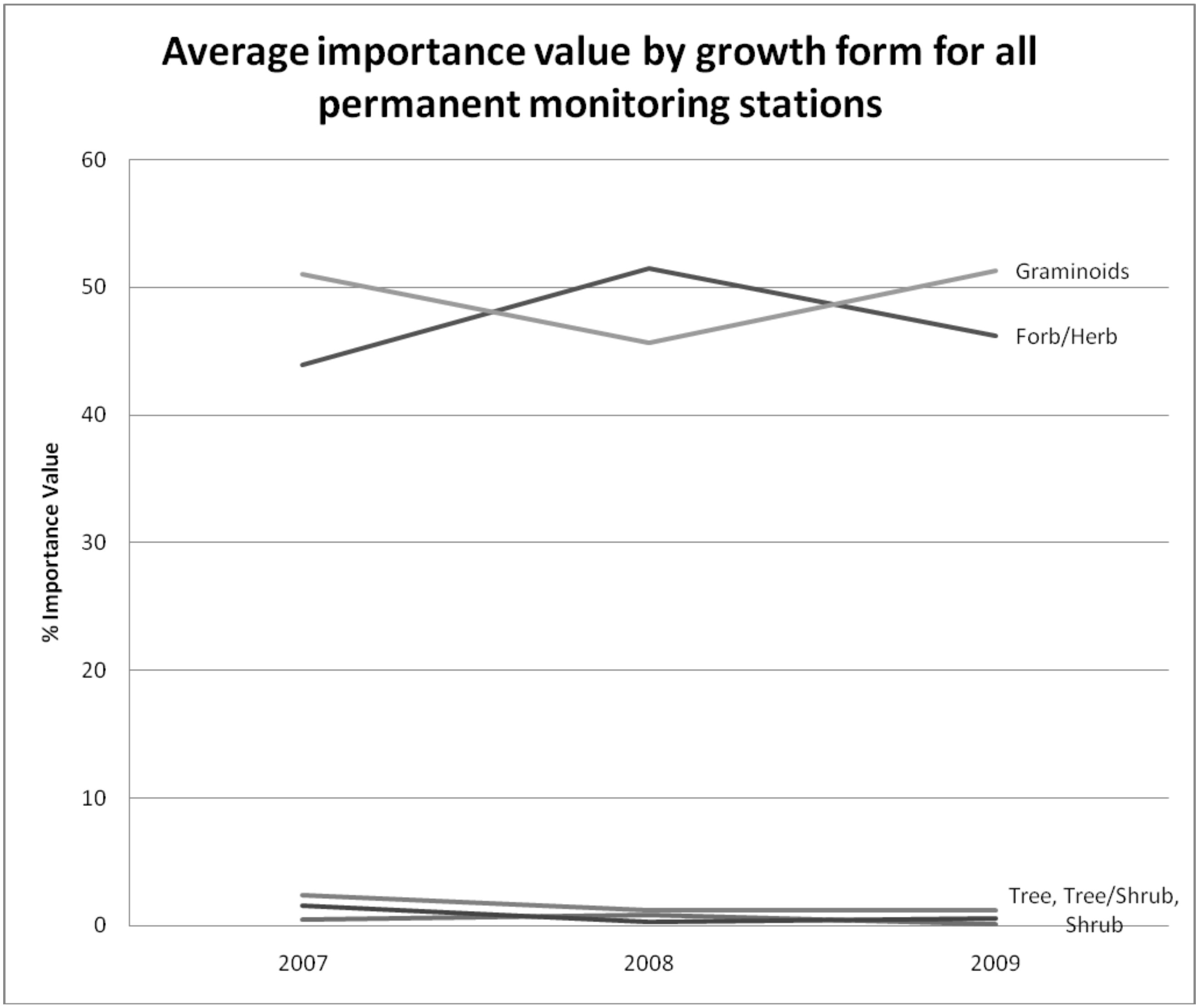
Photo 7. Crews are often required to prepare tamarisk stands by working in the water, thereby making the tasks more hazardous.

