LOWER SANTA CRUZ RIVER
RIPARIAN VEGETATION 2015 SURVEY REPORT

FINAL

SUBMITTED TO:
PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT
TUCSON, ARIZONA 85701

SUBMITTED BY:
HARRIS ENVIRONMENTAL GROUP, INC.
650 N 6TH AVE
TUCSON, ARIZONA 85705

JANUARY 2016

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RIPARIAN VEGETATION ASSESSMENT
2015 SURVEY REPORT

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97 EAST CONGRESS, 3RD FLOOR
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JANUARY 2016

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ACRONYMS

DBH: Diameter at Breast Height
EPA: Environmental Protection Agency
FAC: Facultative
FACU: Facultative Upland
FACW: Facultative Wetland
GIS: Geographic Information Systems
GPS: Global Positioning System
NITRO#: Nitrogen Affinity Score
OBL: Obligate (wetland)
PCRFCD: Pima County Regional Flood Control District
SEINet: Southwest Environmental Information Network
SOW: Statement of Work
UPL: Upland
WIS#: Wetland Indicator Score
WRF: Wastewater Reclamation Facility

INTRODUCTION

Harris Environmental Group, Inc. (Harris Environmental) is under contract with Pima County Regional Flood Control District (PCRFCD) to conduct vegetation surveys along the Santa Cruz River in Tucson, Arizona. The purpose of this study is to determine the effects of facility upgrades at two Wastewater Reclamation Facilities (WRF) on native riparian vegetation. This study is part of a comprehensive, Environmental Protection Agency (EPA)-funded assessment for ecological impacts of improved water quality and changes in effluent volume.

Pima County's $660 million investment for facility upgrades included: 1) the construction of the Agua Nueva WRF, completed mid-December of 2013 to replace the 60-yr old Roger Road WRF that was decommissioned on 8 January 2014; and 2) upgrades to the Tres Rios WRF, completed on 11 October 2013. While Agua Nueva improves the quality of water discharged into the Lower Santa Cruz River (LSCR), the total discharge may decrease from its historical volume due to less overall water being treated as well as increased use of recycled water for municipal purposes. Tres Rios WRF now handles more total metropolitan sewage than Agua Nueva, which increases the total volume of treated water discharged from the Ina outfall.

In 2013, baseline data was collected prior to the WRF upgrades and the first year of post-treatment data was collected in 2014. Data collected in 2015 comprises the second year of post-treatment data. Thus, this report summarizes the third year of vegetation data collected from eight sample sites along the Santa Cruz River. A secondary purpose of this study is to compare results with research along other riparian reaches across the region. The surveys are

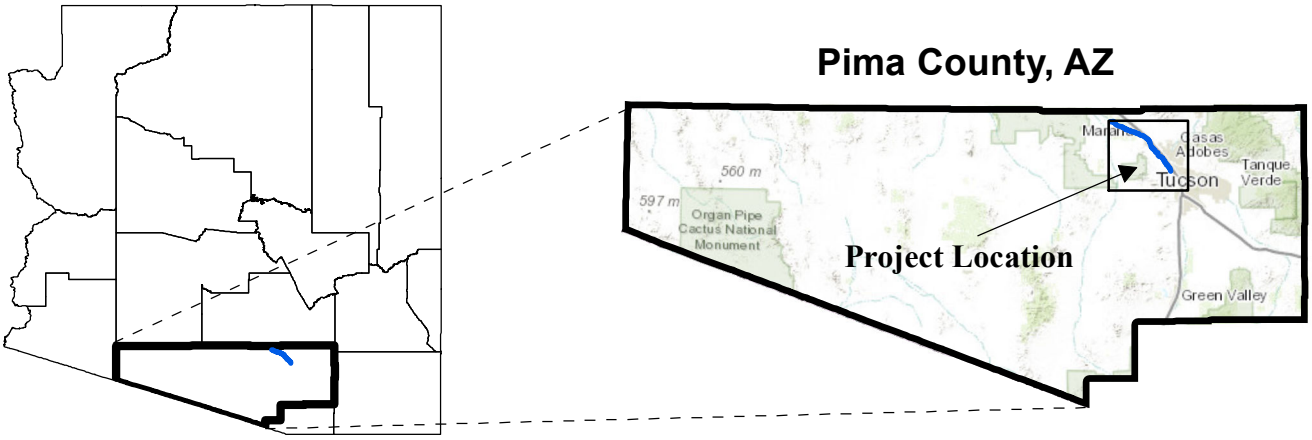
designed to measure vegetation during the growing season when precipitation is lowest and vegetation is most dependent on effluent flows. Therefore, surveys were conducted from May 22 - June 18, 2015 after spring leaf out and before the initiation of summer monsoons.

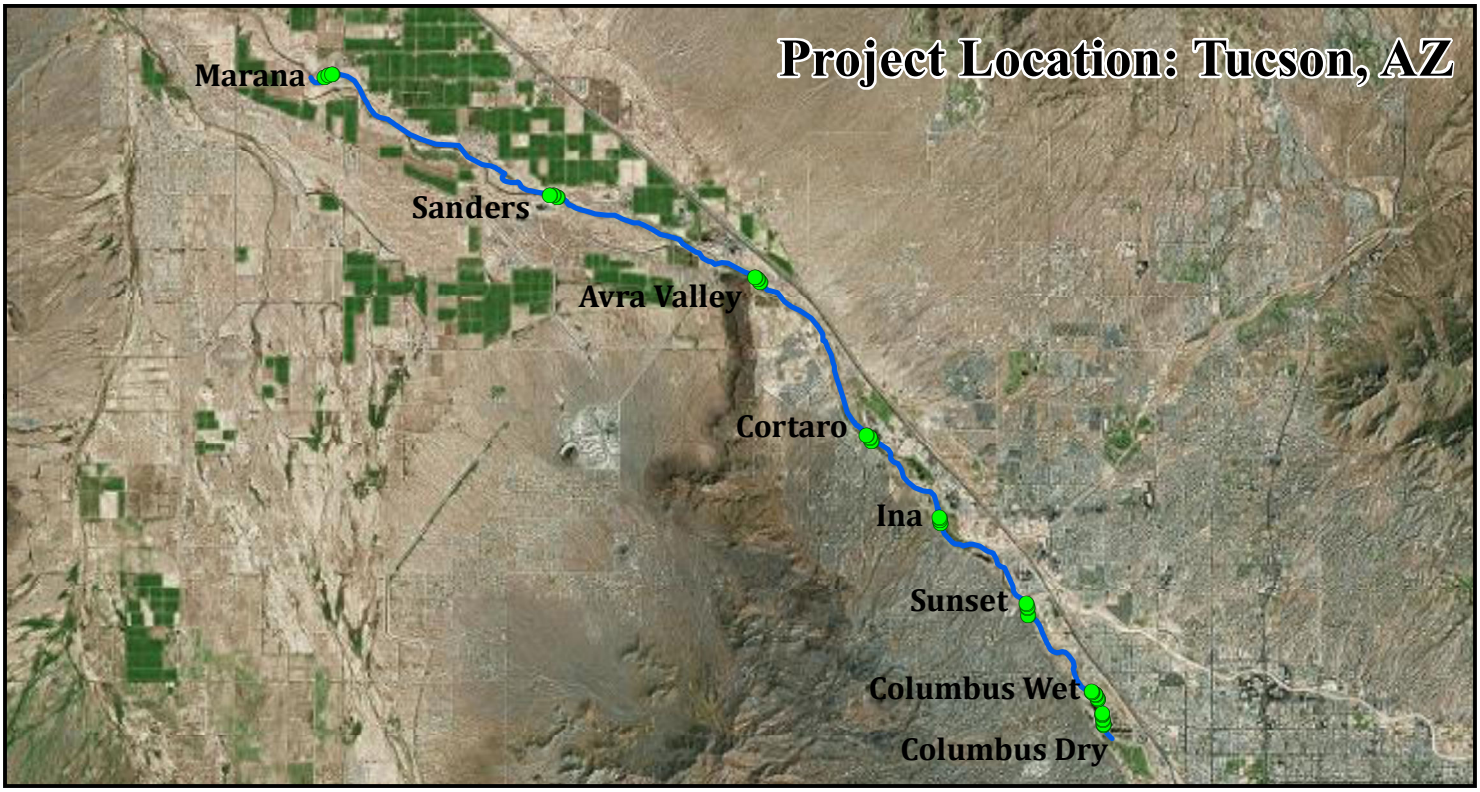
PROJECT LOCATION

The Santa Cruz River flows from south-to-north extending from the US-Mexico international border to the confluence of the Gila River. Surveys for this project were conducted along the LSCR from the city of Tucson to the town of Marana in Pima County, AZ (Figure 1). Specifically, we examined a 40-kilometer [km] (25-mile [mi]) stretch of the LSCR spanning from a reach adjacent to Christopher Columbus Park (12S 0497161 m E, 3571679 m N) to a reach downstream, just south and east of Trico-Marana Rd (12S 0473698 m E, 3590743 m N). Within the project area, the width of the main channel ranges from 8-20 meters [m] (26-66 feet [ft]) with a floodplain width ranging anywhere from 80-500+ m (262-1640+ ft) wide. Stabilized embankments, typically consisting of man-made soil cement, are common along this stretch of the river and often constrain the width of the floodplain to ~100 m. While the channel is free to meander independently throughout many river miles, an edge of the main channel's low-flow often abuts these stabilized banks, which impacts vegetation growth within these reaches.

Excluding significant winter and monsoon rains that can result in seasonal runoff, 100% of the baseflows within the study reach are supported by two outfalls that discharge treated effluent from the Agua Nueva and Tres Rios WRFs. Discharge from the Agua Nueva WRF enters the LSCR via the Roger outfall near Roger Rd and heads north toward the confluence with the Ina outfall, which discharges treated effluent from the Tres Nuevos WRF near Ina Rd.

Lower Santa Cruz River
Streamside & Woody Vegetation Assessment





Miles
0 1 2 4 6 8

HARRIS ENVIRONMENTAL GROUP INC

Map produced by D. Bunting, Harris Environmental, 2015

Legend

- Vegetation Transects
- Study Reach

PIMA COUNTY FLOOD CONTROL

N

ENVIRONMENTAL SETTING

The LSCR is within the basin and range topography typical of southern Arizona. Most of the study area is within the Arizona Upland subdivision of the Sonoran Desertscrub biotic community, but a few areas are characteristic of vegetative zones of the Lower Colorado River subdivision (Brown, 1994). Historically, perennial stretches were more common in the 19thcentury; however, shallow groundwater and seasonal rainfall often produced baseflow for many weeks of the year until the mid-20th century (Wood et al., 1999). In the mid-1900s, factors such as groundwater and surface water pumping, excessive wood-cutting, and overgrazing drastically impacted dense riparian gallery forests of cottonwood (*Populus* spp.), willow (*Salix* spp.), and mesquite (*Prosopis* spp.; Rea, 1983; Bahr, 1991). These negative impacts reduced the overall distribution of riparian gallery forests, reduced tree height and diameter, and altered species composition (Webb and Leake, 2006; Webb and Leake, 2007). Today, native vegetation along the Santa Cruz River includes abundant velvet mesquite (*Prosopis velutina*) and Goodding's willow (*Salix gooddingii*), while non-native species include two tamarisk species (*Tamarix ramosissima* and *T. aphylla*). Streamside herbaceous vegetation consists of obligate and facultative wetland plants, including mixed native and non-native grasses, and encroaching upland vegetation. Current river conditions and associated vegetation communities reflect current management strategies including flood control and prevention, and an altered hydrological regime consisting of treated wastewater discharge at varying volumes throughout the day and year.

SURVEY SITES

In 2013, eight survey sites were selected within river reaches provided by the PCRFCD (Figure 1). The first survey site is located upstream from the Roger outfall and serves as the control site as it is not influenced by reclaimed water (Veg_1). The next three sites are located downstream from the Roger outfall, but upstream from the Ina outfall (Veg_2, Veg_3, Veg_4); and the remaining four locations were downstream from the Ina outfall (Veg_5, Veg_6, Veg_7, Veg_8; Figure 1). The following section describes each site in detail from upstream to downstream.

Site 1 (Veg_1), Columbus Park Dry

The first survey site serves as the control site because it is the only survey reach that is not influenced by treated effluent. This site is located southeast of Christopher Columbus Park and slightly less than 200 m upstream of the Roger outfall. This reach has stabilized banks to the east and the west of the main channel and the width from bank to bank is less than 100 m. Singlewhorl burrobrush (*Hymenoclea monogyra*) is the most abundant species at this site and upland vegetation dominates the landscape.

Site 2 (Veg_2), Columbus Park Wet

The second survey site is located northeast of Columbus Park with the nearest transect beginning approximately 250 m north and downstream of the Roger outfall. The eastern edge of the main channel abuts a stabilized soil cement embankment. This is the first site downstream from the Roger outfall and upstream from the Ina outfall. This site supports larger, facultative phreatophytic trees (i.e., trees using both groundwater and the unsaturated zone for growth and survival) such as *S. gooddingii* and *Tamarix* spp., but soil cement along the eastern border limits growth to the west side of the main channel.

Site 3 (Veg_3), Sunset Rd.

The third survey site lies parallel to Silverbell Rd. and just north of the east-west plane of Sunset Rd. A gravel pit borders the site to the east and power lines cross the river in three separate areas. This is the second site downstream from the Roger outfall and upstream of the Ina outfall. Vegetation is mainly a mix of native species such as *S. gooddingii* and Mexican paloverde (aka. Jerusalem thorn, *Parkinsonia aculeata*), and a high terrace above the eroded western bank includes upland species such as wolfberry (*Lycium* spp.), creosotebush (*Larrea tridentada*), and cattle saltbush (*Atriplex polycarpa*).

Site 4 (Veg_4), Ina Rd.

The fourth survey site is over 200 m south of Ina Rd. and just over 100 m south and upstream of the Ina outfall. This is the furthest site downstream that receives water discharge from the Roger outfall alone. Baseflows through this reach appear to be greatly reduced since the completion of the Agua Nueva WRF. In fact, this site lacked baseflows during the 2014 and 2015 surveys. Small to very large trees are prevalent at this site and include *Tamarix* spp. and *S. gooddingii*.

Site 5 (Veg_5), Cortaro Rd.

The fifth survey site is located just west of Marana Golf Continental Ranch and is over 600 m northwest of Cortaro Rd. This site is relatively open and is the first site to receive treated

wastewater from the Ina WRF. A small sandbar is present at the first transect upstream, a large channel bar encompasses most of the middle transect, and an embankment impacts the third transect downstream. Few trees exist at this site and shrubs such as *H. monogyra* and *Baccharis* spp. dominate the landscape. In 2015, it was noted that the channel had shifted from its 2014 path with an apparent increase in aquatic vegetation near the center of the reach.

Site 6 (Veg_6), Avra Valley Rd.

