Matilija Dam Ecosystem Restoration Project
Giant Reed Removal Element

Post-Treatment Vegetation Monitoring Program

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1.0 Executive Summary. This report establishes a monitoring protocol and describes baseline conditions for monitoring the response of native and non-native vegetation following implementation of the Matilija Giant Reed Removal Element (hereafter called the "Project") along Matilija Creek and portions of the upper main stem of the Ventura River from September 2007 to October 2009.

This study established the following conclusions:

- Treatment of exotic vegetation (primarily composed of giant reed), was highly successful in reducing infestation and percent cover in the project area.
- Native species are recolonizing treated substrates at a 2:1 ratio compared to non-native species.
- Native cover is significantly higher than non-native cover in the treatment areas.
- Re-sprouting of giant reed continues to be a problem despite five re-treatment cycles to date. Percent cover of live giant reed in treatment plots ranged from 0% to 25%, averaging less than 5%.
- Future monitoring of all or a subset of the releve plots established in this study should be conducted to track natural restoration of the project area.

2.0 Introduction. Five invasive plant species were targeted for chemical and mechanical control: giant reed (*Arundo donax*), Scotch broom (*Genista monspessulanus*), castor bean (*Ricinus communis*), pepper tree (*Schinus molle*), and salt cedar (*Tamarix ramossisima*). Giant reed was by far the most common and ecologically-damaging invasive, comprising at least 140 acres (68%) of the 207 acres of non-native vegetation identified for treatment and control in the project area.

This project was the first phase of a watershed-wide effort to control invasive non-native vegetation in the Ventura River and its tributaries. Controlling non-native vegetation is one component of the multi-phase Matilija Dam Ecosystem Restoration Project that includes removing the dam and the sediment it has accumulated in order to improve wildlife habitat quality in the watershed.

The Phase 1 project area was divided into five stream reaches (Reach 9-Reach 5) that extended downstream from a series of waterfalls in the upper watershed of the main stem of Matilija Creek to the Highway 150 Bridge over the main stem of the Ventura River, a distance of approximately 16 stream miles and encompassing approximately 1,272 acres of floodplain habitats (Figure 1).

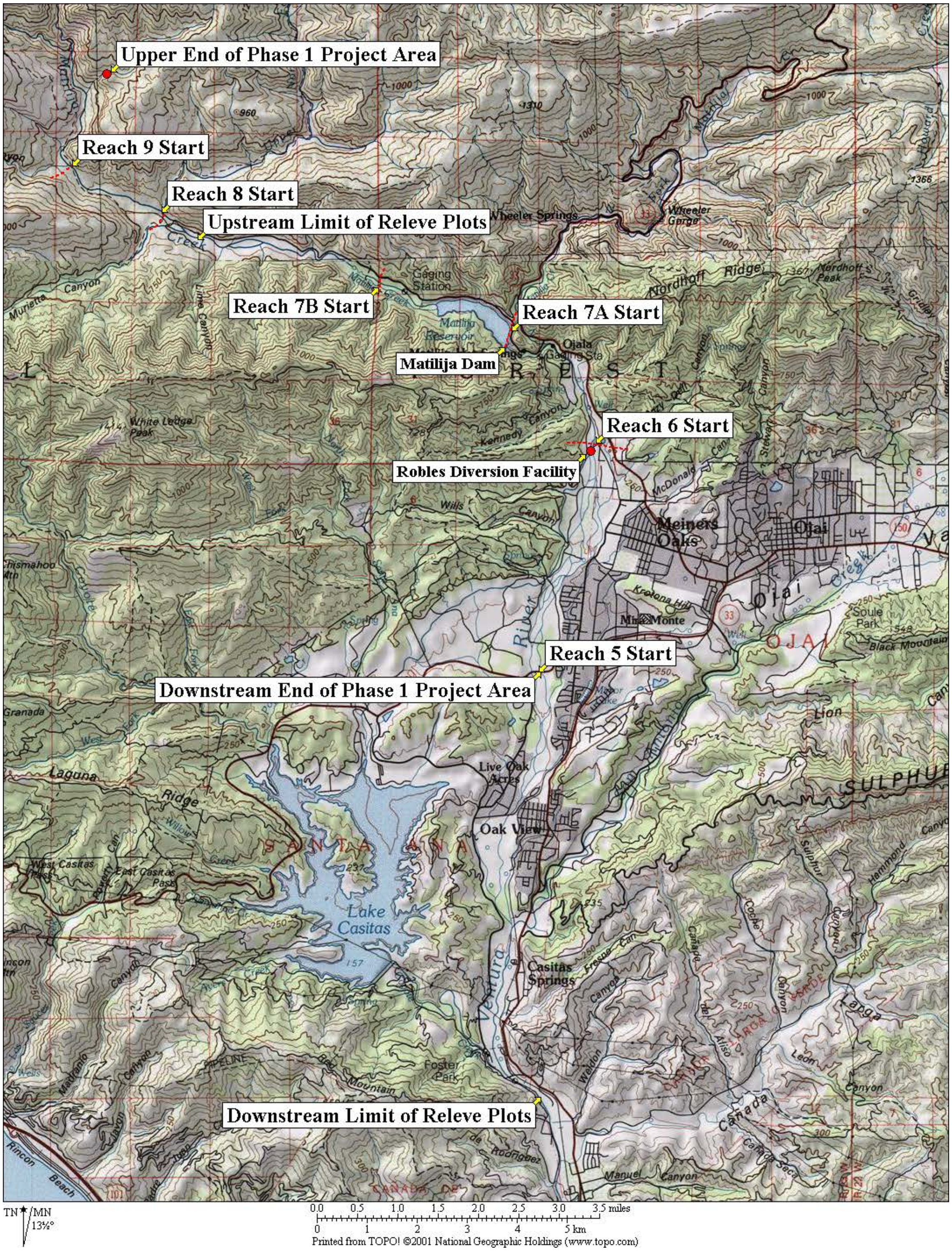

Figure 1. Project and study area limits.