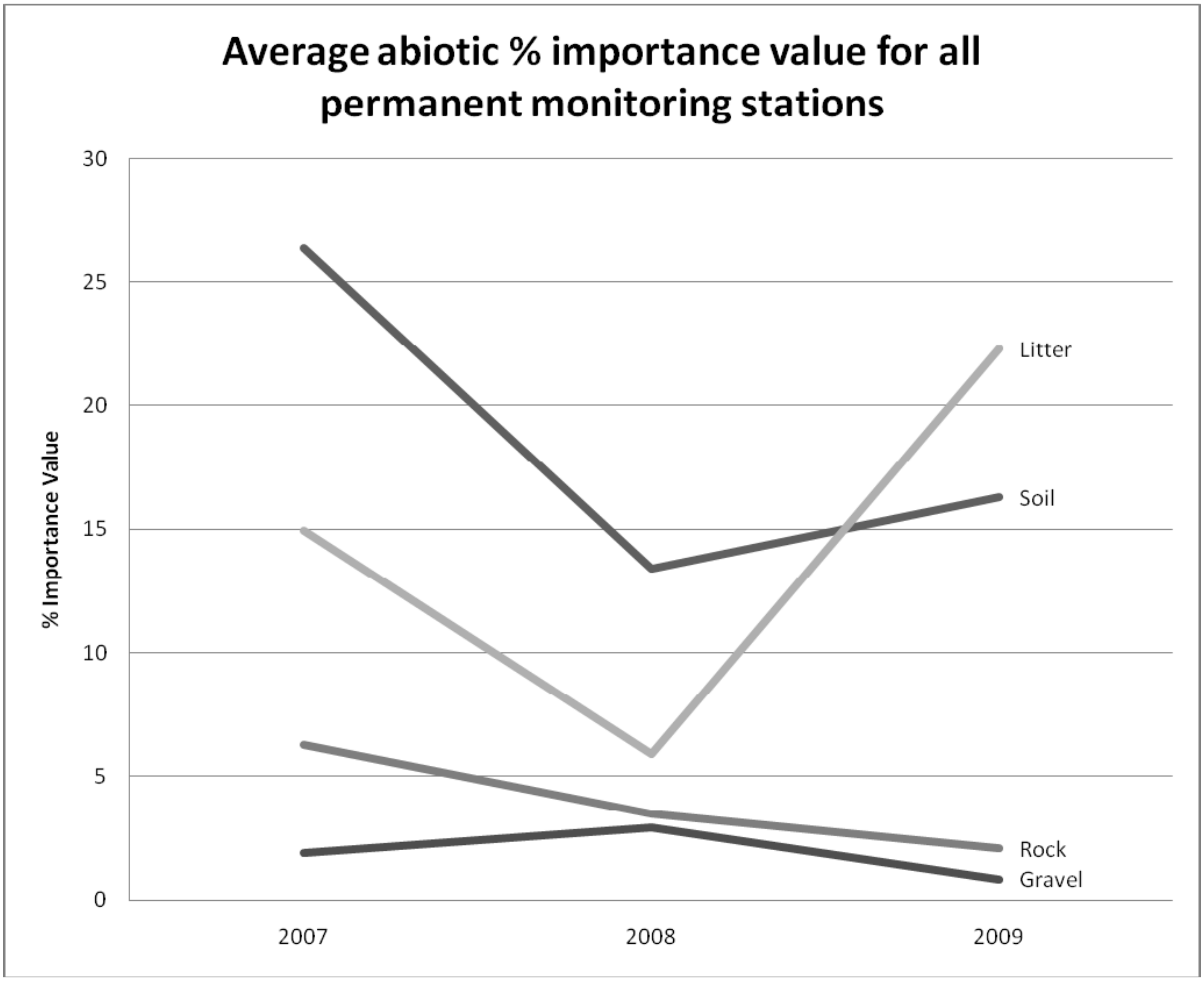
Photo 8. These paired photos exemplify a typical tamarisk stand before and after treatment on the upper Verde River.