The sixth survey site lies parallel to Avra Valley Rd and has a stabilized eastern bank made of soil cement. This site is unique in that the main channel is incised with steep slopes or banks on both sides ranging from three to eight meters. This is the second site to receive treated wastewater from the Ina WRF. Thick stands of non-native, shrubby *T. ramosissima* dominate this site with *B. salicifolia* common in the understory and large stands of *Arundo donax* lining the narrow channel. This site also is less than ½ km downstream from Lake Marana, a basin that was inundated after large storms in September 2014. Noticeable increase of refuse, turbidity, and odor was documented during the 2015 surveys compared to prior years. This was likely a result of the accumulation of debris and stagnant water in Lake Marana, with subsequent outflows back into the LSCR mainstem during increased discharges.

Site 7 (Veg_7), Sanders/Tangerine Rd.

The seventh site, also referred to as "Sanders" is located upstream from and east of Sanders Rd and south and west of Tangerine Rd. This site also has an eastern bank stabilized with soil cement. Channel bars and sand bars are common at this site and contains a large drainage to the east of the middle transect, which likely introduces high volume runoff through a culvert during large storm events. This is the third site to receive treated wastewater from the Ina WRF. The main channel runs roughly east-south-east to west-north-west with the most common woody species being *Tamarix* spp. and common aquatic plants including floating mats and grasses.

Site 8 (Veg_8), Marana-Trico Rd.

The eighth survey site is located south and east of Trico-Marana Rd. The main channel is sinuous along this reach heading east to west then meandering southwest. This is the fourth site to receive treated wastewater from the Ina WRF and is the last study site within the study reach. Large *T. aphylla* dominate the site, but *T. ramosissima* and *S. gooddingii* also are common. This particular site is very remote and active cattle grazing is evident. Plants common at this site in 2013 and 2014, but not common to other sites upstream, include cursed buttercup (*Ranunculus sceleratus*), false daisy (*Eclipta prostrata*, and sedge species (*Cyperus* spp). However, in 2015, no baseflows were present, streamside herbaceous vegetation was scarce, and defoliated and dead trees dominated the landscape.

METHODS

The PCFCD provided site maps with GPS coordinates and restrictions (e.g., jurisdiction/right of entry) to eight survey areas in 2013. Pre-treatment surveys in 2013 included both streamside herbaceous and woody shrub vegetation surveys (HEG 2013). The 2014 surveys were conducted at the same eight survey areas, but only included streamside herbaceous vegetation (HEG 2014). The 2015 field campaign included both streamside herbaceous and woody vegetation surveys, the latter of which may be compared to Light Detection and Ranging (LiDAR) data obtained within the same growing season. Each site included three streamside herbaceous transects with associated upstream and downstream coordinates (Appendix A). We adapted survey methods and analyses from protocols implemented by the Stromberg Research Group, Arizona State University. The metrics and indices used are amenable to other sites, thus, a secondary goal was to be able to compare results with research along other riparian reaches across the region.

Streamside Herbaceous Surveys

We surveyed streamside herbaceous vegetation using four, 20-m transects spaced approximately 100-m apart and parallel to each streambank (Figure 2). Gridded, 1-m x 1-m sampling frames (i.e., quadrats) were used to estimate vegetation cover percentage (Figure 2). The 2014 survey increased the number of quadrats per transect from three to four to increase the sample size. While adding more samples minimally affects overall time and effort, more replications result in better representation of each study site and provide for a more robust analysis with higher statistical power. If an edge of the low-flow channel abutted a stabilized embankment, then a total of eight randomized quadrats were placed along two, 20-m transects on the opposite bank.

We used a stopwatch to pick four random locations along each transect by separating the hundredths of seconds on the stopwatch into five, 20-interval categories (i.e., 0.00-0.19, 0.20-0.39, 0.40-0.59, etc.) to match 1-m intervals of a 20-m transect (Table 1). We also implemented a stratified random rule where at least two quadrats would land in each of the two, 10-m halves of each transect (i.e., no three randomized quadrats could land in the first 10 m or second 10 m of each transect). On each side of the main channel, streamside vegetation was surveyed along the margin of low-flow perpendicular to the randomized transect locations. As suggested by PCRFC staff, stream flow has a diurnal pattern with the first wave of high flow is in the morning resulting from residents beginning their work day. As a result, actual stream flow is dependent on time of survey and location of survey with respect to the upstream outfall. Because placement was inherently subjective, the front edge (i.e., the edge closest to the main channel) of each quadrat was placed at the front edge of the first patch of vegetation influenced by channel moisture. We categorized the moisture at this interface as dry, moist, <3 cm, 3-10 cm,

or >10 cm deep. This strategy allowed for obligate wetland plants to be included in the surveys when present, but also assessed vegetation reaching one meter onto a sandbar, channel bar, or the channel's edge.

A standard cover-abundance class approach was used to estimate cover of each species (FGDC 2008). Specifically, a modified Braun-Blanquet approach was used to assign a cover percentage to each species identified within each quadrat (Braun-Blanquet 1932). Estimating cover percentage is inherently variable among surveyors. It should be noted that one person (i.e., D. Bunting) has made all estimates of streamside plant cover from 2013 to present, which limits subjectively. Herbaceous or woody species not originating in the quadrat but overhanging were included in the survey. Each cover estimate corresponded to a midpoint value falling into one of five possible cover classes (Table 2). For example, if a species covered approximately 30% of the quadrat, then the species was given a value of 37.5, which represents the mid-point between the 25-50% cover class category.

Table 1. Stopwatch table used to randomize quadrats within 20-m transects (whole seconds are ignored).

	Potential Stopwatch Readings				
Quadrat Placement	**0.00-0.19**	**0.20-0.39**	**0.40-0.59**	**0.60-0.79**	**0.80-0.99**
0-1 m	0.00	0.20	0.40	0.60	0.80
1-2 m	0.01	0.21	0.41	0.61	0.81
2-3 m	0.02	0.22	0.42	0.62	0.82
3-4 m	0.03	0.23	0.43	0.63	0.83
4-5 m	0.04	0.24	0.44	0.64	0.84
5-6 m	0.05	0.25	0.45	0.65	0.85
6-7 m	0.06	0.26	0.46	0.66	0.86
7-8 m	0.07	0.27	0.47	0.67	0.87
8-9 m	0.08	0.28	0.48	0.68	0.88
9-10 m	0.09	0.29	0.49	0.69	0.89
10-11 m	0.10	0.30	0.50	0.70	0.90
11-12 m	0.11	0.31	0.51	0.71	0.91
12-13 m	0.12	0.32	0.52	0.72	0.92
13-14 m	0.13	0.33	0.53	0.73	0.93
14-15 m	0.14	0.34	0.54	0.74	0.94
15-16 m	0.15	0.35	0.55	0.75	0.95
16-17 m	0.16	0.36	0.56	0.76	0.96
17-18 m	0.17	0.37	0.57	0.77	0.97
18-19 m	0.18	0.38	0.58	0.78	0.98
19-20 m	0.19	0.39	0.59	0.79	0.99

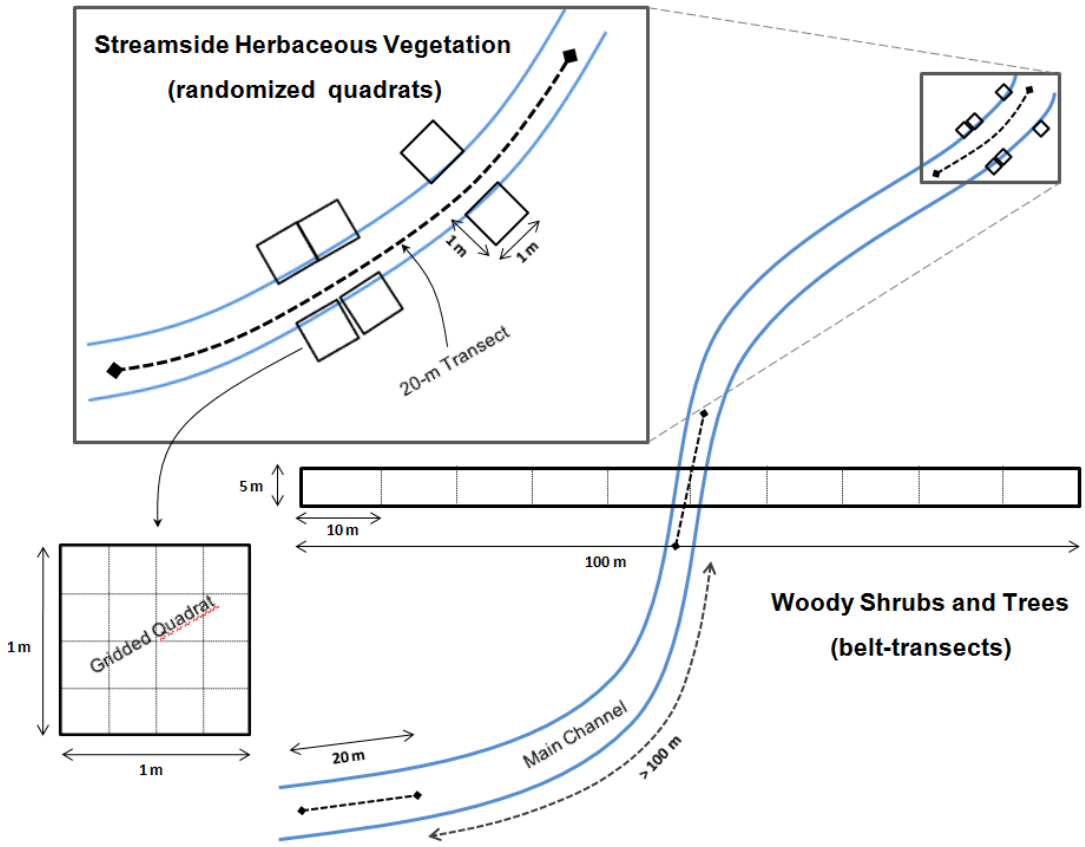


Figure 2. Streamside herbaceous and woody shrub and tree survey design using stratified transects, randomized quadrats, and belt transects.

Table 2. Modified Braun-Blanquet classes used for data analyses.

Cover Class Range	Midpoint
76-100	87.5
51-75	62.5
26-50	37.5
6-25	15.0
1-5	3.0
<1	0.5
0	0.0

Floodplain Woody Vegetation Surveys

We re-measured woody vegetation within the permanent belt-transects established in 2013. Each belt-transect perpendicularly bisected the mid-point of the middle herbaceous transect and was oriented across the floodplain spanning from due west to due east (Figure 2). In 2013, the southwest and southeast corners were permanently staked with rebar and a GPS unit (Garmin 60Cx, 5-m resolution) was used to document coordinates for each corner. In 2015, the same corners were located using a combination of GPS units with known coordinates, a georeferenced aerial image (i.e.; interactive, georeferenced digital imagery on a tablet and app), and 2013 photographs. In a few cases, the rebar was not found and likely was scoured away during runoff events. In one case, a large amount of debris and vegetation overgrowth precluded the crew from finding the rebar, which may also have been buried in sediment. The field crew, to the best of their ability, replicated the footprint of the original 100-m x 5-m belt-transects. Woody vegetation measurements include all shrubs and trees found within the belt-transect at each site. Summary statistics were compiled within each 10-m x 5-m subplot (i.e., belt) for a total of 10 subplots such that data could be analyzed within each belt and across all belts (average of all subplots combined).

We used a spherical concave densiometer to measure canopy cover (i.e., canopy closure) for each woody species. We held the densiometer at 1.25-m above ground surface in the middle of each subplot, and counted vegetation "hits" if plant leaves or live stems were present within any of 37 available crosshairs. A total of 37 hits were possible and canopy closure was post-processed. In addition, for each subplot, we visually estimated vegetation cover within each of three stratified layers: 1) ground (<1 m); 2) mid-canopy (1-5 m); and 3) canopy (>5 m) for all individual woody species as well as combined herbaceous species.

Like streamside herbaceous cover, woody cover was visually estimated and documented using the midpoints of each cover class (Table 2). For each woody species present, stem diameters were measured at six inches above ground surface using either calipers or diameter at breast height (DBH) tape to the nearest mm (e.g., 5.8 cm). Multiple stems were measured per tree if stems branched out below six inches from its base. If a woody species was small, shrubby, and many-branched; size class categories (e.g., <1 m, 1-2 cm) were used to document all stems. If it was not practical or feasible to measure or count all the stems for certain shrubby species, then an individual plant count was taken instead (*see* Table 3). Notes were taken in the field to document whether stems represented new saplings versus being a small stem, ramet, or clonal extension from a mature tree.

Table 3. Definition of target species versus non-target species within the belt-transects for analysis purposes.

Measured Species Trees[1]	Shrubs[2]	Estimated Species Shrubs[3]
POFR, *Populus fremontii*	BASA, *Baccharis salicifolia*	ATEL, *Atriplex elegans*
SAGO, *Salix gooddingii*		ATPO, *Atriplex polycarpa*
TAAP, *Tamarix aphylla*		HYMO, *Hymenoclea monogyra*
TARA, *Tamarix ramosissima*		LATR, *Larrea tridentata*
PAAC, *Parkinsonia aculeata*		LYFR, *Lycium fremontii*
PAFL, *Parkinsonia florida*		ACGR, *Acacia greggii*
PRVE, *Prosopis velutina*		BASA2, *Baccharis sarathroides*
		ZIOB, *Ziziphus obtusifolia*

[1]All stem diameters were systematically measured at 6" above ground surface for all target trees

[2]All stem diameters >2 cm were measured while small stems were estimated within two small classes (i.e., <1 cm and 1-2 cm) for target shrubs

[3]Only individual plant counts were documented for non-target shrubs due to the impracticality of measuring individual stems for each plant

ANALYSIS

Species Identification and Richness

All plants surveyed were identified to species using the USA Plants Database treatment (USDA 2013). Other resources used included SEINet (Southwest Environmental Information Network, http://swbiodiversity.org/portal/index.php), the University of Arizona Herbarium, relevant regional plant identification books, and qualified regional botanists. All species were given a unique four-letter code using the first two letters of the genus and species. When necessary, some coded species were assigned a number to differentiate them from other similarly names species (e.g., *Baccharis salicifolia* and *B. sarathroides* were assigned BASA and BASA2, respectively). Species richness, the total number of individual species observed, was analyzed within each quadrat, transect (i.e., eight quadrats combined), and site (24 quadrats combined) as well as cumulatively for the entire project.

Wetland Indicator Status

A wetland indicator status (WIS) score (WIS#) was computed for each site. Using a list provided by Pima County and adapted from the National Wetland Plant List (Appendix B; USACE 2012), each documented species was assigned to one of five functional groups and assigned wetland values: 1) "1" obligate wetland species (OBL); 2) "2" facultative wetland (FACW); 3) "3" facultative (FAC); 4) "4" facultative upland (FACU); and 5) "5" obligate upland (UPL). The list used in this project had updated WIS values for a number of species. For example, *T. ramosissima*, labeled as an upland plant in other regions, was given a WIS value of 4 instead of 5, indicating that the species functions as a facultative upland plant in the southwestern US.