Pre-Treatment Condition of the Project Area. Exotic vegetation targeted for control occurred throughout the project area prior to initiating treatment, but the magnitude of infestation differed widely between species and areas. Prior to implementation of the project, five categories of infestation (percent cover) were identified and mapped throughout the project area (Ecosystems Restoration Associates, 2007; County of Ventura, 2007). Figure 2 summarizes the results of those calculations. The intensity of infestation was spatially variable within and between reaches. Infestation was lowest in Reaches 8 and 9 in the upper and middle portions of the Matilija Creek watershed, but increased rapidly downstream in the vicinity of Matilija Reservoir. Infestation was highest on floodplain substrates formerly inundated by the reservoir that were exposed when the dam was notched repeatedly beginning in the 1960s for safety reasons in order to reduce the amount of water it impounded. These exposed substrates were rapidly colonized by giant reed that, in time, formed extensive, nearly monotypic stands covering dozens of acres. Exotic species infestation also was relatively high in Reach 6 between the dam and the Robles Diversion facility, then declined in the downstream reach of the project area (Figure 2).

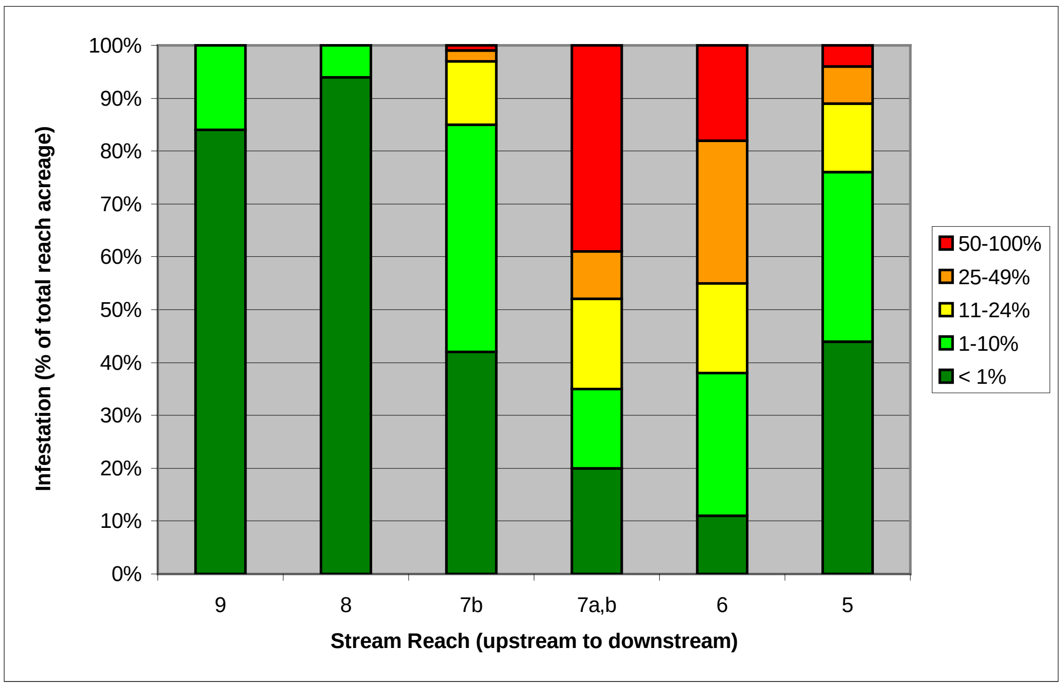

Figure 2. Intensity of infestation of target exotics in the 1,272-acre project area. Stream reaches are shown on Figure 1.

Infestation of giant reed, the dominant non-native species throughout the project area, was spatially variable, ranging from extensive, nearly monotypic stands dispersed individual plants. Where infestation was high, floodplain woodland and scrub habitats were all but completely covered by impenetrable thickets up to 25 feet high (Figures 3a,b). The other four target invasive species usually occurred as sparsely-distributed individual plants throughout the project area.

Figure 3a. Heavy infestation of woodland by giant reed in Reach 7a. Remnant native riparian trees visible here include *Salix lasiolepis, Platanus racemosa*, and *Populus fremontii* (photo taken 4 September 2007).

Figure 3b. Heavy infestation of floodplain scrub by giant reed in Reach 7a,b (photo taken 4 September 2007).

Initial Treatment of Non-Native Vegetation. Initial treatment of target invasives in the project area began on 10 September 2007 and was completed on 12 June 2008 in Reaches 5a,b, and Reaches 6 through 9. Reach 5c (downstream end of Phase 1 project area – Figure 1), received initial treatment in October 2009. A glyphosate-based systemic herbicide was sprayed on target foliage, allowed to translocate to all portions of the plant for a minimum of 30 days, then followed by mechanical shredding and/or cut-daub methods, depending on the intensity of infestation (Figures 4a-f).

Figure 4a. Foliar application of herbicide in monotypic stands of giant reed (photo taken 10 September 2007).

Figure 4b. Worker cutting giant reed with blade trimmer; cut stems were then daubed with herbicide (photo taken 27 September 2007).

Figure 4c. Hauling giant reed cut by hand to central location for shredding. Note amount of ground litter (photo taken 27 September 2007).