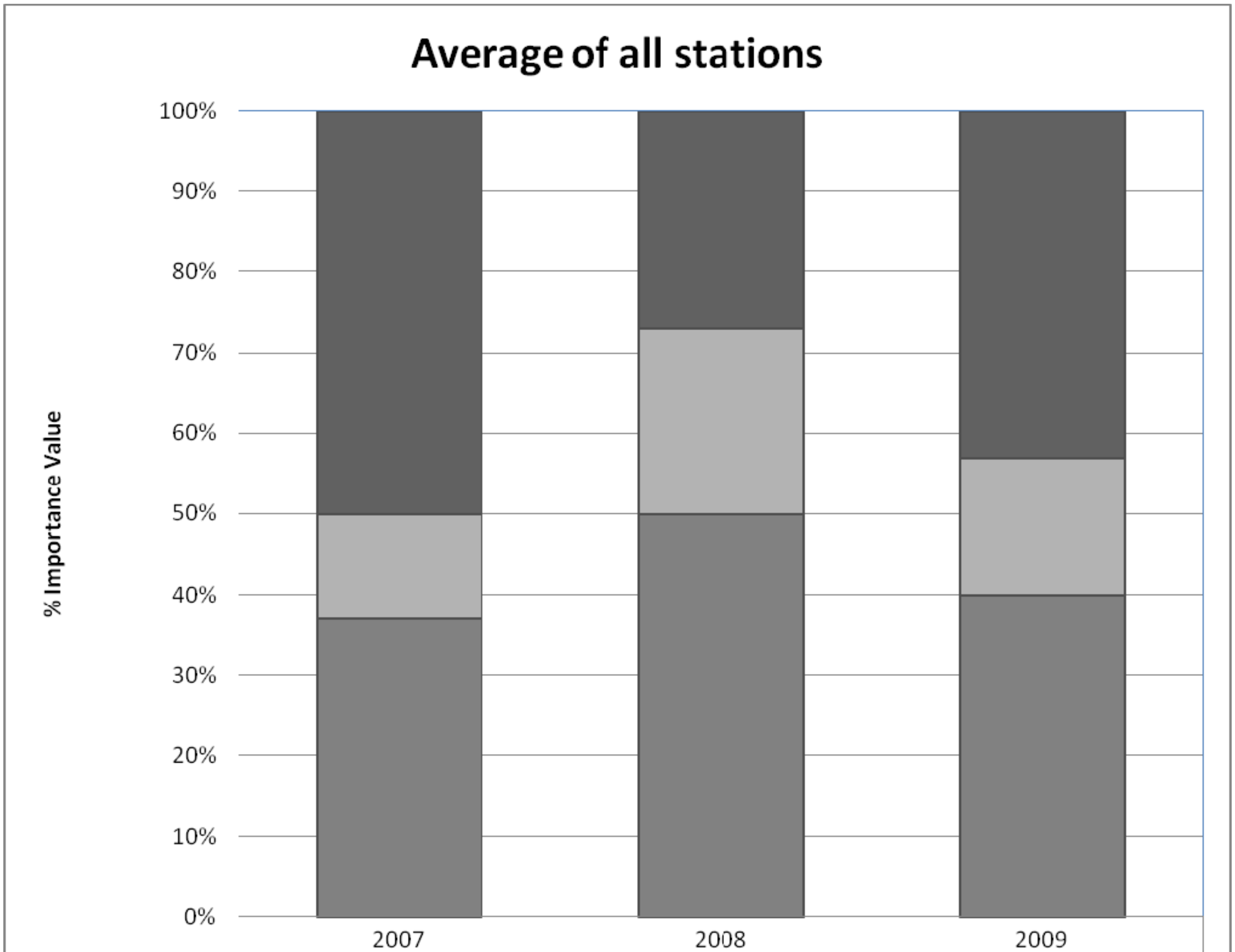
Tamarisk stem counts at individual photo points
Stem Count
600
500
400
300
200
100
0
2007
2008
2009


Average importance value by wetland indicator status for all permanent monitoring stations
% Importance Value
70
60
50
40
30
20
10
0
2007
2008
2009
Obligate
Fac Upland
Fac Wetland
Facultative
No Status, Upland