Similary, *Polygonum lapathifolium*, an upland plant in other regions, is considered a facultative wetland plant in desert riparian ecosystems; thus, this species was given a WIS number of 2 instead of 5. Because this change was not implemented until 2014, the 2013 data was re-analyzed to provide direct comparisons between 2013 and 2014 using the same analysis. The 2013 *a living river* report includes the original 2013 WIS values and the direct comparison between the two analysis methods is found in Appendix C of the 2014 Vegetation Assessment Report (HEG, 2014). A WIS# was computed for each site by weighting each species by their overall cover percentage and then using the functional group number as the multiplier. The WIS# is an index ranging from 1-5 with lower numbers representing sites with prevalent wetland species and higher numbers representing sites more characteristic of upland vegetation. Matched pair analysis (paired t-test) was performed to test for significant differences between sample years and to find any trends occurring at any given location across all years (SPSS v20, IBM Corp. 2011).

Nitrogen Affinity Scores

Sites were also analyzed using a nitrogen affinity index. Each species was assigned a nitrogen number ranging from 1-9 representing low to high affinity to nitrogen, respectively. Similar to the WIS number analysis, the nitrogen score was weighted by cover percentages of species found at each site. Lower nitrogen numbers represented sites characteristic of species with low nitrogen affinity while higher scores represented sites with species having high tolerance to high nitrogen concentrations. Of note, was that the list of species provided did not have nitrogen numbers for all of the species. Any species not having a nitrogen number were excluded from the nitrogen affinity analysis. The 2013 analysis mistakenly assigned zeros to those species without a nitrogen affinity score. The 2013 nitrogen affinity data were re-analyzed to provide direct comparisons between 2013 and 2014 results. Matched pair analysis (paired t-test) was to test for significant differences between sample years (SPSS v20, IBM Corp. 2011).

Woody Species Plant Density, Stem Density, Basal Area, and Recruitment

Stem density of each woody species was analyzed across the entire 100-m x 5-m belt-transect and within each subplot. Stem density was reported as stems per hectare after excluding the area represented by the main channel (Table 4). Similarly, basal area for each woody species was analyzed across the entire belt-transect and within each subplot. Basal area was reported as square meters per hectare excluding the area represented by the main channel. Stem density and basal area could not be analyzed for shrubby, multi-stemmed species in which it was not practical to measure each stem (e.g., *H. monogyra*, *L. tridentata*); however, plant density is reported for these species. Saplings, defined as plants that likely germinated within the last year and determined *in situ* to the best of our ability, were counted across the entire

belt-transect. These counts were assessed by using a combination of quantitative information (i.e., stems that were <1.0 cm) and qualitative information (i.e. field notes that established whether a small stem was a sapling or an extension from an existing mature shrub or tree) taken in the field.

Table 4. Channel width measurements for excluding active channel area from density analyses.

	West Channel Edge (m)	East Channel Edge (m)	Channel Length (m)	Channel Area[a] (m^2)
Veg_1[b]	42	50	8	40
Veg_2	89	100	11	55
Veg_3	45	55	10	50
Veg_4	41	59	18	90
Veg_5	45	54	9	45
Veg_6	87	98	11	55
Veg_7	41	58	17	85
Veg_8	40	78	38	190

[a]Channel area computed by multiplying channel length by 5-m belt width

[b]Veg_1 was only 80 m in length due to limited floodplain within soil cement

Vegetation Canopy Closure, Cover Percentage, and Structure

Multiple methods were used to analyze vegetation cover. Canopy closure was estimated using spherical densiometer readings with the following equation:

$$\text{Canopy Closure} = x * 2.703 \qquad 1)$$

where *x* is total hits and canopy closure is expressed as a percentage. This method consists of holding a densiometer at the standard 1.2 meters above ground surface and recording the number of crosshairs (out of 37) intercepted by live canopy vegetation. At each site, individual species visual cover percentages were analyzed within three stratified layers (described in the methods) by averaging cover estimates across all 10 subplots. Cover percentage was also analyzed within functional groups across the 10 subplots. Using a table provided by Pima County (Table 5), canopy cover by strata data was also used to classify each subplot into one of five structure types: 1) forest; 2) woodland; 3) shrubland; 4) grassland; or 5) open. The percent cover for each structure type was reported for each site using the average across the 10 subplots.

Table 5. Metrics used to classify subplots within each belt-transect into structure types.

	Ground	Mid-canopy	Canopy
forest			>60%
woodland			25-60%
shrubland		>25%	<25%
grassland	>25%		
open	<25%		

RESULTS

Species Identification and Richness

A total of 64 individual plant species were identified during the streamside herbaceous surveys in 2015 (Appendix C). The average number of species documented was 23.3 per site, 14.5 per transect, and 4.3 per quadrat. Species richness varied greatly across the eight survey sites with the least number of species observed at the Columbus Dry site (Veg_1, n=12) and the Trico-Marana site (Veg_8, n=12). The Ina Rd site (Veg_4) had the most species observed (n=37). The Avra Valley (Veg_5) and Marana (Veg_8) sites were the only sites having a reduction in species richness from 2014 to 2015 (19 down from 23, and 12 down from 22; respectively; Table 6).

Species observed most frequently (i.e., most occurrences within quadrats) were as follows: 1) *Cynodon dactylon*, 2), *Polygonum lapathifolium*, 3) *Rumex obtusifolius*, 4) *Polypogon monspeliensis*, 5) *Sorghum halepense*, and 6) *Hymenoclea monogyra*. Species Richness also was broken down within quadrats, transects, and by site (Table 7).

Table 6. Species Richness at all sites from 2013-2015.

	2013	2014	2015	Average
Columbus Dry	11	3	12	8.7
Columbus Wet	20	16	28	21.3
Sunset	24	23	26	24.3
Ina	20	17	37	24.7
Cortaro	20	19	26	21.7
Avra Valley	15	23	19	19.0
Sanders	21	19	26	22.0
Marana	20	22	12	18.0
Average	18.9	17.8	23.3	
Species Richness	51	56	64	

Table 7. Species richness documented across each survey site. Summaries by column include: 1) average species richness per quadrat and average of all four quadrats combined (bold, left); 2) species richness per transect as well as average per transect (bold, center); and 3) total number of species identified per site (bold right).

	Quadrat	Transect	Site
Veg_1	4.00	10	
	1.63	6	
	1.75	3	
	2.46	***6.33***	***12***
Veg_2	4.50	19	
	5.63	21	
	2.75	11	
	4.29	***17.00***	***28***
Veg_3	5.13	16	
	5.13	19	
	5.50	16	
	5.25	***17.00***	***26***
Veg_4	6.50	23	
	8.25	26	
	4.88	16	
	6.54	***21.67***	***37***
Veg_5	4.25	13	
	5.63	21	
	3.38	14	
	4.42	***16.00***	***26***
Veg_6	3.50	11	
	3.63	12	
	2.38	11	
	3.17	***11.33***	***19***
Veg_7	5.63	17	
	4.38	17	
	5.63	20	
	5.21	***18.00***	***26***
Veg_8	3.00	10	
	2.63	8	
	2.50	9	
	2.71	***9.00***	***12***

Wetland Indicator Status

The average WIS# for all survey sites combined increased in 2015 (3.19), but still was not significantly higher than 2014 (2.76, p=0.149, matched pairs analysis, Appendix D) (Figure 4). The sites with the lowest WIS#s were Sanders (2.34), Cortaro (2.34), and Sunset (2.40), representing the sites with the most wetland species observed. The driest site was the Columbus Park Dry site (Veg_1) which had a WIS# of 4.69, indicating the site with the most upland species present. Two sites that were dry in 2015 had WIS#s that increased markedly from 2014. The Ina Rd site (Veg_4) increased from 1.91 to 3.66 and the Marana site (Veg_8) increased from 2.40 to 3.74 (Figure 3). When running a paired t-test that excluded these two

dry sites from 2014-2015, the results were even less significant (3.01, p=0.627, matched pairs analysis, Appendix D). This suggests that the Ina (Veg_4) and Marana (Veg_8) Sites are responsible for the overall increase in 2015 WIS# average, although it was still not significantly different from 2014. If this trend continues over time, the results may become significant in the near future.

Nitrogen Affinity

The average NITRO# for all survey sites combined decreased in 2015 (5.76), but was not significantly lower than 2014 (6.16, p=0.380, matched pairs analysis, Appendix D) (Figure 5). The lowest NITRO# was 3.88 for the Columbus Park Dry site (Veg_1) and the two highest NITRO#s, 7.00 and 6.78, were at the Sanders Rd site (Veg_7) and the Cortaro Rd site (Veg_5), respectively (Figure 3). Two sites had markedly lower NITRO#s when comparing 2015 scores to those of 2014. The Ina Rd site (Veg_4) decreased from 7.40 to 4.92 and the Marana Rd site (Veg_08) decreased from 6.79 to 4.96 (Figure 5). The Avra Valley site (Veg_6) showed an increase from 5.37 to 6.47 from 2014 to 2015.

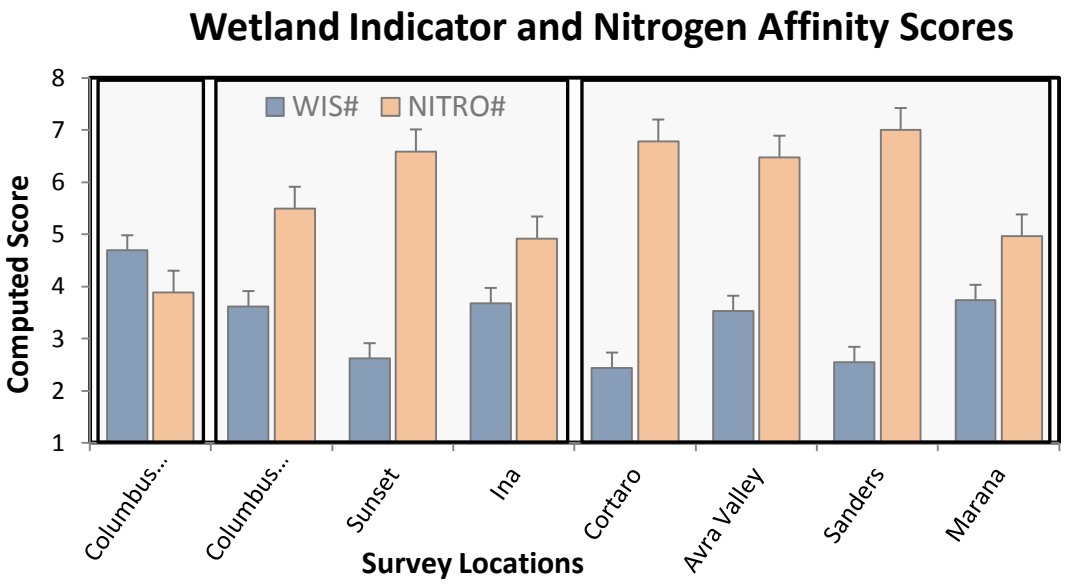


Figure 3. Computed wetland indicator scores (WIS#) and nitrogen affinity scores (NITRO#) for each survey site in 2015. Wetland Indicator Scores range from 1-5 with lower scores representing sites with more wetland species. Nitrogen Affinity Scores range from 1-9 with higher numbers indicating higher tolerance to nitrogen concentrations. Error bars represent standard error from the mean. Boxes from left to right depict influences from outfalls: none, Roger Outfall, Roger/Ina Outfall.

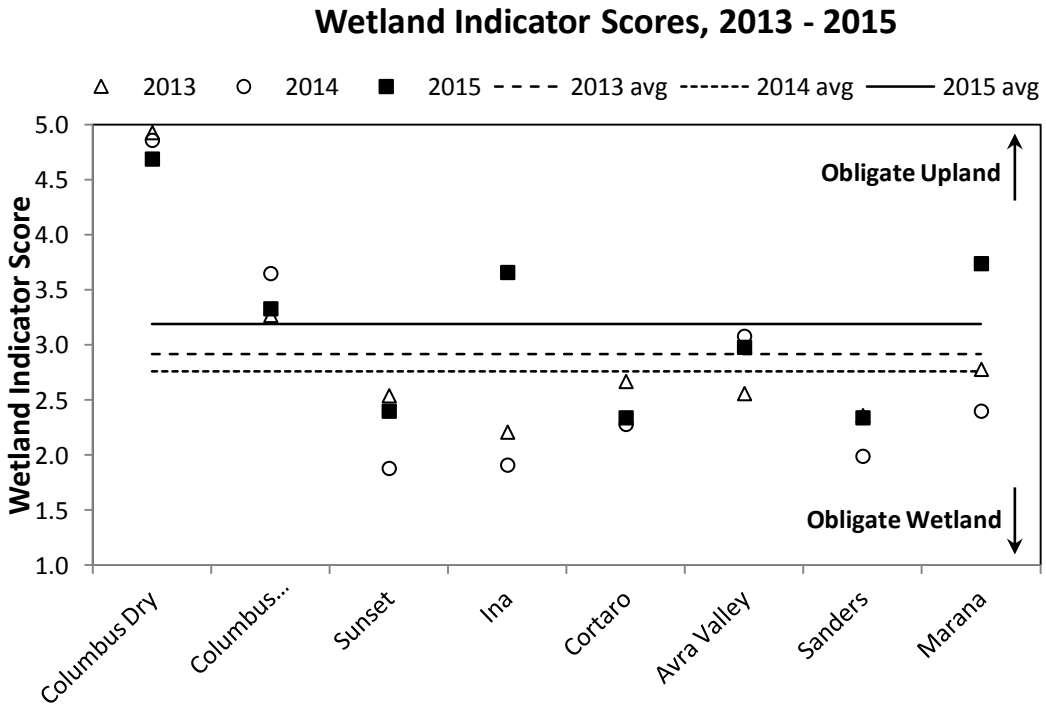


Figure 4. Computed Wetland Indicator Scores for Santa Cruz River vegetation surveys, 2013-2015.

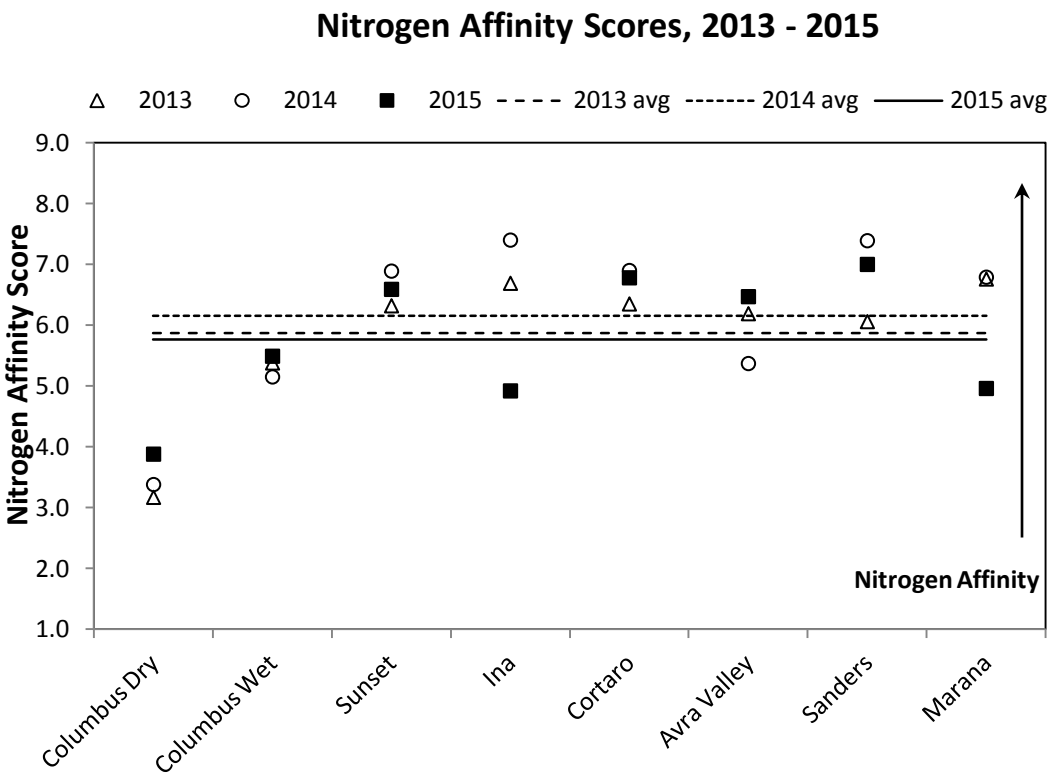


Figure 5. Computed Nitrogen Affinity Scores for Santa Cruz River vegetation surveys, 2013-2015.