Figure 4d. Post-treatment aspect of floodplain woodland in area where giant reed was sprayed and left in place (photo taken 11 April 2008).

Figure 4e. *In situ* shredding of giant reed in woodland (photo taken 12 December 2007).

Figure 4f. Woodland substrate following shredding of giant reed with shredder shown in Figure 5e (photo taken 12 December 2007).

Shredding was conducted over approximately 103 acres of Reaches 7a and 7b where giant reed infestation was greatest. Cut-daub methods were applied elsewhere. Target vegetation was sprayed and the standing biomass was left intact in some areas with sparse to medium infestations of giant reed (Figure 4d). The other four target species were typically sprayed and left in place. Initial treatment of the target vegetation throughout the project area took approximately 180 work-days to complete (Figure 5).

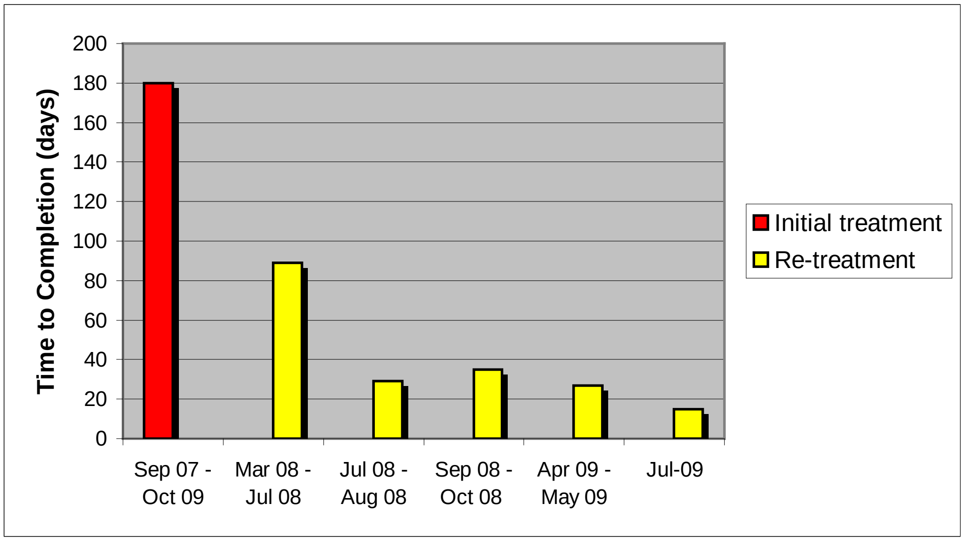

Figure 5. Timing and effort of initial and re-treatment phases of project.

Re-Treatment of Non-Native Vegetation. Re-treatment employed hand methods only (foliar spraying using backpack sprayers and cut-daub technique), to control re-sprouting vegetation or to treat plants that were either missed or survived the initial treatment. To date, target vegetation in the project area has been re-treated five times since initial treatment was completed (15 March 2008 to 31 July 2009) and the level of effort required to re-treat re-sprouting vegetation typically declined with each re-treatment cycle (Figure 5). The first re-treatment cycle began in March 2008 and moved from reach to reach as initial treatment and/or the 30-day herbicide translocation period was completed. Four subsequent treatment cycles began in Reach 5b and moved systemically upstream in a coordinated sweep, to Reach 9. Initial treatment of Reach 5c, the downstream portion of the Phase 1 project area (Figure 1), occurred in October 2009. This reach has not been re-treated to date.

3.0 Methods. The study reported herein seeks to answer the central question: *What is the structure and composition of vegetation colonizing areas that were formerly infested with invasive, non-native species?* A proper sampling design would set up a series of experimental treatments and controls to reject one or more *a priori* null hypotheses (H_0), such as: H_0*: spatial variation in native species richness or percent cover is unrelated to infestation* or H_0*: the recovery of treatment areas is independent of infestation.*

The study reported herein analyzes a *natural experiment.* Non-native vegetation was treated over a relatively large portion of the watershed with no supplemental habitat restoration effort. Consequently, this study is more observational than experimental. It establishes one or more *a posteriori* null hypotheses to answer an alternative question: *How can I optimally describe variation in native species richness and percent cover in this data set?* This study compares native species richness and percent cover in different infestation and treatment categories to control plots established in two types of floodplain environments that were not subjected to treatment: a) infested areas and, b) areas devoid of target non-native species.

Proper experimental field and laboratory designs employ random sampling methods to collect data. Diamond (1986) described the trade-off between control of independent variables and correct experimental design versus the large spatio-temporal scales and realism afforded by natural experiments. He advocates conducting small-scale, statistically correct experimental studies as an adjunct to natural experiments. Leps and Smilauer (2007) concluded that random sampling is not logistically feasible in many studies of vegetation patterns, but rather than not applying statistical analyses to natural experiments, they recommend collecting the data that can be collected even if it does not conform to strict statistical requirements, then keeping these limitations in mind when interpreting the results. Truly random samples in vegetation studies are difficult to collect because plant communities themselves defy operational definition and the boundaries are typically broadly distributed across environmental gradients.

In this study, random vegetation sampling methods, such as transect-based point-quarter or wandering point-quarter methods (Cottam and Curtis, 1956; Catana, 1963), were not used in favor of a non-random, plot-based approach. The most appropriate vegetation sampling technique for this kind of natural experiment is the releve. The releve is a plot-based method that was developed by vegetation scientists in the 1930s as means of rapidly (and largely subjectively), characterizing vegettion patterns in a defined area (Braun-Blanquet, 1932). The releve or plot is considered to be a “semi-quantitative” method because it relies on visual estimates of plant cover rather than counts of the “hits” of a particular species along a transect line or on precise measurements of cover/biomass by planimetric techniques used in quadrat-based studies.