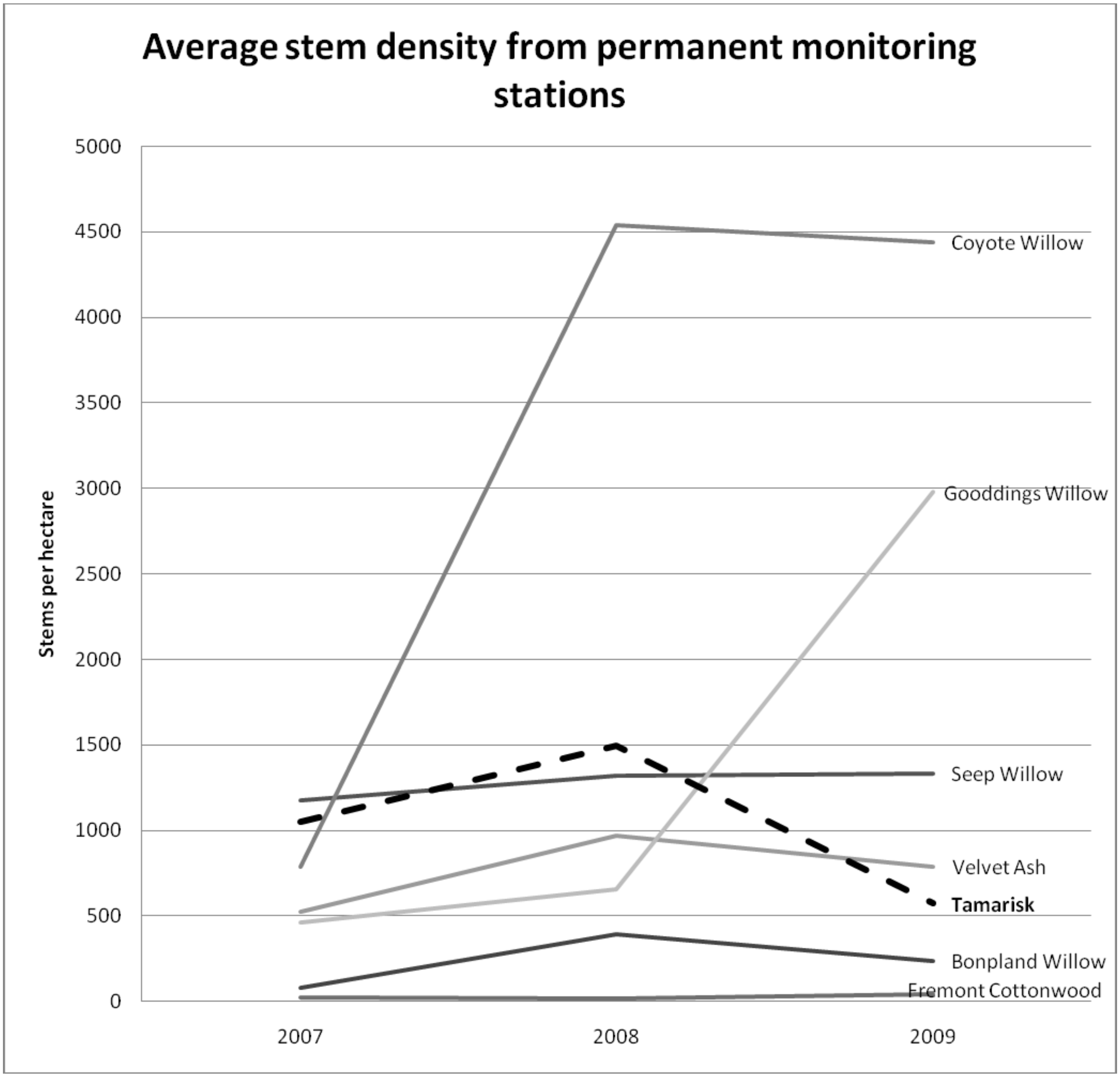

Average importance value by growth form for all permanent monitoring stations
% Importance Value
60
50
40
30
20
10
0
2007
2008
2009
Graminoids
Forb/Herb
Tree, Tree/Shrub, Shrub