Woody Species Plant Density, Stem Density, Basal Area, and Recruitment

The highest average plant and stem density of all tree species across all sites was *T. ramosissima* with an estimate of 140 plants/ha and 741 stems/ha (Figure 6, Table 8.1). The second highest woody species density observed was *B. salicifolia* with estimates of 68 plants/ha and 256 stems/ha (Figure 6). Density rank remained the same between 2013 and 2015 with *T. ramosissima* (saltcedar), *B. salicifolia* (seep willow), and *P. velutina* (velvet mesquite) rounding out the top three (Figure 6). The highest shrubby plant density was *H. monogyra* with estimates of just over 1,000 plants/ha (Figure 7, Table 8.2). Shrubby plant density rank remained the same between 2013 and 2015 with *H. monogyra* (singlewhorl burrobrush), *A. polycarpa* (cattle saltbush), and *B. sarathroides* (desert broom) rounding out the top three (Figure 7). When analyzed within functional groups, the highest plant density observed was by upland species with estimates of 1311 plants/ha, followed by facultative species (203 plants/ha). No obligate wetland trees exist along the study reach and facultative wetland species exist at low densities (50 plants/ha, Table 8.3). The highest dead plant and stem density was *T. ramosissima* with estimates of 37 dead plants/ha and over 150 dead stems/ha (Figure 8, Table 8.2). While *T. ramosissima* was the highest dead plant density in both 2013 and 2015, the species was

observed at a much lower dead density in 2015. Interestingly, dead *T. aphylla* (athel tamarisk) and *S. gooddingii* (Goodding's willow) were observed at higher densities in 2015 compared to 2013.

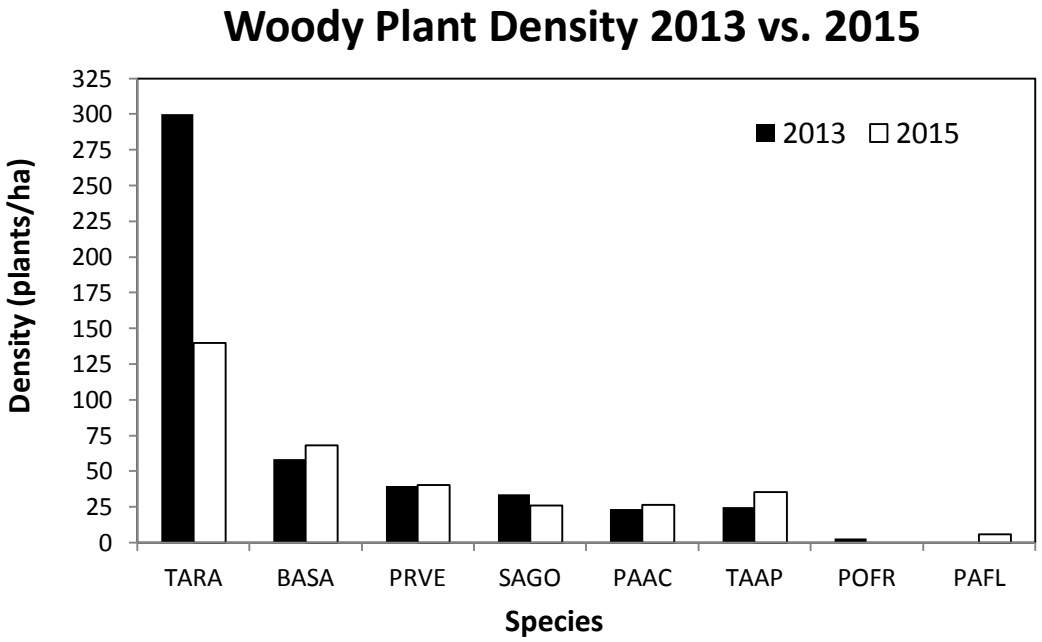


Figure 6. Woody plant densities compared between the 2013 and 2015 survey years.

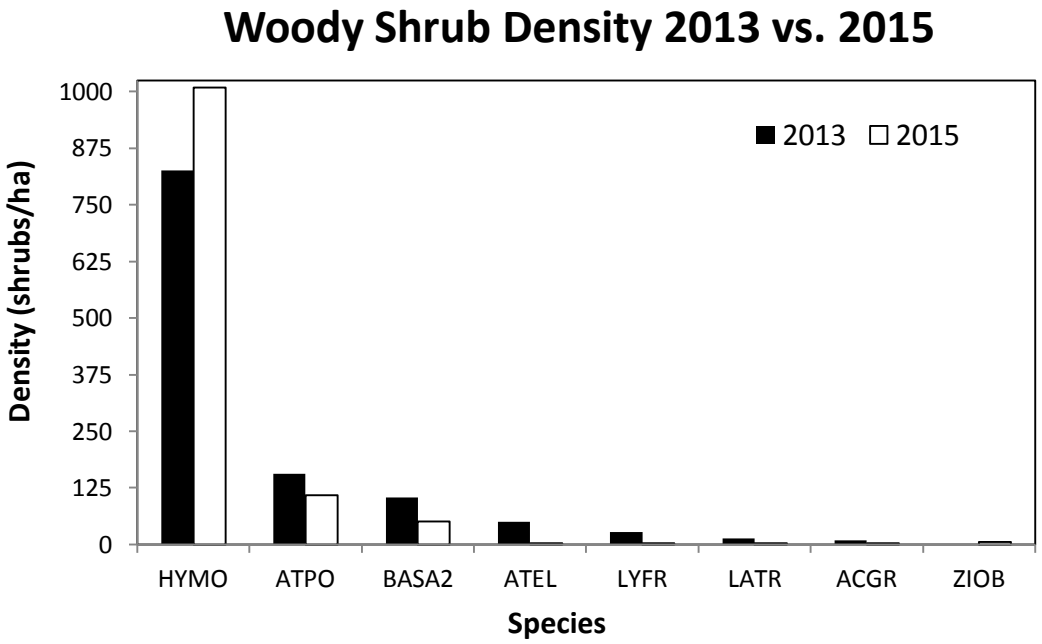


Figure 7. Woody shrub densities compared between the 2013 and 2015 survey years.

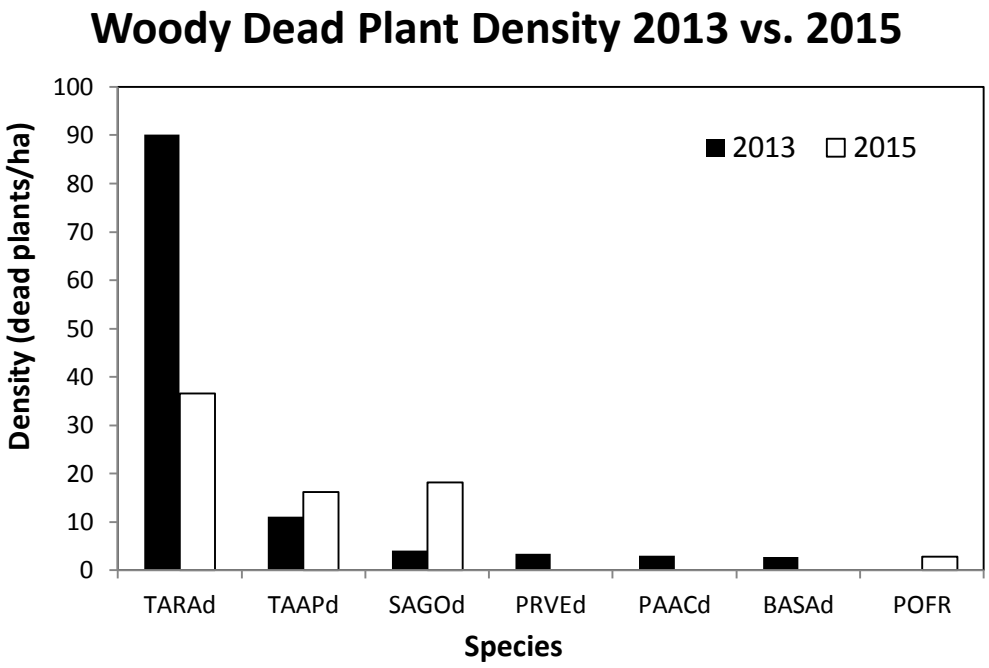


Figure 8. Dead woody plant densities compared between the 2013 and 2015 survey years.

The greatest basal area of woody species observed across sites was *S. gooddingii* estimated at 1.4 m^2/ha followed by *T. aphylla* with 1.2 m^2/ha. When analyzed by functional group, facultative wetland species had the greatest basal area with 2.3 m^2/ha while the least basal area was represented by facultative upland species with 0.6 m^2/ha (Table 8.2). The greatest dead species basal area observed across sites was *S. gooddingii* with 0.91 m^2/ha followed by *T. aphylla and T. ramosissima* with 0.04 m^2/ha and 0.03 m^2/ha, respectively. In 2013, *S. gooddingii* high seedling recruitment was observed with an average of 66 new saplings counted per site. The 2015 woody surveys did not document sapling recruitment within the belt transects for any target woody species.

Vegetation Canopy Closure, Cover Percentage, and Structure

The highest average percentage of canopy closure (i.e., computed densiometer measurements) observed across all sites was *T. aphylla* with 4.3% followed by *T. ramosissima* with 2.8% (Table 9). Averaging cover by strata data across all sites, open areas made up 45.3% of the total survey area while grasslands made up 42.2% of the total area within the belt-transects. Shrublands made up 11.3% followed by woodlands with 1.3%. Open areas and grasslands were present at all sites while shrublands were documented within five of the eight sites (Figure 9). Only the Columbus Park Wet site (Veg_2) had a small portion classified as woodland and no areas were classified as forest in 2015 (Figure 9).

Table 8.1. Average plant density, stem density, and basal area statistics for woody trees within belt-transect surveys for live plant species.

		seep willow **BASA**	Mexican paloverde **PAAC**	blue paloverde **PAFL**	Fremont cottonwood **POFR**	velvet mesquite **PRVE**	mesquite hybrid **PRVEx**	Goodding's willow **SAGO**	athel tamarisk **TAAP**	saltcedar **TARA**
AVG	plants/site	3.0	1.1	0.3	0.1	0.9	0.9	1.0	1.3	6.1
	plants/ha	68.1	26.4	5.6	2.8	20.8	19.7	26.1	35.4	140.0
	stems/site	11.3	2.5	0.6	0.3	2.6	2.9	2.4	3.9	32.6
	stems/ha	256.1	58.4	14.0	5.6	68.8	64.6	60.3	105.0	741.1
	basal area (cm^2)	29.1	106.3	0.7	156.7	280.2	7.7	502.3	401.7	243.1
	basal area (m^2/ha)	0.1	0.2	0.002	0.4	0.6	0.02	1.4	1.2	0.6

Table 8.2. Average plant density statistics for all woody shrubs analyzed within belt-transect surveys for live plant species.

		catclaw acacia **ACGR**	wheelscale saltbush **ATEL**	cattle saltbush **ATPO**	desert broom **BASA2**	singlewhorl burrobrush **HYMO**	creosotebush **LATR**	Fremont's desert-thorn **LYFR**	graythorn **ZIOB**
AVG	plants/site	0.1	0.1	4.9	2.0	42.6	0.1	0.1	0.3
	plants/ha	2.8	3.0	108.3	51.1	1008.7	2.8	2.8	5.6

Table 8.3. Average plant density, stem density, and basal area statistics for dead woody trees surveyed within belt-transect and summary of live species as analyzed within functional group.

		Fremont cottonwood **POFRd**	Goodding's willow **SAGOd**	saltcedar **TARAd**	athel tamarisk **TAAPd**	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
AVG	plants/site	0.1	0.6	1.6	0.5	0.0	1.9	8.1	1.8	56.0
	plants/ha	2.8	18.2	36.5	16.1	0.0	49.9	202.6	40.5	1310.5
	stems/site	0.1	0.9	7.3	0.6	0.0	3.9	18.3	5.5	40.3
	stems/ha	2.8	26.3	162.9	20.2	0.0	100.6	439.7	133.4	912.4
	basal area (cm^2)	3.8	288.0	15.5	12.3	0.0	790.9	549.4	287.8	419.5
	basal area (m^2/ha)	0.01	0.91	0.03	0.04	0.0	2.3	1.6	0.6	1.0

Table 9. Canopy closure percentage across survey sites as computed from densiometer readings for individual species as well as functional group.