Releves or plots measure vegetation patterns in a *stand* of vegetation. A stand is the basic physical unit of vegetation in a landscape and may vary in size from less than one acre to thousands of acres, depending on the type of vegetation. Stands must be *homogeneous*, i.e., they must possess two unifying characteristics:

- *Compositional* integrity: Throughout a stand, the combination of species is similar. The stand is differentiated from other stands by a discernable boundary that may be abrupt or indistinct. This study identified two types of stands: woodland and scrub.

- *Structural* integrity: A stand has a similar history or environmental setting that affords relatively similar horizontal and vertical spacing of plant species. For example, woodland on upper slopes with shallow soils and sparse canopy cover would be considered a different stand from woodland on lower slopes with deep soils and dense canopy cover. In this study, woodland and scrub stands identified for analysis were restricted to the floodplain of the drainages and on stream terraces of similar heights above the low-flow channel.

It is difficult and time-consuming to efficiently summarize species composition, cover, and structure of an entire stand because of the size of most stands of vegetation. Consequently, smaller, representative portions of stands are sampled. The releve method of sampling vegetation is stand-based and in many cases is preferable to stand-blind sampling methods, such as line or belt transects, especially where the goal is to characterize vegetation patterns, rather than define vegetation boundaries (i.e., map community types) (CNPS, 2009).

Exploratory analyses might lack statistical rigor, but they are still a mainstay of vegetation research. The purpose of exploratory analysis is to find pattern in nature, which is an inherently subjective enterprise. While it is possible to perform exploratory analyses on sample plots located according to a rigorous, objective sampling design, such careful placement is not necessary. Indeed, an exploratory analysis can be aided if the investigator subjectively places study plots in locations he or she considers to be important or interesting. Vegetation scientists have found that orienting plots within vegetation that appears homogeneous is highly subjective, but very useful in evaluating differences between plots (CNPS/CDFG, 2009).

Sampling Design. Existing maps of treatment areas (County of Ventura, 2007) were used to select infestation categories for sampling. Samples were stratified by:

- Stand (woodland or scrub);
- Pre-Treatment Infestation (51-100% (uniform); 1-50% (dispersed), or no infestation);
- Treatment Type (shred, cut-daub, or no treatment).

Treatment plots were collected across the various Infestation and Treatment categories. Treatment plots were subjectively located within a particular infestation polygon within the project area. Two types of control plots were established: infested areas outside the project area that were not treated, and areas within and outside of the project area that were devoid of invasive vegetation (Table 1).

Table 1. Sampling design.

Stratum 1	Stratum 2	Stratum 3	Plot Number
Stand	Pre-Treatment Infestation	Treatment Type*	
Riparian Woodland	51-100%	Spray-Shred	1, 4, 5, 9, 10, 11, 12, 13, 20, 21
Riparian Woodland	51-100%	None (Control)	32, 35, 36, 43, 44
Floodplain Alluvial Scrub	51-100%	Spray-Shred	2, 3, 6, 7, 8, 14
Floodplain Alluvial Scrub	51-100%	None (Control)	45
Riparian Woodland	1-50%	Spray Cut-Daub	19, 25, 37, 39, 40, 41
Riparian Woodland	1-50%	None (Control)	49
Floodplain Alluvial Scrub	1-50%	Spray Cut-Daub	15, 23, 26, 27, 28, 29
Floodplain Alluvial Scrub	1-50%	None (Control)	33, 34, 46, 47, 50
Riparian Woodland	0%	No Infestation (Control)	30, 31, 38, 48, 42
Floodplain Alluvial Scrub	0%	No Infestation (Control)	16; 17; 18, 22, 24

* Treatment and Infestation are largely coincident because shredding was largely restricted to uniform stands of giant reed and cut-daub methods were used where giant reed was dispersed. In some areas, non-native vegetation was sprayed and left standing. This was considered equivalent to the cut-daub technique.

Plot Size and Site Selection. This study used square releves or plots, measuring 20 meters on a side (400 m^2 total size). Plot size was determined by recommendations from the Sawyer and Keeler-Wolf (1995) and California Native Plant Society/California Department of Fish and Game (2009) releve protocols.

Plot locations were not randomly selected. Mapped infestation polygons frequently contained stands of both floodplain alluvial scrub and riparian woodland habitat. Once the infestation polygon had been identified, one or both stands within the polygon were reconnoitered on foot. Sites that appeared to be representative of each stand with regards to species composition, substrate, and vegetation structure and pre-treatment infestation were selected for measurement. Multiple plots were sometimes collected in large stands.