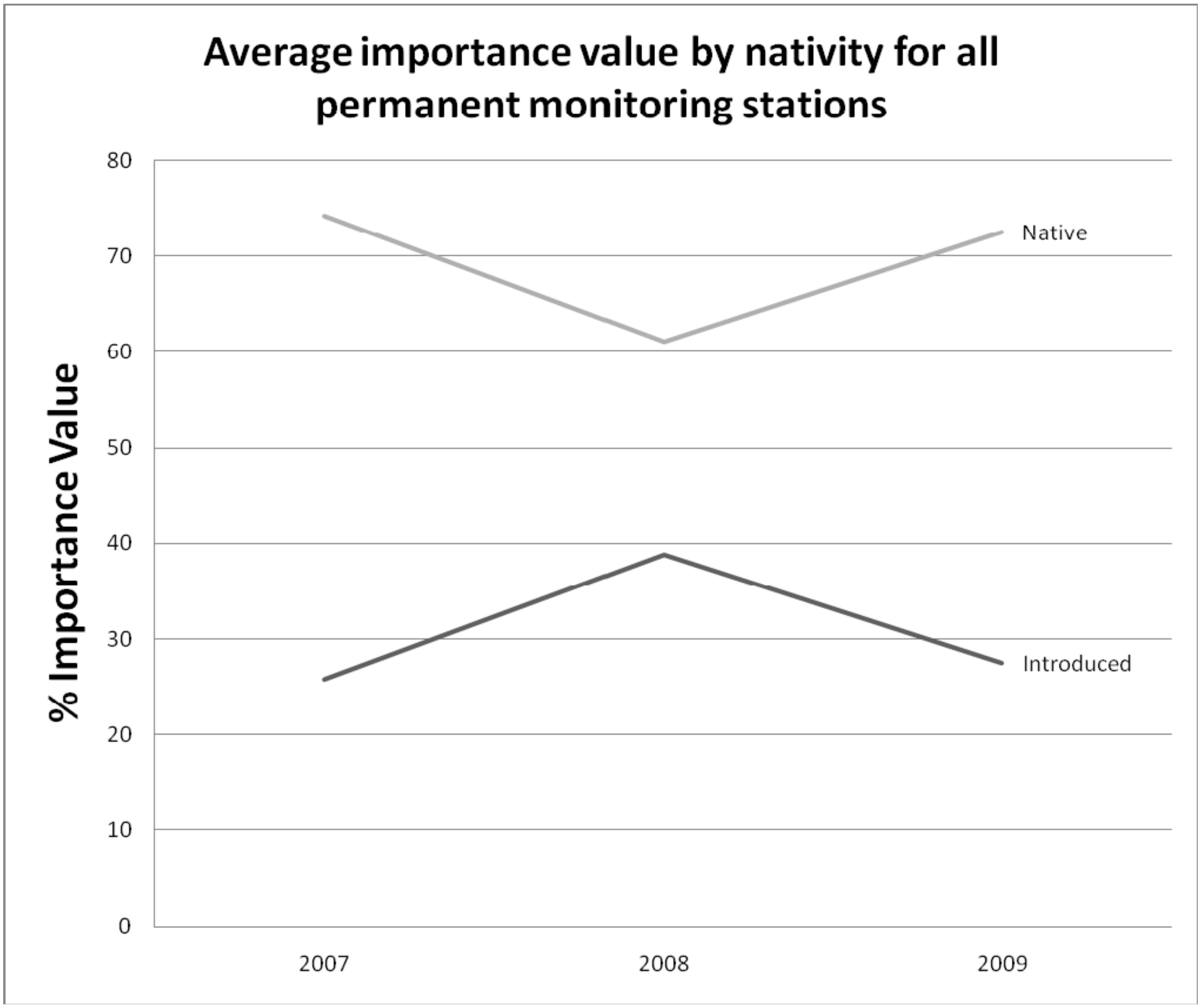
Average abiotic % importance value for all permanent monitoring stations
% Importance Value
30
25
20
15
10
5
0
2007
2008
2009
Litter
Soil
Rock
Gravel