	HYMO	ARDO	PAAC	PRVE	POFR	SAGO	TAAP	TARA	OBL	FACW	FAC	FACU	UPL
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	3.51	0.00	5.41	1.89	0.00	0.00	0.00	1.89	3.51	0.00	5.41
3	0.00	0.00	0.00	15.41	0.00	4.86	0.00	0.00	0.00	4.86	0.00	15.41	0.00
4	0.00	0.00	0.00	0.00	0.00	5.95	9.19	0.00	0.00	5.95	9.19	0.00	0.00
5	0.00	0.00	4.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.86	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.43	0.00	0.00	0.00	0.00	22.43
7	0.00	0.00	0.00	0.00	0.00	0.00	11.89	0.00	0.00	0.00	11.89	0.00	0.00
8	0.54	4.05	0.00	0.00	0.00	2.97	13.51	0.00	0.00	7.03	13.51	0.00	0.54
Sum	*0.54*	*4.05*	*8.37*	*15.41*	*5.41*	*12.70*	*34.59*	*22.43*	*0*	*19.73*	*42.96*	*15.41*	*28.38*
Average	*0.07*	*0.51*	*1.05*	*1.93*	*0.68*	*1.96*	*4.32*	*2.80*	*0.00*	*2.47*	*5.37*	*1.93*	*3.55*

HYMO (*Hymenoclea monogyra*), ARDO (*Arundo donax*), PAAC (*Parkinsonia aculeata*), PRVE (*Prosopis velutina*), POFR (*Populus fremontii*), SAGO (*Salix gooddingii*), TAAP (*Tamarix aphylla*), TARA (*Tamarix ramosissima*), OBL (Obligate Wetland), FACW (Facultative Wetland), FAC (Facultative), FACU (Facultative Upland), UPL (Obligate Upland)

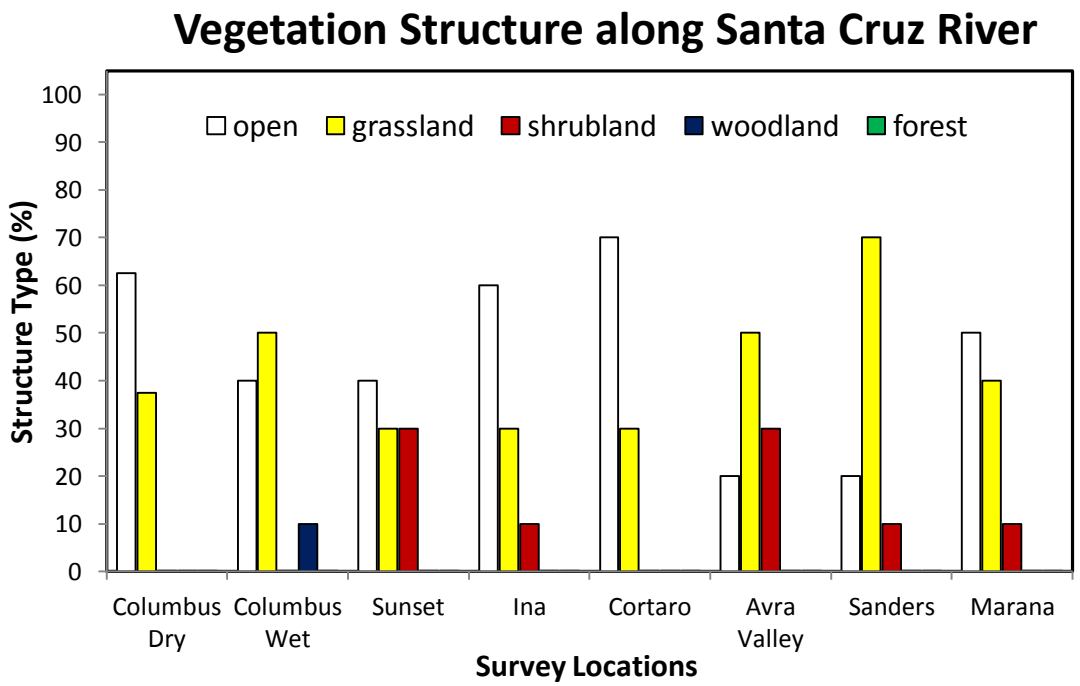


Figure 9. Structure types found along the Santa Cruz River using stratified visual cover percentages within belt-transects.

DISCUSSION

This data is the second year of post-treatment data, and gives insight to potential impacts that the WRF upgrades have on streamside herbaceous vegetation. However, it may take several years to fully understand how effluent treatment improvements will affect riparian vegetation along the Santa Cruz River.

Streamside Herbaceous Vegetation Surveys

Species richness has increased each year from 2013-2015 consisting of 51, 56, 64 species, respectively. Most of the new species documented in 2014 were common grass species that did not land in a survey quadrat in 2013. Some of the new species in 2015 are attributed to species tolerant of drier conditions found at the Ina Rd site (Veg_4). These include redwhisker clammyweed (*Polanisia dodecandra*), a facultative upland legume common in the dry riverbed, and Coulter's horseweed (*Laennecia coulteri*), a facultative species common at the Ina site along the dry banks. Many factors other than treated effluent and its associated moisture downstream from their respective outfalls may influence the presence and/or shift of riparian species over time. Therefore, it is difficult to infer whether climate, WRF management, or other human disturbances may contribute to changes in vegetation.

In general, sites comprised of large stretches of southern cattail (*Typha domingensis*) or large mats of emergent vegetation such as marsh seedbox (*Ludwigia palustris*), tended to have lower species richness because these species dominated the survey area. As a result, sites with low WIS#s did not necessarily contain more plant species than drier sites that were more open. This pattern also is supported by the increase in species observed at the dry Ina site, which may have had a broader range of conditions for plant establishment.

Wetland Indicator Scores in 2015 were similar to 2014 scores at sites that had similar site characteristics (i.e., sites having baseflows or available soil moisture) to the year before. However, the Ina and Marana sites were very dry in 2015 and exhibited large decreases in WIS#s. In 2014, these sites were dry during the survey; however it was evident that baseflows were frequent and shallow soil moisture was present to support streamside vegetation. In 2015, shallow soil moisture was lacking and the quantitative data supports negative impacts on herbaceous vegetation. Likewise, qualitative data revealed substantial loss of soil moisture and withered and dying trees (*see* Appendix F, Photos 1-13).

Some aquatic plants that influence low WIS#s include: *T. domingensis*, curlytop knotweed (*P. lapathifolium*) and rabbitsfoot grass (*Polypogon monspeliensis*), which have high abundance and low WIS values. On the other hand, singlewhorl burrobrush (*Hymenoclea monogyra*) and Bermuda grass (*Cynodon dactylon*), which have higher WIS values, tend to influence higher WIS#s when present in large quantities. While WIS and Nitro values for the plants observed

during the study are not correlated, our findings demonstrate that lower WIS#s were highly correlated with higher NITRO#s at each site (see Appendix D). This is explained, in part, by common plants that fall into the surveys. These plants include *T. domingensis* and *P. lapathifolium* which have low WIS values and high nitrogen values, and *H. monogyra* which has a high WIS value and low nitrogen value.

The average nitrogen scores (NITRO#) across all sites showed the same pattern, but inverse from the WIS#s. The dry Ina and Marana sites had lower NITRO#s in 2015 compared to 2014. This can be explained by the abundance of *C. dactylon* (nitrogen value = 5), Johnson grass (*Sorghum halepense*, [4]), and London rocket (*Sisymbrium irio*, [5]) at the Ina site and *C. dactylon* at the Marana site, all of which have lower nitrogen values than the common plants observed along wetter sites (e.g., *T. domingensis* [8], *P. lapathifolium* [8], and bitter dock (*Rumex obtusifolius* [9]). The lowest NITRO# was computed for the Columbus Park Dry (Veg_1), which is due to the high cover percentage of *H. monogyra* [3] and *C. dactylon*, respectively.

Floodplain Woody Vegetation Surveys

The results of the woody vegetation survey in 2015 showed a reduced density of both native and non-native trees. The high recruitment of *S. gooddingii* seedlings in 2013 skewed the data such that the density appeared much higher in 2013. As a result, in 2013, *S. gooddingii* had the highest numbers followed by T. ramosissima. In 2015, the highest tree densities were *T. ramosissima* followed by *B. salicifolia*. *T. ramosissima* density was markedly higher in 2013 (13.3 plants/site) compared to 2015 (6.1 plants/site). While the highest dead tree densities in 2015 were *T. ramosissima*, it does not, alone, explain the significant decrease in density between sample years. Furthermore, *T. ramosissima* dead tree density was lower in 2015 (1.6 dead trees/site) than in 2013 (4.0 dead trees/site). Density of dead *S. gooddingii* also increased in 2015, which is not surprising considering the qualitative observations of dead and dying native trees along the study reach.

It is difficult to determine whether differences between survey years are due to inherent subjectivity in sampling, environmental factors, or a combination of both. While belt-transects in this project are permanent survey areas, it was difficult to replicate the exact survey areas due to changes in physical characteristics (e.g., soil deposition, channel meandering, and obstructions due to changes in vegetation). A couple of permanent rebar markers were not relocated and were either removed or buried during flood events. Future surveys could include a sub-sample of permanently tagged trees to document growth and survival. This could help in the orientation of permanent transects and provide robust data. The GPS corners were marked using Garmin 60Cx APS unit, which is limited by it's sub 5-m resolution. The use of a sub-meter GPS unit to mark the corners of each belt-transect will allow for better replication of each belt-transect while providing datum for overlaying and analyzing LiDAR data.

Notes Specific to Sites and Surveys

Other than the Columbus Dry site (Veg_1) that is always dry, the Ina (Veg_4) and Marana (Veg_8) sites were dry upon arrival in 2015. During the 2014 survey, the Ina Site (just south of the Ina Rd bridge and Ina outfall) was also dry, but it was evident that water was close to the surface and that the lack of baseflow had little impact to the vegetation along the streamside. Cattails and other obligate plants were healthy and not impacted by dry soils (*see* Appendix F, Photos 1-6). In 2015, all streamside herbaceous was absent and the width of the dry riverbed expanded many meters. Vehicle tracks in the dry riverbed along with grasses and weeds growing within the riverbed showed evidence that the channel had not received baseflows in quite some time (*see* Appendix F, Photos 1-6).

The Marana Site was also was dry in 2014, but a pulse of water arrived during the survey. Healthy streamside herbaceous vegetation and green native and non-native trees along the banks showed evidence of sufficient soil moisture promoting vegetation growth along this reach. However, in 2015 the reach was considerably drier, with little to no streamside vegetation, and defoliated and dead trees along the banks (*see* Appendix F, Photos 7-13). It is obvious, by examining both quantitative and qualitative data, that vegetation is negatively impacted by lack of baseflows in the main channel along the Ina and Marana sites. It would be beneficial to continue monitoring these sites while analyzing any available stream gauge and precipitation data.

The Avra Valley site (Veg_6) is unique in that the main channel is incised with steep banks on both sides ranging from three to eight meters. This results in a narrower channel, deeper water, and increased stream velocity (*see* Appendix F, Photo 15). Water does not likely inundate the floodplain unless large tropical storms or monsoon events occur. Dense stands of saltcedar were observed at this site along the disconnected, incised banks while giant reed was common within the channel in shallower areas. This site, as stated previously, had evidence of debris, turbidity, and odor likely from the Marana Lake outflow just upstream (*see* Appendix F, Photo 16). The next site downstream, the Sanders site (Veg_7), was perhaps the most natural looking site in 2014. It was common to find braided channels with point bars, backwaters, and a high diversity of plants and wildlife. These characteristics were consistent in 2015, but upstream water quality resulted in residual odor and turbidity. Streamflows also appeared to have reduced velocities and riffles were not as prevalent.

Wildlife was common during the surveys. Although garbage and human disturbance were also common on the floodplain, the main channel was relatively isolated. Shorebirds and waterfowl such as Killdeer (*Charadrius vociferus*), ducks (family Anatidae, e.g., Mallards [*Anas platyrhynchos*]), and herons (family Ardeidae, e.g., Great Blue [*Ardea herodias*] and Green [*Butorides virescens*]) were common along the entire study reach. Water turtles (e.g., red-eared

slider [*Trachemys scripta elegans*], spiny softshell turtle [*Apalone spinifera*], Sonora mud turtle [*Kinosternon sonoriense*]) were observed, but less often than in previous years. A Sonora mud turtle documented in 2015 was observed along the same reach at the Sanders site as the individual documented in 2014. Although the turtle was not captured or photographed, it had a light, whitish color on its shell from age that potentially distinguishes it from the individual observed in 2014. Small fish were abundant throughout the surveys, mostly comprised of mosquitofish (*Gambusia* spp). Catfish and possibly a school of sunfish were observed along the Cortaro reach, which has consistently been the reach with the most fish observations. Bullfrog (*Rana catesbiana*) tadpoles and bullfrog calls were common along the Sanders reach. A pack of javelina (*Tayassu tajacu*) were observed crossing the dry Ina site and a coyote (*Canis latrans*) pup was observed at the Avra Valley site (*see* Appendix F, Photo 14). While no formal surveys are conducted, the vegetation crew continues to note all wildlife observed during survey events.

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APPENDIX A – GPS Coordinates for All Transects

FID	SiteName	Site #	Subsite	Info	UTM (NAD 83)	Latitude	Longitude
1	Columbus Dry	Veg_1	1E1	start	12S 0497291 3571431	-111.028768	32.279624
2	Columbus Dry	Veg_1	1E1	end	12S 0497286 3571451	-111.028821	32.279805
3	Columbus Dry	Veg_1	1E2	start	12S 0497286 3571451	-111.028821	32.279805
4	Columbus Dry	Veg_1	1E2	end	12S 0497282 3571470	-111.028864	32.279976
5	Columbus Dry	Veg_1	2	start	12S 0497276 3571594	-111.028928	32.281095
6	Columbus Dry	Veg_1	2	end	12S 0497274 3571612	-111.028949	32.281257
7	Columbus Dry	Veg_1	3W1	start	12S 0497265 3571736	-111.029045	32.282376
8	Columbus Dry	Veg_1	3W1	end	12S 0497261 3571756	-111.029087	32.282556
9	Columbus Dry	Veg_1	3W2	start	12S 0497261 3571756	-111.029087	32.282556
10	Columbus Dry	Veg_1	3W2	end	12S 0497258 3571778	-111.029119	32.282755
11	Columbus Dry	Veg_1	2	NE	12S 0497308 3571601	-111.028588	32.281158
12	Columbus Dry	Veg_1	2	NW	12S 0497229 3571607	-111.029427	32.281212
13	Columbus Dry	Veg_1	2	SE	12S 0497307 3571599	-111.028598	32.281140
14	Columbus Dry	Veg_1	2	SW	12S 0497229 3571604	-111.029427	32.281185
15	Columbus Wet	Veg_2	1W1	start	12S 0497142 3572206	-111.030352	32.286616
16	Columbus Wet	Veg_2	1W1	end	12S 0497134 3572224	-111.030437	32.286778
17	Columbus Wet	Veg_2	1W2	start	12S 0497134 3572224	-111.030437	32.286778
18	Columbus Wet	Veg_2	1W2	end	12S 0497125 3572245	-111.030533	32.286967
19	Columbus Wet	Veg_2	2W1	start	12S 0497065 3572332	-111.031171	32.287752
20	Columbus Wet	Veg_2	2W1	end	12S 0497051 3572346	-111.031319	32.287878
21	Columbus Wet	Veg_2	2W2	start	12S 0497051 3572346	-111.031319	32.287878
22	Columbus Wet	Veg_2	2W2	end	12S 0497038 3572360	-111.031457	32.288005
23	Columbus Wet	Veg_2	3W1	start	12S 0496972 3572424	-111.032159	32.288582
24	Columbus Wet	Veg_2	3W1	end	12S 0496954 3572432	-111.032350	32.288654
25	Columbus Wet	Veg_2	3W2	start	12S 0496964 3572427	-111.032244	32.288609
26	Columbus Wet	Veg_2	3W2	end	12S 0496936 3572439	-111.032541	32.288717
27	Columbus Wet	Veg_2	2	NE	12S 0497071 3572345	-111.031107	32.287869
28	Columbus Wet	Veg_2	2	NW	12S 0496975 3572352	-111.032127	32.287932
29	Columbus Wet	Veg_2	2	SE	12S 0497073 3572342	-111.031086	32.287842
30	Columbus Wet	Veg_2	2	SW	12S 0496972 3572346	-111.032158	32.287878
31	Sunset	Veg_3	1	start	12S 0495066 3574710	-111.052413	32.309198
32	Sunset	Veg_3	1	end	12S 0495047 3574723	-111.052615	32.309315
33	Sunset	Veg_3	2	start	12S 0495032 3574918	-111.052775	32.311074
34	Sunset	Veg_3	2	end	12S 0495033 3574938	-111.052765	32.311255
35	Sunset	Veg_3	3	start	12S 0494996 3575033	-111.053158	32.312112
36	Sunset	Veg_3	3	end	12S 0494986 3575050	-111.053265	32.312265
37	Sunset	Veg_3	2	NE	12S 0495080 3574936	-111.052265	32.311237
38	Sunset	Veg_3	2	NW	12S 0494982 3574931	-111.053306	32.311191
39	Sunset	Veg_3	2	SE	12S 0495081 3574930	-111.052255	32.311183
40	Sunset	Veg_3	2	SW	12S 0494982 3574928	-111.053306	32.311164
41	Ina	Veg_4	1	start	12S 0492444 3577432	-111.080288	32.333739
42	Ina	Veg_4	1	end	12S 0492438 3577451	-111.080352	32.333911
43	Ina	Veg_4	2	start	12S 0492431 3577525	-111.080427	32.334578
44	Ina	Veg_4	2	end	12S 0492431 3577546	-111.080427	32.334768
45	Ina	Veg_4	3	start	12S 0492408 3577613	-111.080672	32.335372

cont.