Plots were established by positioning a pin-flag at the southwestern corner of the plot, then aligning the western edge of the plot with north using a compass. The UTM coordinates and the elevation of the southwestern corner of the plot were recorded using a Garmin GPSmap 60CSx hand-held unit. Most coordinate locations had an accuracy of 3-3 meters. The remaining three orthogonal corners of the plot were established with an open-reel 50-meter tape measure and a compass and marked with colored plastic flagging tape. Photographs were taken in a north and northwestern direction from the southwestern corner of each plot (see CD attached to this report). Information on exposure, steepness, macro- and micro-topography, geology, soil texture, % surface cover of substrate types, site history, vegetative structure, canopy cover, species composition and % cover of each species were recorded on standardized releve data forms provided on the California Native Plant Society/California Department of Fish and Game website (www.cnps.org). A densitometer was used to determine percent canopy cover at five points in each woodland plot: plot center and each corner, and the values were averaged. Percent cover of each living perennial plant species or dead annual species in the plot was estimated visually initially using standard Braun-Blanquet percent cover intervals: < 1%; 1-5%; >5-15%; >15-25%; >25-50%; >50-75%; >75%, then refined to get an estimate of % cover for each species. Plant species that could not be identified in the field were collected and identified using Hickman (1993) and Smith (1998) or, in some cases, were brought to local botanists and the Santa Barbara Botanic Garden for identification. Pre-treatment cover of target exotics in each plot (usually giant reed) was estimated from the percent cover of cut stumps and/or dead standing vegetation of these species. Living non-native target vegetation that re-sprouted after initial treatment was counted as post-treatment infestation and was not included in pre-treatment infestation cover estimates. Data were collected on the variables listed in Table 2.

Table 2. Data collected for this study.

Variable (Variable Name)*	Description
Plot Number (PLOT)	Field number of releve
Date (DATE)	Date releve was recorded
UTME (UTME)	Universal Transverse Mercator coordinate - Easting (meters)
UTMN (UTMN)	Universal Transverse Mercator coordinate - Northing (meters)
Elevation (ELEVATION)	Elevation above mean sea level (feet)
Stand (STAND$)	Two plant communities were identified (CNDDB, 2002): • Riparian Woodland (Southern Cottonwood-Willow Riparian Forest, White Alder Riparian Forest, Southern Sycamore-Alder Riparian Woodland) • Riparian Scrub (Scalebroom Scrub)
Infestation (INFESTATION$)	Pre-treatment (pre-September 2007) percent cover of target non-native vegetation (primarily giant reed and Scotch broom) in stand, as determined from Ecosystems Restoration Associates mapped polygons (VCWPD, 2007), or current condition where releve plot is outside project area limits. Three infestation categories were identified: • 0% • 1-50% (clumped distribution) • 51-100% (uniform distribution)
Treatment (TREATMENT$)	Method of initial treatment of giant reed. Three treatment categories were identified: • None (no treatment - 6 sub-categories) • Shred (2 sub-categories) • Cut-daub or spray only (2 sub-categories)
Soil Texture (SOILTEXT$)	Dominant surface soil texture in releve, using CNPS/CDFG Simplified Key to Soil Texture (2009)
Canopy Cover (CANOPYCOV)	Percent of plot covered by overstory and low-medium trees
% Surface Cover Fines (FINECOVER)	Percent of exposed, fine-textured soils in releve
% Surface Cover Litter (LITTERCOVER)	Total percent cover of woody, stick, and/or leaf litter in releve
Total % Vascular Vegetative Cover (TOTVEGCOVR)	Total percentage of releve covered by living vascular vegetation (all vegetative strata combined)
% Non-Native Vegetative Cover (RELNNATCOVR)	% of releve covered by non-native vegetation (all vegetative strata combined)

% Native Vegetative Cover (RELNATCOVR)	% of releve covered by native vegetation (all vegetative strata combined)
% Live Giant Reed (LIVEARUNDO)	Percent of releve covered by live giant reed and/or other target species (e.g., Scotch broom and/or castor bean)
Pre-Treatment Infestation (PRETRINFEST)	Percent of releve covered by giant reed or other target species prior to treatment
Total Species Richness (SPRICHNESS)	Total number of vascular plant species in releve
Non-Native Species Richness (RELNNATSPRICH)	% number of non-native vascular plant species in releve
Native Species Richness (RELNATSPRICH)	% number of native vascular plant species in releve

*** "$" after name denotes categorical variable**

Fifty 400 m^2 plots were recorded between 4 November 2009 and 27 December 2009: 27 plots were located in woodland stands; 23 were located in scrub stands. Twenty-eight treatment plots and 22 control plots (12 no treatment plots; 10 no infestation plots) were collected (Table 1). Treatment plots were collected within project reaches 5, 6, and 7 within the project area. Control plots were collected within these reaches as well as downstream of the project area ("no treatment" and some "no infestation" plots). The location of each of the 50 plots is tabulated and mapped in Appendix 1. The field data sheets for the releves are found in Appendix 4.

Raw data taken from the field data sheets is tabulated in Appendix 2. Six variables were extracted from these data for analysis in this report: species list, pre-treatment infestation; post-treatment infestation, total species richness, native species richness, and native species cover. Exploratory univariate and multivariate statistical analyses were conducted using SYSTAT, version 7 statistical software.

4.0 Results. Exploratory data analysis (analysis of variance (ANOVA), comparisons of group means and variances, etc.) revealed that the most important variables of interest (native plant cover, native species richness, and pre-treatment infestation) in the treatment plots did not differ significantly between Treatment (shred, cut-daub), Infestation (uniform, dispersed), or Stand (woodland, scrub) categories (single factor ANOVA, $p > 0.05$), so the data set was collapsed into comparisons between the 28 treatment plots and 22 control plots in subsequent analyses.

Species Richness. A total of 152 plant species were recorded in the 50 releve plots. Non-native taxa comprised about 30% of total species richness (Figure 6; Appendix 3).