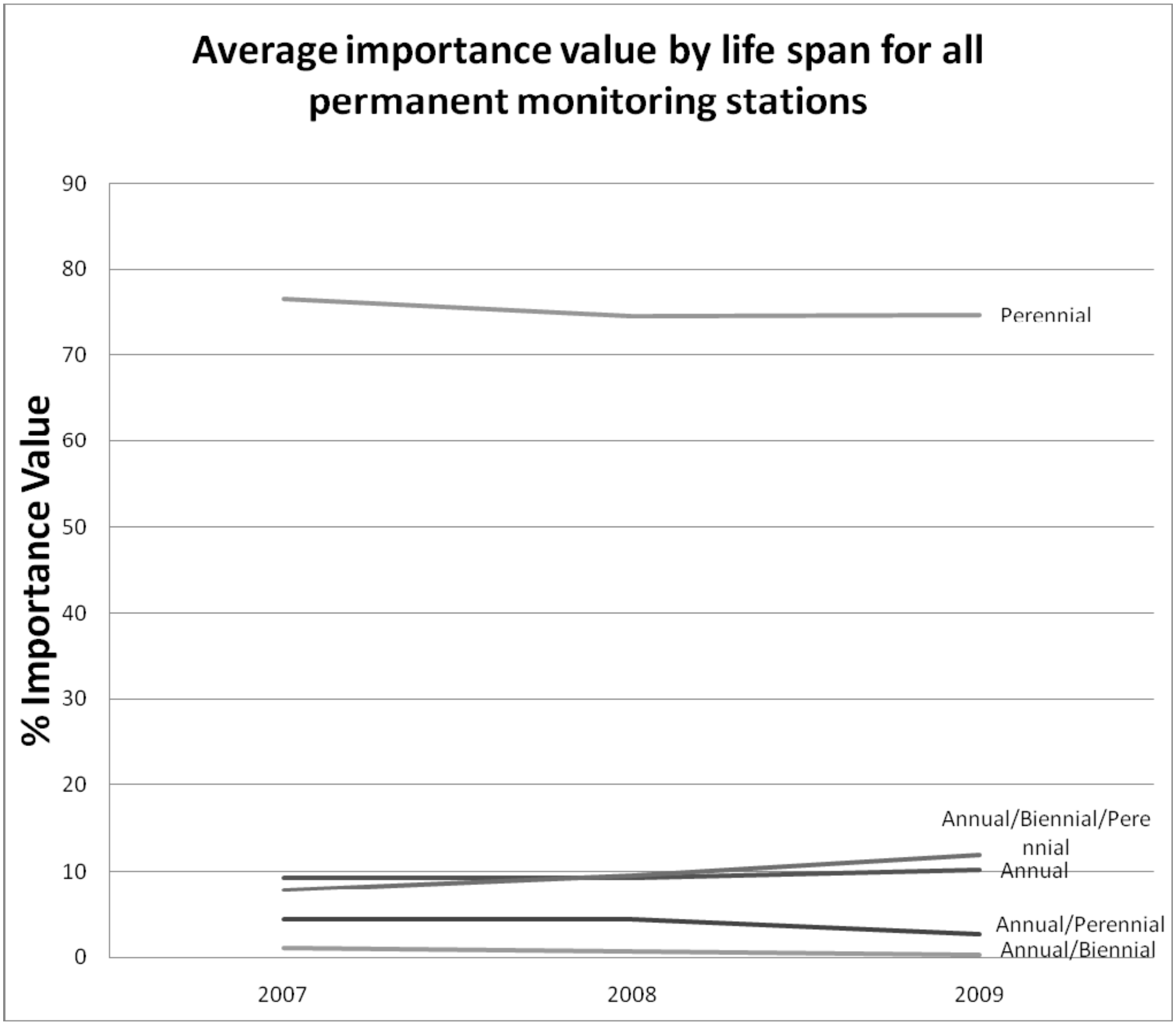


	2007	2008	2009
Non-vegetative	50	27	43
Introduced	13	23	17
Native	37	50	40


Average stem density from permanent monitoring stations
Stems per hectare
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
2007
2008
2009
Coyote Willow
Gooddings Willow
Seep Willow
Velvet Ash
Tamarisk
Bonpland Willow
Fremont Cottonwood