FID	SiteName	Site #	Subsite	Info	UTM (NAD 83)	Latitude	Longitude
46	Ina	Veg_4	3	end	12S 0492398 3577633	-111.080778	32.335552
47	Ina	Veg_4	2	NE	12S 0492472 3577544	-111.079991	32.334750
48	Ina	Veg_4	2	NW	12S 0492376 3577541	-111.081011	32.334722
49	Ina	Veg_4	2	SE	12S 0492473 3577537	-111.079980	32.334687
50	Ina	Veg_4	2	SW	12S 0492377 3577539	-111.081000	32.334704
51	Cortaro	Veg_5	1	start	12S 0490393 3579896	-111.102106	32.355952
52	Cortaro	Veg_5	1	end	12S 0490376 3579905	-111.102287	32.356033
53	Cortaro	Veg_5	2	start	12S 0490324 3579988	-111.102840	32.356782
54	Cortaro	Veg_5	2	end	12S 0490316 3580007	-111.102925	32.356953
55	Cortaro	Veg_5	3	start	12S 0490249 3580091	-111.103638	32.357710
56	Cortaro	Veg_5	3	end	12S 0490231 3580099	-111.103830	32.357782
57	Cortaro	Veg_5	2	NE	12S 0490364 3580005	-111.102415	32.356935
58	Cortaro	Veg_5	2	NW	12S 0490265 3580006	-111.103467	32.356943
59	Cortaro	Veg_5	2	SE	12S 0490365 3580000	-111.102404	32.356890
60	Cortaro	Veg_5	2	SW	12S 0490266 3580002	-111.103457	32.356907
61	Avra Valley	Veg_6	1	start	12S 0487071 3584629	-111.137478	32.398616
62	Avra Valley	Veg_6	1	end	12S 0487057 3584644	-111.137627	32.398751
63	Avra Valley	Veg_6	2	start	12S 0487000 3584712	-111.138234	32.399364
64	Avra Valley	Veg_6	2	end	12S 0486983 3584722	-111.138415	32.399454
65	Avra Valley	Veg_6	3	start	12S 0486919 3584769	-111.139096	32.399877
66	Avra Valley	Veg_6	3	end	12S 0486899 3584771	-111.139308	32.399895
67	Avra Valley	Veg_6	2	NE	12S 0487004 3584722	-111.138191	32.399454
68	Avra Valley	Veg_6	2	NW	12S 0486906 3584722	-111.139233	32.399453
69	Avra Valley	Veg_6	2	SE	12S 0487005 3584721	-111.138181	32.399445
70	Avra Valley	Veg_6	2	SW	12S 0486906 3584718	-111.139233	32.399417
71	Sanders	Veg_7	1	start	12S 0481040 3587174	-111.201658	32.421489
72	Sanders	Veg_7	1	end	12S 0481017 3587178	-111.201902	32.421525
73	Sanders	Veg_7	2	start	12S 0480915 3587214	-111.202988	32.421848
74	Sanders	Veg_7	2	end	12S 0480898 3587223	-111.203169	32.421928
75	Sanders	Veg_7	3	start	12S 0480818 3587235	-111.204020	32.422035
76	Sanders	Veg_7	3	end	12S 0480800 3587236	-111.204211	32.422044
77	Sanders	Veg_7	2	NE	12S 0480950 3587217	-111.202616	32.421875
78	Sanders	Veg_7	2	NW	12S 0480850 3587213	-111.203679	32.421837
79	Sanders	Veg_7	2	SE	12S 0480951 3587212	-111.202605	32.421830
80	Sanders	Veg_7	2	SW	12S 0480852 3587209	-111.203658	32.421801
81	Marana	Veg_8	1	start	12S 0474100 3590746	-111.275568	32.453572
82	Marana	Veg_8	1	end	12S 0474088 3590735	-111.275696	32.453473
83	Marana	Veg_8	2	start	12S 0474215 3590802	-111.274346	32.454080
84	Marana	Veg_8	2	end	12S 0474199 3590798	-111.274516	32.454044
85	Marana	Veg_8	3	start	12S 0474323 3590819	-111.273198	32.454236
86	Marana	Veg_8	3	end	12S 0474303 3590814	-111.273410	32.454191
87	Marana	Veg_8	2	NE	12S 0474249 3590797	-111.273984	32.454036
88	Marana	Veg_8	2	NW	12S 0474149 3590805	-111.275049	32.454106
89	Marana	Veg_8	2	SE	12S 0474249 3590793	-111.273984	32.454000
90	Marana	Veg_8	2	SW	12S 0474149 3590800	-111.275049	32.454061

APPENDIX B – Plant List Provided by Pima County

Genus species	ABBR	Family	Nitro #	Pre-2012 FG	Pre-2012 WIS	New FG	New WIS
Acalypha neomexicana	CHMI	Euphorbiaceae	4	N/A	5	UPL	5
Acalypha neomexicana	ACNE	Euphorbiaceae		N/A	5	UPL	5
Acalypha ostryifolia	ACOS	Euphorbiaceae		N/A	5	UPL	5
Amaranthus fimbriatus	AMFI	Amaranthaceae	7	N/A	4	UPL	5
Amaranthus palmeri	AMPA	Amaranthaceae	7	FACU	4	FACU	4
Ambrosia ambrosioides	AMAM	Asteraceae	6	N/A	4	UPL	5
Ambrosia artemisiifolia	AMAR	Asteraceae	6	FACU	4	FACU	4
Ambrosia deltoidea	AMDE	Asteraceae	6	N/A	4	UPL	5
Ambrosia psilostachya	AMPS	Asteraceae	4	FAC	3	FACU	4
Ambrosia trifida	AMTR	Asteraceae	5	FACW-	2	FAC	3
Androsace occidentalis	ANOC2	Primulaceae	2	FACU	4	FACU	4
Anoda cristata	ANCR2	Malvaceae		FAC	3	FAC	3
Apodanthera undulata	APUN	Cucurbitaceae		NI	5	UPL	5
Argemone pleiacantha	ARPL3	Papaveraceae		NI	5	UPL	5
Aristida adscensionis	ARAD	Poaceae		N/A	5	UPL	5
Arundo donax	ARDO	Poaceae	7	FACW	2	FACW	2
Astragalus thurberi	ASTH	Fabaceae	2	N/A	5	UPL	5
Baccharis salicifolia	BASA	Asteraceae	6	FACW	2	FAC	2
Baccharis salicifolia	BASAd	Asteraceae	6	FACW	2	FAC	2
Baccharis sarothroides	BASA2	Asteraceae	6	FAC-	3	FACU	4
Bidens leptocephala	BILE	Asteraceae	8	FAC	3	FAC	3
Boerhavia coccinea	BOCO	Nyctaginaceae	2	N/A	5	UPL	5
Boerhavia coulteri	BOCO2	Nyctaginaceae	2	N/A	5	UPL	5
Bouteloua aristidoides	BOAR	Poaceae	1	N/A	5	UPL	5
Bouteloua rothrockii	BORO	Poaceae	1	N/A	5	UPL	5
Bowlesia incana	BOIN	Apiaceae	2	UPL	5	FACU	4
Bromus catharticus	BRCA	Poaceae	4	N/A	5	UPL	5
Calibrachoa parviflora	CAPA	Solanaceae	1	FACW	2	FACW	2
Celtis laevigata var. reticulata	CELAR	Ulmaceae		FACU	4	FAC	3
Cenchrus spinifex	CESP	Poaceae		NI	4	UPL	5
Chamaecrista nictitans	CHNI	Fabaceae		NO	4	UPL	5
Chamaesyce capitellata	CHCA	Euphorbiaceae	2	N/A	5	UPL	5
Chamaesyce florida	CHFL	Euphorbiaceae	2	N/A	5	UPL	5
Chamaesyce hyssopifolia	CHHY	Euphorbiaceae	2	NI	3	FACU	4
Chamaesyce setiloba	CHSE	Euphorbiaceae	2	N/A	5	UPL	5
Chenopodium ambrosioides	CHAM	Chenopodiaceae	7	FAC	3	UPL	5
Chenopodium berlandieri	CHBE	Chenopodiaceae	7	N/A	4	UPL	5
Chenopodium fremontii	CHFR	Chenopodiaceae	7	UPL	5	UPL	5
Chloris virgata	CHVI	Poaceae	2	N/A	5	FACU	4
Cirsium vulgare	CIVU	Asteraceae	8	FACU	4	FACU	4
Clematis drummondii	CLDR	Ranunculaceae	5	N/A	4	UPL	5
Clematis hirsutissima	CLHI	Ranunculaceae	5		4	UPL	5

cont…

Genus species	**ABBR**	**Family**	**Nitro #**	**Pre-2012 FG**	**Pre-2012 WIS**	**New FG**	**New WIS**
Conium maculatum	COMA	Apiaceae	8	OBL	1	FACW	2
Conyza canadensis	COCA	Asteraceae	5	FACU	4	UPL	5
Crotalaria pumila	CRPU	Fabaceae		N/A	5	UPL	5
Croton pottsii	CRPO	Euphorbiaceae		N/A	5	UPL	5
Cryptantha angustifolia	CRAN	Boraginaceae	3	N/A	5	UPL	5
Cryptantha micrantha	CRMI	Boraginaceae	3	N/A	5	UPL	5
Cyclospermum leptophyllum	CYLE	Apiaceae	5	UPL	5	FACU	4
Cynodon dactylon	CYDA	Poaceae	5	FACU	4	FACU	4
Cyperus esculentus	CYES	Cyperaceae	5	FACW	2	FACW	2
Cyperus involucratus	CYIN	Cyperaceae	5	NO	2	FACW	2
Cyperus odoratus	CYOD	Cyperaceae	5	FACW+	2	FACW	2
Cyperus strigosus	CYST	Cyperaceae	5	FACW	2	FACW	2
Dactyloctenium aegyptium	DAAE	Poaceae		N/A	5	UPL	5
Datura wrightii	DAWR	Solanaceae	8	N/A	5	UPL	5
Daucus carota	DACA	Apiaceae	4	N/A	3	UPL	5
Descurainia pinnata	DEPI	Brassicaceae	6	N/A	5	UPL	5
Dicliptera resupinata	DIRE	Acanthaceae		N/A	5	UPL	5
Digitaria sanguinalis	DISA	Poaceae	5	FACU	4	FACU	4
Distichlis spicata	DISP	Poaceae	2	FACW	2	FAC	3
Dysphania ambrosioides	DYAM	Chenopodiaceae		FAC	3	FAC	3
Echinochloa colona	ECCO	Poaceae	8	FACW	2	FAC	2
Echinochloa crus-galli	ECCR	Poaceae	8	FACW-	2	FACW	2
Eclipta prostrata	ECPR	Asteraceae		FAC	3	FAC	3
Equisetum laevigatum	EQLA	Equisetaceae	4	FACW	2	FACW	2
Eragrostis cilianensis	ERCI	Poaceae	3	FACU+	4	FACU	4
Eragrostis lehmanniana	ERLE	Poaceae	3	N/A	5	UPL	5
Eragrostis pectinacea	ERPE	Poaceae	3	FAC	3	FAC	3
Erigeron divergens	ERDI	Asteraceae	4	N/A	5	UPL	5
Eriochloa acuminata	ERAC	Poaceae	3	FACW	2	FACW	2
Eriochloa aristata	ERAR	Poaceae	3	FACW	2	FACW	2
Eriogonum polycladon	ERPO	Polygonaceae		N/A	5	UPL	5
Erodium cicutarium	ERCI2	Geraniaceae	3	N/A	5	UPL	5
Eschscholzia californica	ESCAM	Papaveraceae	2	N/A	5	UPL	5
Euphorbia heterophylla	EUHE	Euphorbiaceae	4	UPL	5	UPL	5
Gaura mollis	GAMO	Onagraceae		NI	4	UPL	5
Helianthus annuus	HEAN	Asteraceae	8	FAC-	3	FACU	4
Heliotropium curassavicum	HECU	Boraginaceae	6	FACW	2	FACU	4
Heterotheca subaxillaris	HESU	Asteraceae		UPL	5	UPL	5
Hydrocotyle verticillata	HYVE	Apiaceae	2	OBL	1	OBL	1
Hymenoclea monogyra	HYMO	Asteraceae	3	N/A	5	UPL	5
Ipomoea barbatisepala	IPBA	Convovulaceae		N/A	4	UPL	5
Ipomoea cristulata	IPCR	Convovulaceae	2	N/A	4	UPL	5
Ipomoea hederacea	IPHE	Convovulaceae	2	FACU*	4	FACU	4
Ipomoea purpurea	IPPU	Convovulaceae	2	UPL	5	UPL	5
Ipomoea ternifolia	IPTE	Convovulaceae	2	N/A	4	UPL	5