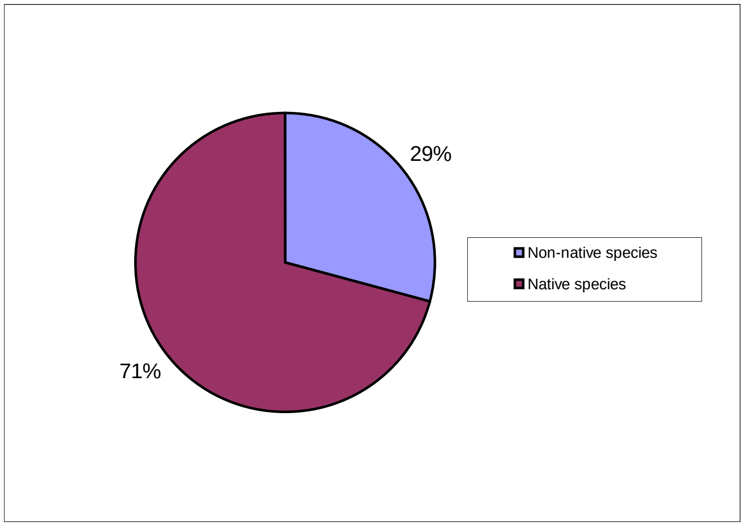

Figure 6. Proportion of native and non-native vascular plant species found in the 50 releve plots.

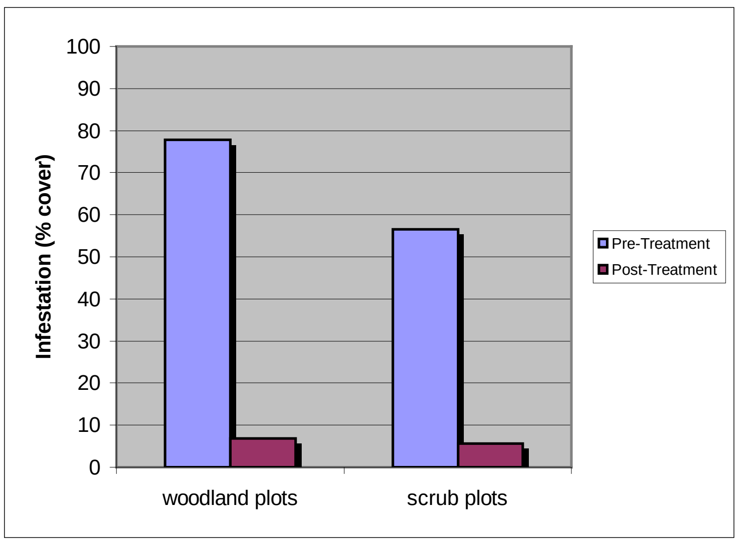

Figure 7. Infestation in 16 woodland and 12 scrub plots before and after treatment.

Effect of Initial Treatment and Re-Treatment Effort. Initial treatment of target vegetation was highly successful at reducing the relative cover of this vegetation, especially giant reed, in both woodland and scrub habitats in the project area (Figure 6). Woodland and scrub plots did not differ significantly in average pre- or post-treatment infestation ($p > 0.05$; two-tailed t-test). Infestation averaged 68% cover before initial treatment in the woodland and scrub treatment plots, compared to less than 6% cover after treatment (single-factor ANOVA, $p < 0.0001$) a highly significantly reduction in percent cover of the target exotics. However, treatment did not eliminate giant reed and/or the other target species from the project area. Live giant reed or other target vegetation was recorded in 82% of the 28 treatment plots.

Native Species Richness. Infestation by the target exotics significantly depressed native species richness (r = -0.738***) and native cover (r = -0.473***) in both the treatment and the control plots (Figures 8 and 9).

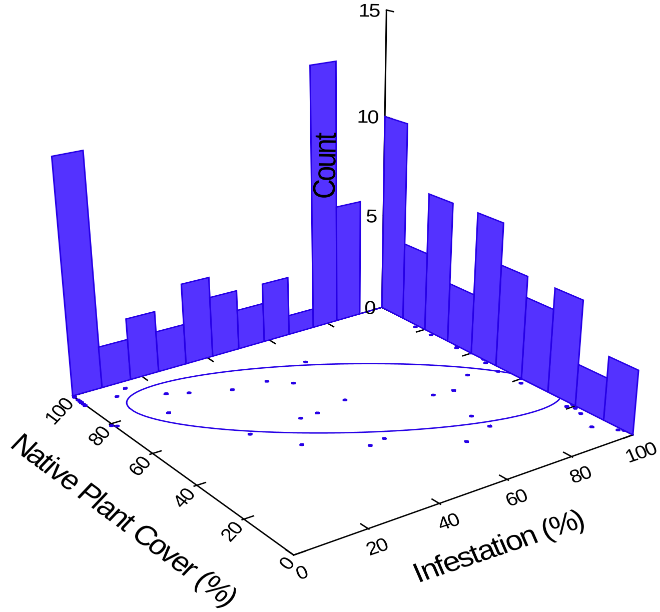

Figure 8. Relationship between infestation and native plant cover (all plots). Centroid captures 95% of variation (r = -0.738*).**

This inverse relationship was most strongly demonstrated in control plots where the relationship between these two cover categories could be directly observed without having to extrapolate infestation from dead, treated vegetation (Figure 9). Even in control plots where infestation was currently very high, native cover composed up to 20% of the plot because of stratified vegetation, particularly in woodland plots where a sparse native canopy was typically present above nearly homogeneous stands of giant reed.