TAXA	GENUS	SPECIES	%IV	% Cover	%FREQ	% Con	FORM	LIFE	NAT	WET	COMMON NAME
BEER	Berula	erecta	10.86 {1}	13.53 {1}	9.95 {1}	100 {1}	F/H	P	N	O	stalky berula, cutleaf waterparsnip
SCPUL4	Schoenoplectus	pungens var. longispicatus	10.24 {2}	11.38 {2}	9.35 {2}	70.37 {17}	G	P	N	O	common three-square
MEOF	Meliotus	officinalis	9.08 {3}	7.73 {4}	8.44 {3}	100 {1}	F/H	A/B/P	I	FU	yellow sweetclover
LEOR	Leersia	oryziodes	7.36 {4}	7.28 {5}	7.32 {4}	98.14 {4}	G	P	N	O	rice cutgrass
SCACO2	Schoenoplectus	acutus var. occidentalis	7.33 {5}	8.59 {3}	5.83 {5}	42.59 {26}	G	P	N	O	hardstem bulrush
NAOF	Nasturtium	officinale	5.57 {6}	6.28 {6}	5.75 {6}	94.44 {6}	F/H	P	I	O	watercress
POMO5	Polypogon	monspelienis	5.26 {7}	4.79 {8}	5.74 {7}	100 {1}	G	A	I	FW	rabbitfoot polypogon
PADI6	Paspalum	distichum	4.96 {8}	5.59 {7}	5.41 {8}	98.14 {4}	G	P	N	O	knotgrass
POLA4	Polygonum	lapathifolium	2.94 {9}	2.21 {12}	3.23 {9}	83.33 {12}	F/H	A	N	O	curleytop knotweed, curlytop ladysthumb
ELMA5	Eleocharis	macrostachya	2.53 {10}	2.61 {11}	3.21 {10}	90.74 {10}	G	P	N	O	pale spike rush
CYDA	Cynodon	dactylon	2.30 {11}	3.00 {9}	1.88 {14}	79.62 {14}	G	P	I	FU	Bermudagrass
AGGI2	Agrostis	gigantea	2.29 {12}	2.96 {10}	1.79 {15}	77.77 {15}	G	P	I	FW	redtop
AMPS	Ambrosia	psilostachya	2.15 {13}	1.47 {13}	2.76 {11}	92.59 {8}	F/H	A/P	N	F	Cuman ragweed, western ragweed
RUCR	Rumex	crispus	1.77 {14}	1.41 {14}	2.16 {13}	94.44 {6}	F/H	P	I	FW	curly dock
EQLA	Equisetum	laevigatum	1.58 {15}	0.66 {20}	2.29 {12}	85.18 {11}	F/H	P	N	FW	smooth horsetail


Average importance value by nativity for all permanent monitoring stations
% Importance Value
80
70
60
50
40
30
20
10
0
Native
Introduced
2007
2008
2009



Public outreach

The following is a listing of public outreach activities conducted:

- The local Forest Service District Ranger informed key agency specialists, environmental organizations, ranchers and concerned publics about this project before work started.
- An initial tri-fold brochure was made for classroom use. Information on the project was presented to student groups at the local Chino middle/high school and to two NAU forestry

classes. Noted environmental writer Dan Dagget did photography, created a PowerPoint presentation, and helped present to the Chino school.

• Our project botanist, Tyler Johnson, presented three oral presentations and three poster presentations on this project to professional meetings at various conventions concerned with tamarisk and invasive plant control. He also published his master's thesis and a professional paper on this project.

• A meeting was held at the USFS Chino Ranger District office with representatives from the Arizona Game and Fish and The Nature Conservancy (who own the Verde River headwaters properties directly upstream from this project) to discuss their role in treating tamarisk on their lands.

• Through frequent informational meetings with over 40 different crew members doing tamarisk treatment, Al Medina educated them about changes in the river system and how treatments can improve conditions.

• A media day was held in April 2010 with representatives from the Prescott National Forest and Prescott's newspaper The Daily Courier. An article about the project was published in The Daily Courier on July 14th.

• On July 13, 2010 42 students from all areas of Yavapai County and six supervisors with the Yavapai Summer Youth program spent six hours on the river learning about how riverine ecosystem works, how the river has changed, and what this tamarisk removal project has accomplished. They constructed large slash piles on two sections of river to benefit wildlife.

• A final 8-panel brochure entitled "Tamarisk Removal on the Upper Verde River; Protecting a Desert Jewel" (see attached) was produced in July 2010 to explain the purpose and the results of the project. The brochureis to be distributed widely to local and regional Forest Service and BLM offices, for placement in lobby displays, at to environmental organizations. The brochure presents an example of how seven entities collaborated to do this project, and it offers a list of tips for success to others in encouraging them to effectively eliminated invasive trees on waterways in their areas.

• A project overview is kept on our EcoResults web site (www.Ecoresults.org)

Photo 9. Al Medina of the USFS Rocky Mountain Research Station instructs Summer Youth Program crews.

Photo 10. Summer Youth Program crews stack slash to create wildlife habitat.

6. SUMMARY and RECOMMENDATIONS

Evaluation of Project Success

The three main goals of this project were met: 1) Stands of tamarisk were reduced in the headwaters of the Verde River while preserving the native plant species diversity; 2) Comprehensive monitoring was conducted on both temporary vegetation plots as well as continuing data collection on permanent monitoring stations, and 3) Public outreach efforts reached hundreds of students through presentations and activities, hundreds of professional scientists through symposia and papers, and hundreds of residents of the region through news articles and brochures provided through Forest Service and BLM offices.