cont…

Genus species	**ABBR**	**Family**	**Nitro #**	**Pre-2012 FG**	**Pre-2012 WIS**	**New FG**	**New WIS**
Isocoma tenuisecta	ISTE	Asteraceae		N/A	5	UPL	5
Kallstroemia parviflora	KAPA	Zygophyllaceae		N/A	5	UPL	5
Lepidium thurberi	LETH	Brassicaceae	5	N/A	4	FACU	4
Ludwigia palustris	LUPA	Onagraceae	4	OBL	1	OBL	1
Lupinus concinnus	LUCO	Fabaceae		N/A	5	UPL	5
Machaeranthera canescens	MACA	Asteraceae		UPL	5	UPL	5
Malacothrix glabrata	MAGL	Asteraceae		N/A	5	UPL	5
Malva parviflora	MAPA	Malvaceae		N/A	5	UPL	5
Melilotus alba	MEAL	Fabaceae	4	FACU+	4	FACU	4
Melilotus indicus	MEIN	Fabaceae	7	FACU+	4	FACU	4
Melilotus officinalis	MEOF	Fabaceae	3	FACU+	4	UPL	4
Mentzelia multiflora	MEMU	Loasaceae	4	N/A	5	UPL	5
Mimulus guttatus	MIGU	Scrophulariaceae	6	OBL	1	OBL	1
Mirabilis longiflora	MILO	Nyctaginaceae	3	N/A	4	UPL	5
Myosurus cupulatus	MYCO	Ranunculaceae				FAC	3
Nama hispidum	NAHI	Hydrophyllaceae		N/A	5	UPL	5
Nasturtium officinale	NAOF	Brassicaceae	7	OBL	1	OBL	1
Nicotiana glauca	NIGL	Solanaceae	6	FAC	3	FAC	3
Nicotiana obtusifolia	NIOB	Solanaceae	6	FACU	4	FACU	4
Panicum antidotale	PAAN	Poaceae	6	N/A	5	UPL	5
Parkinsonia aculeata	PAAC	Fabaceae				FAC	4
Parkinsonia florida	PASP	Fabaceae		N/A		FAC	5
Paspalum dilatatum	PADI	Poaceae		FAC	3	FAC	3
Pectis papposa	PEPA	Asteraceae		N/A	5	UPL	5
Pectis prostrata	PEPR	Asteraceae		N/A	5	UPL	5
Phacelia arizonica	PHAR	Solanaceae		N/A	5	UPL	5
Physalis acutifolia	PHAC	Solanaceae	7	N/A	5	UPL	5
Polygonum lapathifolium	POLA	Polygonaceae	8	OBL	1	UPL	2
Polypogon monspeliensis	POMO	Poaceae	6	FACW+	2	FACW	2
Populus fremontii	POFR	Salicaceae	6	FACW	2	UPL	2
Portulaca halimoides	POHA	Portulaceae	7	NO	4	FAC	3
Portulaca oleracea	POOL	Portulaceae	7	FAC	3	FAC	3
Portulaca suffrutescens	POSU	Portulaceae	7	N/A	4	UPL	5
Proboscidea parviflora	PRPA	Pedaliaceae		N/A	5	UPL	5
Prosopis velutina	PRVE	Fabaceae		N/A		FACU	4
Pseudognaphalium canescens	PSCA	Asteraceae	2	UPL	5	FACU	4
Ranunculus sceleratus	RASC	Ranunculaceae	9	OBL	1	OBL	1
Rumex dentatus	RUDE	Polygonaceae	6	NO	1	FACW	2
Rumex obtusifolius	RUOB	Polygonaceae	9	FACW	2	FAC	3
Salix gooddingii	SAGO	Salicaceae	5	OBL	1	FACW	2
Salsola tragus	SATR	Chenopodiaceae	6	FACU	4	FACU	4
Schismus arabicus	SCAR	Poaceae	1	N/A	5	UPL	5
Schismus barbatus	SCBA	Poaceae	1	N/A	5	UPL	5

cont…

Genus species	**ABBR**	**Family**	**Nitro #**	**Pre-2012 FG**	**Pre-2012 WIS**	**New FG**	**New WIS**
Schoenoplectus americanus	SCAM	Cyperaceae	7	OBL	1	OBL	1
Setaria grisebachii	SEGR	Poaceae	7	N/A	4	UPL	5
Sida spinosa	SISP	Malvaceae		UPL	5	UPL	5
Sisymbrium irio	SIIR	Brassicaceae	5	N/A	5	UPL	5
Solanum americanum	SOAM	Solanaceae	7	FAC	3	FACU	4
Solanum elaeagnifolium	SOEL	Solanaceae	7	N/A	5	UPL	5
Solanum lycopersicum	SOLY	Solanaceae	7	N/A	5	UPL	5
Sonchus asper	SOAS	Asteraceae	7	FACW	2	FAC	3
Sorghum halepense	SOHA	Poaceae	4	FACU+	4	FACU	4
Sphaeralcea laxa	SPLA	Malvaceae	3	NI	5	UPL	5
Sporobolus contractus	SPCO	Poaceae	4	N/A	4	UPL	5
Sporobolus cryptandrus	SPCR	Poaceae	4	FACU-	4	FACU	4
Stemodia durantifolia	STDU	Scrophulariaceae		OBL	1	OBL	1
Symphyotrichum ascendens	SYAS	Asteraceae		N/A	5	FAC	3
Tamarix aphylla	TAAP	Tamaricaceae		FAC	3	FAC	3
Tamarix ramosissima	TARA	Tamaricaceae		NI		UPL	4
Tidestromia lanuginosa	TILA	Amaranthaceae		N/A	5	UPL	5
Trianthema portulacastrum	TRPO	Aizoaceae		NI	2	FAC	3
Typha domingensis	TYDO	Typhaceae	8	OBL	1	OBL	1
Urochloa arizonica	URAR	Poaceae	1	N/A	5	UPL	5
Verbesina encelioides	VEEN	Asteraceae		FAC	3	FACU	4
Veronica anagallis-aquatica	VEAN	Scrophulariaceae	5	OBL	1	OBL	2
Vulpia octoflora	VUOC	Poaceae	1	NI	5	UPL	5
Xanthium strumarium	XAST	Asteraceae	6	NI	4	FAC	3

APPENDIX C – Species Observed during Streamside Herbaceous Surveys

Family	*Genus species*	ABBR	Common Names
Amaranthaceae	*Amaranthus palmeri*	AMPA	careless weed
Apiaceae	*Conium maculatum*	COMA	poison hemlock
Apiaceae	*Daucus pusillus*	DAPU	American wild carrot
Asteraceae	*Baccharis salicifolia*	BASA	mule fat, seep willow
Asteraceae	*Baccharis sarothroides*	BASAR	desert broom
Asteraceae	*Conyza canadensis*	COCA	Canadian horseweed
Asteraceae	*Eclipta prostrata*	ECPR	false daisy
Asteraceae	*Helenium thurberi*	HETH	Thurber's sneezeweed
Asteraceae	*Hymenoclea monogyra*	HYMO	singlewhorl burrobrush
Asteraceae	*Lactuca serriola*	LASE	prickly lettuce
Asteraceae	*Laennecia coulteri*	LACO	Coulter's horseweed
Asteraceae	*Matricaria discoidea*	MADI	pineappleweed
Asteraceae	*Pseudognaphalium canescens*	PSLA	Wright's cudweed
Asteraceae	*Sonchus asper*	SOAS	spiny sowthistle
Asteraceae	*Xanthium strumarium*	XAST	rough cocklebur
Boraginaceae	*Cryptantha angustifolia*	CRAN	panamint cat's eye
Brassicaceae	*Capsella bursa-pastoris*	CABU	Shepherd's purse
Brassicaceae	*Lepidium lasiocarpum*	LELA	desert peppergrass
Brassicaceae	*Lepidium thurberi*	LETH	Thurber's pepperweed
Brassicaceae	*Lesquerella gordoni*	LEGO	Gordon's bladderpod
Brassicaceae	*Nasturtium officinale*	NAOF	watercress
Brassicaceae	*Sisymbrium irio*	SIIR	London rocket
Capparaceae	*Polanisia dodecandra*	PODO	redwhisker clammyweed
Chenopodiaceae	*Atriplex elegans*	ATEL	wheelescale saltbush
Chenopodiaceae	*Chenopodium ambrosioides*	CHAM	Mexican tea
Chenopodiaceae	*Chenopodium berlandieri*	CHBE	pitseed goosefoot
Chenopodiaceae	*Chenopodium fremontii*	CHFR	Fremont's goosefoot
Cyperaceae	*Cyperus erogrostis*	CYER	umbrella nutsedge
Fabaceae	*Medicago polymorpha*	MEPO	burclover
Fabaceae	*Melilotus officinalis*	MEOF	sweetclover
Fabaceae	*Parkinsonia aculeata*	PAAC	MX palo verde, Jerusalem thorn
Fabaceae	*Prosopis spp.*	PRVEx	hybrid Chilean mesquite
Fabaceae	*Prosopis velutina*	PRVE	velvet mesquite
Hydrophyllaceae	*Nama hispidum*	NAHI	bristly nama
Juncaceae	*Juncus bufonius*	JUME	toad rush
Malvaceae	*Malva parviflora*	MAPA	cheeseweed mallow
Onagraceae	*Ludwigia palustris*	LUPA	marsh seedbox
Plantaginaceae	*Plantago ovata*	PLOV	Indian wheatgrass
Poaceae	*Bromus catharticus*	BRCA	rescue grass
Poaceae	*Bromus rubens*	BRRU	red brome
Poaceae	*Chloris virgata*	CHVI	feather fingergrass
Poaceae	*Cynodon dactylon*	CYDA	Bermuda grass
Poaceae	*Echinochloa colona*	ECCO	jungle rice
Poaceae	*Echinochloa crus-galli*	ECCR	barnyard grass
Poaceae	*Hordeum murinum*	HOMU	mouse barley

cont…

Family	*Genus species*	ABBR	Common Names
Poaceae	*Leptochloa fusca*	LEFU	Malabar sprangletop
Poaceae	*Paspalum distichum*	PADI2	knotgrass
Poaceae	*Pennisetum ciliare*	PECI	buffelgrass
Poaceae	*Polypogon monspeliensis*	POMO	annual rabbitsfoot grass
Poaceae	*Schismus barbatus*	SCBA	common Mediterranean grass
Poaceae	*Sorghum halepense*	SOHA	Johnsongrass
Polygonaceae	*Polygonum lapathifolium*	POLA	curlytop knotweed
Polygonaceae	*Rumex obtusifolius*	RUOB	bitter dock
Portulaceae	*Portulaca oleracea*	POOL	little hogweed
Ranunculaceae	*Ranunculus sceleratus*	RASC	cursed buttercup
Salicaceae	*Salix gooddingii*	SAGO	Goodding's willow
Scrophulariaceae	*Mimulus guttatus*	MIGU	seep monkeyflower
Scrophulariaceae	*Veronica anagallis-aquatica*	VEAN	water speedwell
Solanaceae	*Physalis acutifolia*	PHAC	sharpleaf groundcherry
Solanaceae	*Solanum americanum*	SOAM	American black nightshade
Tamaricaceae	*Tamarix aphylla*	TAAP	Athel tamarisk
Tamaricaceae	*Tamarix ramosissima*	TARA	saltcedar
Typhaceae	*Typha domingensis*	TYDO	southern cattail
Zygophyllaceae	*Tribulus terrestris*	TRTE	puncturevine

APPENDIX D – Statistical Test Results

Paired Sample T-test, Wetland Indicator Status (WIS#)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	2014	2.756250	8	1.0524928	.3721124
	2015	3.185000	8	.8371721	.2959850

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	2014 & 2015	8	.708	.049

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	2014 - 2015	-.4287500	.7488360	.2647535	-1.0547926	.1972926	-1.619	7	**.149**
Pair 2	2013 - 2014	.1587500	.4100675	.1449808	-.1840750	.5015750	1.095	7	**.310**
Pair 3	2013 - 2015	-.2700000	.6332907	.2239021	-.7994443	.2594443	-1.206	7	**.267**

Paired Sample T-test WIS#, Excluding Dry Ina (Veg_4) and Marana (Veg_8) Sites

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	2013	3.0550	6	.96988	.39595
	2014	2.956667	6	1.1550007	.4715271
Pair 2	2014	2.956667	6	1.1550007	.4715271
	2015	3.013333	6	.9160277	.3739667
Pair 3	2013	3.0550	6	.96988	.39595
	2015	3.013333	6	.9160277	.3739667

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	2013 & 2014	6	.918	.010
Pair 2	2014 & 2015	6	.978	.001
Pair 3	2013 & 2015	6	.962	.002

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	2013 - 2014	.0983333	.4661080	.1902878	-.3908170	.5874837	.517	5	**.627**
Pair 2	2014 - 2015	-.0566667	.3220352	.1314703	-.3946219	.2812885	-.431	5	**.684**
Pair 3	2013 - 2015	.0416667	.2668645	.1089470	-.2383905	.3217238	.382	5	**.718**

Paired Sample T-test, Nitrogen Affinity (NITRO#)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	2014.	6.1587	8	1.40918	.49822
	2015.	5.7613	8	1.11636	.39469

Paired Samples Correlations

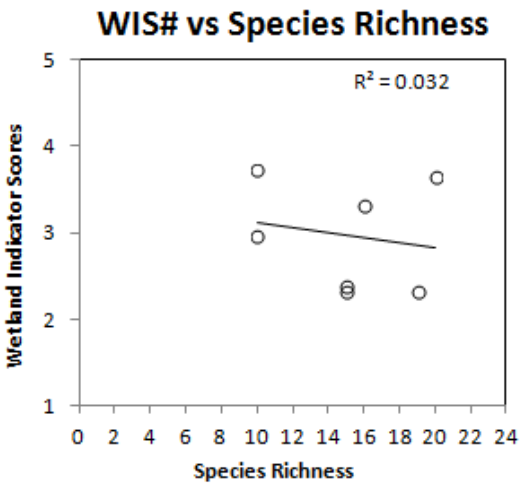
		N	Correlation	Sig.
Pair 1	2014. & 2015.	8	.570	.140

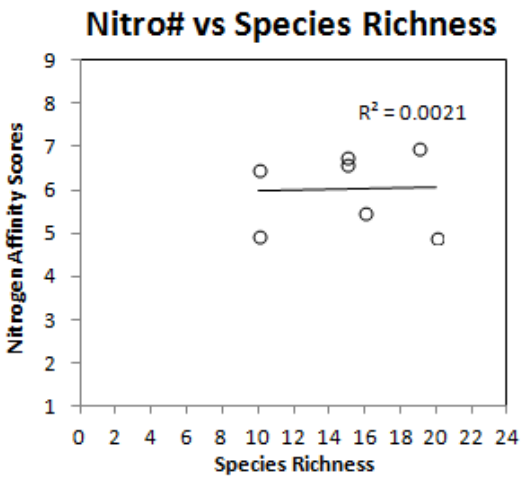
Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	2014. - 2015.	.39750	1.19925	.42400	-.60510	1.40010	.938	7	**.380**
Pair 2	2013. - 2014.	-.29375	.65251	.23070	-.83926	.25176	-1.273	7	**.244**
Pair 3	2013. - 2015.	.10375	1.07057	.37850	-.79127	.99877	.274	7	**.792**

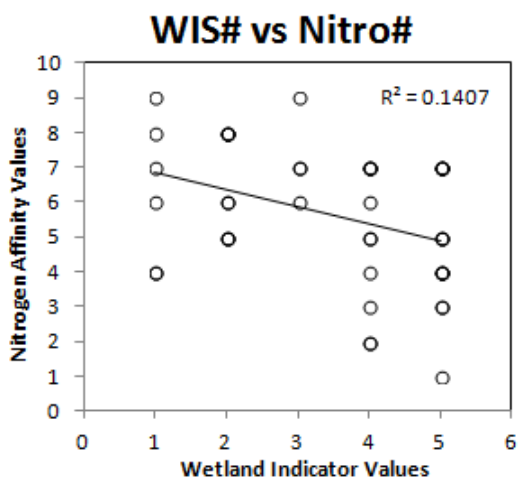
Using the standard deviation and standard error of the difference between 2014 and 2015, a paired sample T-test was used to test whether the metric values were significantly different between 2014 and 2015. Above we see that neither WIS#s (p=0.15) nor Nitro#s (p=0.38) are significantly different between years 2014 and 2015. Furthermore, values have not been different between any years including 2013. Each site is differentially impacted by various factors including baseflows, water quality, and geomorphology. Additionally, there has been evidence that some sites have undergone changes in baseflows and quality of effluent, among other factors, all of which can contribute to variance within the data. It will take many more survey years to understand overall trends across and within all sites.