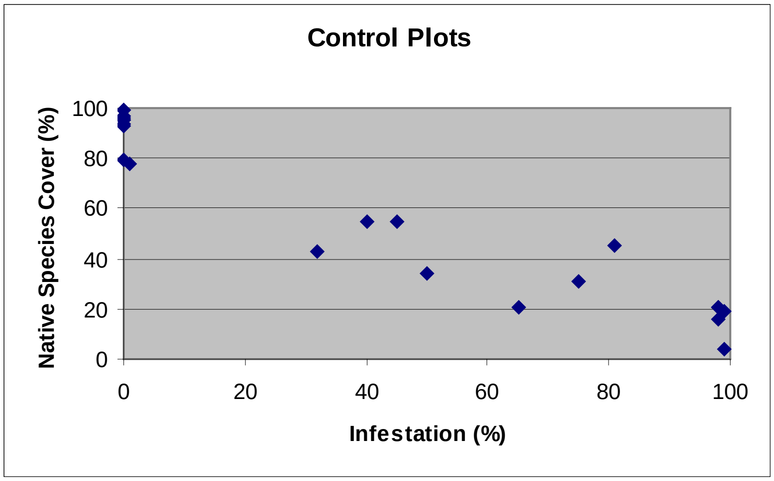

Figure 9. Infestation and native species cover in control plots (r = -0.953*).**

The same a significant inverse relationship between pre-treatment infestation and native plant cover was observed in the treatment plots (Figure 10). Consequently, native cover actually increased at the highest pre-treatment infestation rates, particularly in plots in scrub habitats, because these areas were all but cleared of vegetation during initial treatment.

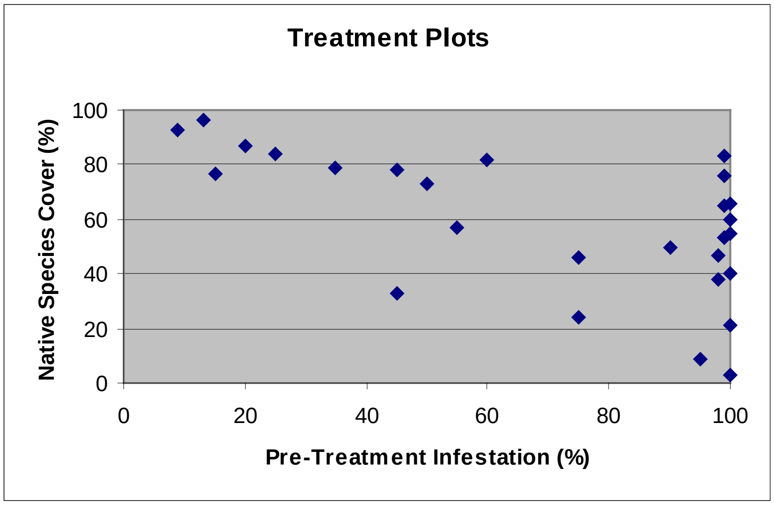

Figure 10. Infestation (pre-treatment) and native species cover in treatment plots (r = -0.600*). Note: pre-treatment infestation is actually an extrapolation of former infestation.**

Treatment plots showed a highly significant increase in native species cover following treatment (mean 29.4% pre-treatment versus 58.2% post-treatment; single-factor ANOVA; $p << 0.001$) (Figure 11). Pre-treatment cover in the treatment plots was estimated by the amount of dead exotic vegetation (primarily giant reed) present in the plot. This is largely an estimate of pre-treatment infestation of giant reed based on the amount of shredded litter and/or cut stems in the plot. Pre-treatment and no treatment infestation was similar. Plots in uninfested areas had significantly higher native cover compared to treatment plots (mean: 92.5% versus 58.2%, respectively; $p < 0.001$). Spatial variation in native plant cover in treatment plots was significantly greater in treatment plots compared to uninfested plots ($F_{max} = 10.75$; $p < 0.0001$).

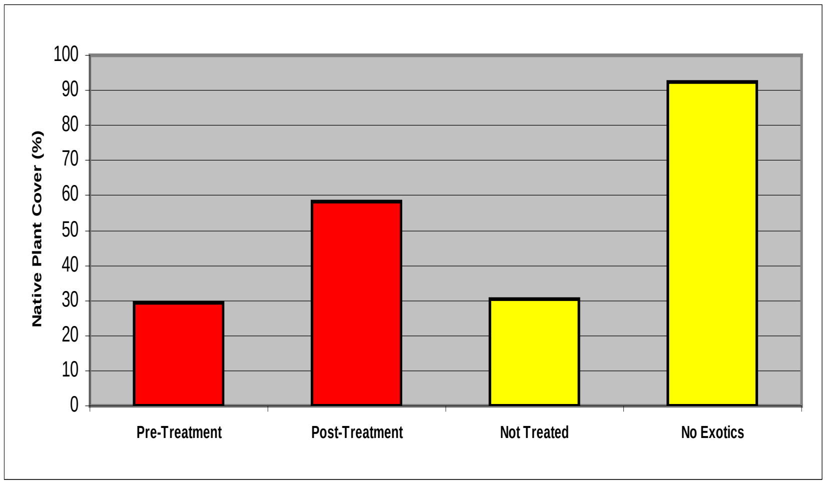

Figure 11. Native plant cover in treatment plots (red) before and after treatment versus control plots (yellow).

Native Species Richness. Total species richness was significantly lower and spatially less variable in uninfested woodland plots compared to uninfested floodplain scrub plots (mean: 12 species versus 29 species, respectively; $p < 0.0001$) (Figure 12).