The elimination of all large tamarisk stems and the 98.7 percent total eradication of all tamarisk on this 12 mile section of river means that maintenance followup treatments will be simple. At a minimum, one person can retreat the small resprout stems in a few days of walking the river with an herbicide applicator, and not even need to carry a chainsaw. Russian olive, Siberian elm and Russian Knapweed were also treated by crews.

The success of this project exemplifies how private organizations can assist land management agencies to achieve land restoration goals for the long-term benefit of Arizona's communities. This project was a cooperative undertaking led by EcoResults Institute (www.ecoresults.org) and the Arizona Water Protection Fund Commission, with technical assistance from the U.S. Forest Service Prescott National Forest and Rocky Mountain Research Station, Flagstaff, Arizona. Pioneer taramisk removal on the Y-D Ranch and Verde River Ranch inspired the project. On-site work was performed by the Lake Mead Exotic Plant Management Team and the Coconino Rural Environment Corps.

Recommendations for follow-on projects

This project treated the first 12 miles of the Upper Verde River starting at the western boundary of the Forest Service, which is located within three miles of where the river waters originate from springs located on lands owned by the Arizona Game and Fish and The Nature Conservancy. It is desirable that tamarisk also be eradicated on these lands, as well as on the ephemeral Granite Creek watershed, so that seeds will not float downstream and reinfest the treated areas. There are an additional 21 miles of the downstream from this project which need to be treated to eliminate tamarisk on the whole of the Upper Verde River.

Following the comprehensive guidelines posted on the AWPF website is recommended to assure thorough planning to avoid project delays and to do good field documentation for monitoring and reporting purposes.

Meeting with the public agencies, local ranchers, local environmental groups and concerned citizens is recommended early in the planning process to obtain support for the project as well as secure volunteers to help with the projects many phases.

Success tips for other projects

This project provided us an opportunity to share with many people countless work experiences. Herein, we provide several recommendations for other restorationists that would endeavor similar work. The single most important recommendation is that a maintenance schedule is needed to maintain control over the expansion of tamarisk in the upper Verde River. This schedule can span between 3-5 years to perform re-spray treatment of young plants. The density, distribution, and aggressiveness of new stands pretty much dictate when treatments are needed. Re-treatment by spraying is the most cost effective method to control tamarisk and associated invasive trees on the upper Verde River. It is estimated that a single re-treatment may be accomplished within a 2-week period over the same project area.

In addition, the following are additional recommendations that provide for project efficiency and effectiveness.

- *Careful planning is a requisite of any tamarisk control project. Plan to work over at least a 3-4 year period to allow time for complete initial removal and treatment of massive stands, time to see which stands exhibit resprouting, and time to do additional respraying.*
- *Do a thorough inventory of all invasive plants. Treat other species as part of the project for better overall treatment effectiveness.*
- *Do a thorough initial GPS mapping of stands and selection of monitoring sites. This is essential to monitor project success as flooding can cause major changes in site conditions once plants are removed.*
- *Install basic monitoring plots that include the spatial diversity of tamarisk stands. 25 photopoint sites which include 10 meter transects is adequate and will help make conclusions more solid in light of treatment, flooding and weather impacts.*
- *Employ only hardy and well-trained crews to assure plants are first prepared well by removing all flood debris, plant stems are then cut at the base close to the ground, and then spayed properly with the appropriate herbicide.*
- *Remote riparian areas often have access limitations, so obtain necessary clearances to facilitate transport of materials and personnel to increase field efficiency.*
- *Cut and treat tamarisk when plants are actively growing, yet when temperatures are not so hot that the herbicide vaporizes.*
- *Plan to avoid rainy periods or flooding periods. Allow a 20% downtime cost estimate for uncontrollable delays from weather, equipment and scheduling problems.*
- *Plan re-spray treatments 1.5 to 2 years after initial treatment to allow enough time to detect surviving plants, while also allowing plants time to produce enough growth to effectively translocate herbicide to surviving roots.*
- *Stack cut stems in piles to benefit wildlife. Do this either on benchland or lodged between native brush and trees to secure it from flood removal.*