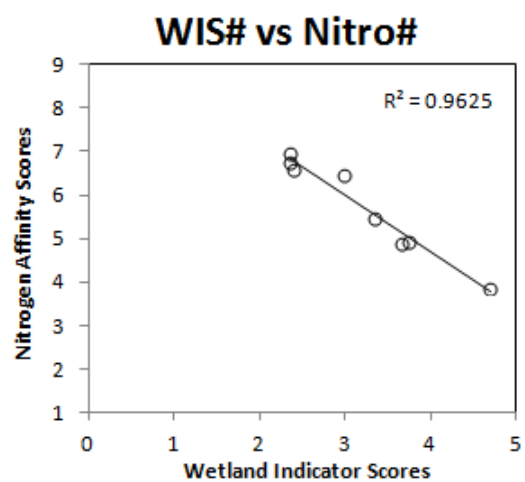
Below, we find little relationship between Species Richness and WIS or Nitro Scores. In other words, although we might expect that wetter sites may have more species, we find that a lower WIS score does not correlate to increased numbers of species. As discussed in the 2014 report, one explanation could be that wet sites during this study often included large, homogenous mats of aquatic vegetation or stands of cattail that dominated the survey area.





Below, we find that nitrogen values (i.e., values documented in literature), of the plants falling into our surveys that have known values, are not correlated with wetland indicator values (i.e., values documented in literature). For example, we see that the group of obligate plants (WIS=1) has a range of nitrogen values from 4-9 while facultative upland plants (WIS=4) range from 2-7. Interestingly, the project WIS Scores were highly correlated with Nitro Scores. This is explained by some of the more common plants documented during the survey having low WIS and high Nitro (e.g., TYPHA & POLA = 1,8) and high WIS and low Nitro (e.g., HYMO = 5,3) during the surveys. In general, this means that plants along the wetter reaches of the Santa Cruz tend to have higher nitrogen affinity, while plants in less wet areas tend to have lower nitrogen affinity. This pattern was consistent between 2014 and 2015 surveys.





APPENDIX E – Density and Basal Area Metrics by Survey Site

Table A. Plant density, stem density, and basal area statistics for woody trees within belt-transect surveys for live plant species.

		seep willow **BASA**	Mexican paloverde **PAAC**	blue paloverde **PAFL**	Fremont cottonwood **POFR**	velvet mesquite **PRVE**	mesquite hybrid **PRVEx**	Goodding's willow **SAGO**	athel tamarisk **TAAP**	saltcedar **TARA**
VEG_01	plants/site	--	--	--	--	2	--	--	--	--
	plants/ha	--	--	--	--	55.6	--	--	--	--
	stems/site	--	--	--	--	15.0	--	--	--	--
	stems/ha	--	--	--	--	416.7	--	--	--	--
	basal area (cm^2)	--	--	--	--	56.3	--	--	--	--
	basal area (m^2/ha)	--	--	--	--	0.2	--	--	--	--
VEG_02	plants/site	--	1	2	1	--	7	--	--	4
	plants/ha	--	22.5	44.9	22.5	--	157.3	--	--	89.9
	stems/site	--	3.0	5.0	2.0	--	23.0	--	--	20.0
	stems/ha	--	67.4	112.4	44.9	--	516.9	--	--	449.4
	basal area (cm^2)	--	397.9	5.7	1253.9	--	61.5	--	--	126.6
	basal area (m^2/ha)	--	0.9	0.0	2.8	--	0.1	--	--	0.3
VEG_03	plants/site	18	2	--	--	5	--	1	--	--
	plants/ha	400.0	44.4	--	--	111.1	--	22.2	--	--
	stems/site	64.0	6.0	--	--	6.0	--	2.0	--	--
	stems/ha	1422.2	133.3	--	--	133.3	--	44.4	--	--
	basal area (cm^2)	195.6	177.9	--	--	2185.0	--	3.5	--	--
	basal area (m^2/ha)	0.4	0.4	--	--	4.9	--	0.0	--	--
VEG_04	plants/site	--	5	--	--	--	--	5	4	--
	plants/ha	--	122.0	--	--	--	--	122.0	97.6	--
	stems/site	--	10.0	--	--	--	--	14.0	12.0	--
	stems/ha	--	243.9	--	--	--	--	341.5	292.7	--
	basal area (cm^2)	--	42.6	--	--	--	--	2425.3	71.8	--
	basal area (m^2/ha)	--	0.1	--	--	--	--	5.9	0.2	--

cont…		seep willow **BASA**	Mexican paloverde **PAAC**	blue paloverde **PAFL**	Fremont cottonwood **POFR**	velvet mesquite **PRVE**	mesquite hybrid **PRVEx**	Goodding's willow **SAGO**	athel tamarisk **TAAP**	saltcedar **TARA**
VEG_05	plants/site	--	--	--	--	--	--	--	--	2
	plants/ha	--	--	--	--	--	--	--	--	44.0
	stems/site	--	--	--	--	--	--	--	--	30.0
	stems/ha	--	--	--	--	--	--	--	--	659.3
	basal area (cm^2)	--	--	--	--	--	--	--	--	15.7
	basal area (m^2/ha)	--	--	--	--	--	--	--	--	0.0
VEG_06	plants/site	--	1	--	--	--	--	--	--	41
	plants/ha	--	22.5	--	--	--	--	--	--	921.3
	stems/site	--	1.0	--	--	--	--	--	--	203.0
	stems/ha	--	22.5	--	--	--	--	--	--	4561.8
	basal area (cm^2)	--	232.4	--	--	--	--	--	--	1730.4
	basal area (m^2/ha)	--	0.5	--	--	--	--	--	--	3.9
VEG_07	plants/site	6	--	--	--	--	--	--	1	--
	plants/ha	144.6	--	--	--	--	--	--	24.1	--
	stems/site	26.0	--	--	--	--	--	--	8.0	--
	stems/ha	626.5	--	--	--	--	--	--	192.8	--
	basal area (cm^2)	36.9	--	--	--	--	--	--	759.3	--
	basal area (m^2/ha)	0.1	--	--	--	--	--	--	1.8	--
VEG_08	plants/site	--	--	--	--	--	--	2	5	2
	plants/ha	--	--	--	--	--	--	64.5	161.3	64.5
	stems/site	--	--	--	--	--	--	3.0	11.0	8.0
	stems/ha	--	--	--	--	--	--	96.8	354.8	258.1
	basal area (cm^2)	--	--	--	--	--	--	1589.3	2382.7	71.8
	basal area (m^2/ha)	--	--	--	--	--	--	5.1	7.7	0.2
AVG	plants/site	3.0	1.1	0.3	0.1	0.9	0.9	1.0	1.3	6.1
	plants/ha	68.1	26.4	5.6	2.8	20.8	19.7	26.1	35.4	140.0
	stems/site	11.3	2.5	0.6	0.3	2.6	2.9	2.4	3.9	32.6
	stems/ha	256.1	58.4	14.0	5.6	68.8	64.6	60.3	105.0	741.1
	basal area (cm^2)	29.1	106.3	0.7	156.7	280.2	7.7	502.3	401.7	243.1
	basal area (m^2/ha)	0.1	0.2	0.002	0.4	0.6	0.02	1.4	1.2	0.6

Table B. Plant density statistics for all woody shrubs analyzed within belt-transect surveys for live plant species.

		catclaw acacia **ACGR**	wheelscale saltbush **ATEL**	cattle saltbush **ATPO**	desert broom **BASA2**	singlewhorl burrobrush **HYMO**	creosotebush **LATR**	Fremont's desert-thorn **LYFR**	graythorn **ZIOB**
VEG_01	plants/site	--	--	--	9	79	--	--	--
	plants/ha	--	--	--	250.0	2194.4	--	--	--
VEG_02	plants/site	1	--	--	3	52	--	--	--
	plants/ha	22.5	--	--	67.4	1168.5	--	--	--
VEG_03	plants/site	--	--	39	3	5	1	1	2
	plants/ha	--	--	866.7	66.7	111.1	22.2	22.2	44.4
VEG_04	plants/site	--	1	--	1	7	--	--	--
	plants/ha	--	24.4	--	24.4	170.7	--	--	--
VEG_05	plants/site	--	--	--	--	182	--	--	--
	plants/ha	--	--	--	--	4000.0	--	--	--
VEG_06	plants/site	--	--	--	--	1	--	--	--
	plants/ha	--	--	--	--	22.5	--	--	--
VEG_07	plants/site	--	--	--	--	10	--	--	--
	plants/ha	--	--	--	--	241.0	--	--	--
VEG_08	plants/site	--	--	--	--	5	--	--	--
	plants/ha	--	--	--	--	161.3	--	--	--
AVG	plants/site	0.1	0.1	4.9	2.0	42.6	0.1	0.1	0.3
	plants/ha	2.8	3.0	108.3	51.1	1008.7	2.8	2.8	5.6

Table C. Plant density, stem density, and basal area statistics for woody trees within belt-transect surveys for dead species and as analyzed by live species within functional group.

		Fremont cottonwood **POFRd**	Goodding's willow **SAGOd**	saltcedar **TARAd**	athel tamarisk **TAAPd**	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
VEG_01	plants/site	--	--	--	--	--	--	9	2	79
	plants/ha	--	--	--	--	--	--	250.0	55.6	2194.4
	stems/site	--	--	--	--	--	--	--	15.0	--
	stems/ha	--	--	--	--	--	--	--	416.7	--
	basal area (cm^2)	--	--	--	--	--	--	--	56.3	--
	basal area (m^2/ha)	--	--	--	--	--	--	--	0.2	--
VEG_02	plants/site	1	--	--	--	--	2	4	7	59.0
	plants/ha	22.5	--	--	--	--	44.9	89.9	157.3	1325.8
	stems/site	1.0	--	--	--	--	5.0	3.0	23.0	23.0
	stems/ha	22.5	--	--	--	--	112.4	67.4	516.9	516.9
	basal area (cm^2)	30.2	--	--	--	--	5.7	397.9	61.5	1413.5
	basal area (m^2/ha)	0.1	--	--	--	--	0.01	0.9	0.1	3.2
VEG_03	plants/site	--	--	--	--	--	1	25	5	46
	plants/ha	--	--	--	--	--	22.2	555.6	111.1	1022.2
	stems/site	--	--	--	--	--	2.0	70.0	6.0	--
	stems/ha	--	--	--	--	--	44.4	1555.6	133.3	--
	basal area (cm^2)	--	--	--	--	--	3.5	373.5	2185.0	--
	basal area (m^2/ha)	--	--	--	--	--	0.01	0.8	4.9	--
VEG_04	plants/site	--	2	--	--	--	7	10	--	8
	plants/ha	--	48.8	--	--	--	170.7	243.9	--	195.1
	stems/site	--	2.0	--	--	--	16.0	22.0	--	--
	stems/ha	--	48.8	--	--	--	390.2	536.6	--	--
	basal area (cm^2)	--	161.6	--	--	--	2586.9	114.4	--	--
	basal area (m^2/ha)	--	0.4	--	--	--	6.3	0.3	--	--

cont…		Fremont cottonwood **POFRd**	Goodding's willow **SAGOd**	saltcedar **TARAd**	athel tamarisk **TAAPd**	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
VEG_05	plants/site	--	--	--	--	--	--	--	--	184
	plants/ha	--	--	--	--	--	--	--	--	4044.0
	stems/site	--	--	--	--	--	--	--	--	30.0
	stems/ha	--	--	--	--	--	--	--	--	659.3
	basal area (cm^2)	--	--	--	--	--	--	--	--	15.7
	basal area (m^2/ha)	--	--	--	--	--	--	--	--	0.0
VEG_06	plants/site	--	--	13	--	--	--	1	--	55
	plants/ha	--	--	292.1	--	--	--	22.5	--	1236.0
	stems/site	--	--	58.0	--	--	--	1.0	--	261.0
	stems/ha	--	--	1303.4	--	--	--	22.5	--	5865.2
	basal area (cm^2)	--	--	124.2	--	--	--	232.4	--	1854.6
	basal area (m^2/ha)	--	--	0.3	--	--	--	0.5	--	4.2
VEG_07	plants/site	--	--	--	--	--	--	7	--	10
	plants/ha	--	--	--	--	--	--	168.7	--	241.0
	stems/site	--	--	--	--	--	--	34.0	--	--
	stems/ha	--	--	--	--	--	--	819.3	--	--
	basal area (cm^2)	--	--	--	--	--	--	796.2	--	--
	basal area (m^2/ha)	--	--	--	--	--	--	1.9	--	--
VEG_08	plants/site	--	3	--	4	--	5	9	--	7
	plants/ha	--	96.8	--	129.0	--	161.3	290.3	--	225.8
	stems/site	--	5.0	--	5.0	--	8.0	16.0	--	8.0
	stems/ha	--	161.3	--	161.3	--	258.1	516.1	--	258.1
	basal area (cm^2)	--	2142.2	--	98.0	--	3731.4	2480.7	--	71.8
	basal area (m^2/ha)	--	6.9	--	0.3	--	12.0	8.0	--	0.2
AVG	plants/site	0.1	0.6	1.6	0.5	0.0	1.9	8.1	1.8	56.0
	plants/ha	2.8	18.2	36.5	16.1	0.0	49.9	202.6	40.5	1310.5
	stems/site	0.1	0.9	7.3	0.6	0.0	3.9	18.3	5.5	40.3
	stems/ha	2.8	26.3	162.9	20.2	0.0	100.6	439.7	133.4	912.4
	basal area (cm^2)	3.8	288.0	15.5	12.3	0.0	790.9	549.4	287.8	419.5
	basal area (m^2/ha)	0.01	0.91	0.03	0.04	0.0	2.3	1.6	0.6	1.0

APPENDIX F - Ancillary Work Photographs

Photo 1 – 2014, dry streambed at Ina Site (Veg_4) just upstream of Ina Outfall.

Photo 2 - 2015, dry streambed at Ina Site (Veg_4) just upstream of Ina Outfall.

Photo 3 – 2014, dry streambed at Ina Site, but with lush streamside vegetation

Photo 4 - 2015, dry streambed at Ina Site, dry and withered streamside vegetation

Photo 5 – 2015, dry streambed at Ina Site, looking west across main channel

Photo 6 – 2015, dry Goodding's willow (*Salix gooddingii*) at Ina Site, from end of belt-transect

Photo 7 – 2013, Trico-Marana Site (Veg_8), baseflow and healthy riparian vegetation

Photo 8 - 2015, Marana Site (Veg_8), dry streambed, defoliated trees, dry streamside vegetation

Photo 9 - 2013, Trico-Marana Site (Veg_8), baseflow and green saltcedar trees

Photo 10 - 2015, Trico-Marana Site (Veg_8), no baseflow and defoliated saltcedar trees

Photo 11 - 2014, Trico-Marana Site (Veg_8), dry streambed transect, looking east, green trees

Photo 12 - 2014, Trico-Marana Site (Veg_8), dry streambed transect, looking east, defoliated trees

Photo 13 – 2015, Trico-Marana, dry streambed with cocklebur (*Xanthium strumarium*) growth

Photo 14 – 2015, Coyote pup observed at Avra Valley site (Veg_6)

Photo 15 – 2014. Clear water at Avra Valley site (Veg_6)

Photo 16 – 2015. Turbid water at Avra Valley site (Veg_6)