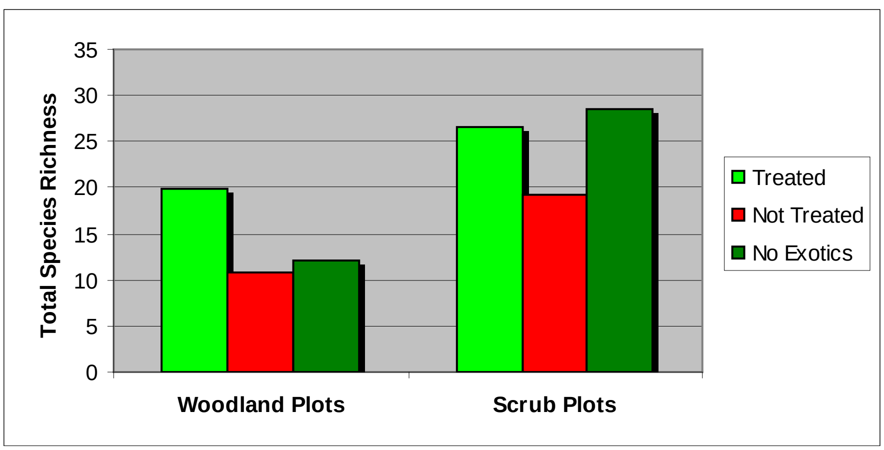

Figure 12. Total species richness in treated and control plots.

Overall, woodland plots had lower species richness than scrub plots across both treatment and control plots (Figure 12). Species richness in treatment plots in woodland and scrub habitats was significantly higher than untreated control plots and, in woodland plots, exceeded species richness in uninfested woodland.

Mean native species richness in the various treatment and control plots was surprisingly high, varying from 58% of total species richness in treated scrub plots to 85% of total species richness in uninfested scrub plots. Species richness in woodland and scrub treatment plots was dominated by native species, which comprised 65% and 58% of total species richness, respectively. Native species richness as a proportion of total species richness did not differ significantly in treated and untreated woodland plots (65% and 63%, respectively), treated and untreated scrub plots (58% and 62%, respectively), or in uninfested woodland plots (68%), but the proportion of native species in uninfested scrub plots was significantly greater than any other group (85%).

Multivariate Analyses. Discriminant function analysis (DFA) was used to examine the robustness of a set of important predictor variables (canopy cover, pre-treatment infestation, native species richness, and native species cover) in classifying infestation categories (uniform, dispersed, and none). Despite high spatial variability in these metrics, this set of predictors correctly classified 80% of the plots (40 out of 50) into infestation categories, and had the highest classification success compared to other combinations of variables (Table 3) (e.g., these predictors were only able to correctly classify 38% of the plots into treatment categories). Collective variation in these variables was highly significant and directly related to intensity of infestation (i.e., F-matrix values are lowest with the "no infestation" category; highest with the "uniform infestation category").

Table 3. Jackknifed classification matrix from discriminant function analysis.

Infestation Category	Dispersed	Uninfested	Uniform	Plots Correctly Classified (%)
Dispersed	9	5	3	53
Uninfested	0	10	0	100
Uniform	2	0	21	91
Total	**11**	**15**	**24**	**80**

The centroids of the group means of these infestation categories are plotted on DFA axes 1 and 2. The 95% confidence intervals around these centroids do not overlap, indicating they are significantly different (Figure 13).

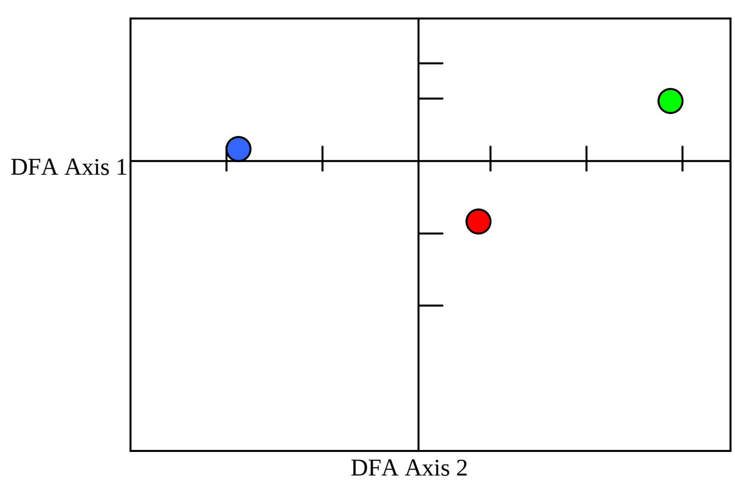

Figure 13. Group centroids plotted from canonical scores of group means. Tick marks on the axes represent one canonical unit. Blue = uniform infestation; red = no infestation; green = dispersed infestation.

Table 4 shows the combination of variables that explained the greatest amount of variation in the data set, as determined by factor analysis.

Table 4. Factor analysis component loadings.

Variable	Factor 1	Factor 2
% Native Cover	-0.873	-0.307
Pre-Treatment Infestation	0.798	0.418
% Live Giant Reed	0.749	0.039
Litter Cover	0.672	-0.340
Total Species Richness	-0.503	0.799
Total Variance Explained	**53.3%**	**20.5%**

Approximately 74% of the total variation in the data set could be explained using this combination of variables along two factors. Percent live giant reed in the plots and pre-treatment infestation of the plots are not significantly separable on these two factors, indicating that infestation and re-sprouting rate are directly related.

5.0 Discussion. By exposing extensive areas of floodplain substrates that formerly were all but covered with giant reed, particularly in Reaches 7a and 7b, initial treatment set the stage for a natural experiment of native and non-native vegetation colonization. The releve plots captured a large proportion of the total plant species richness within and beyond the project area and about 30% of these species are not native to California.

Plant communities typically contain many species, and the species vary greatly in their abundance from common to rare. Determining the distribution of abundances of different species is a fundamental task of plant and animal community ecology (MacArthur and Wilson, 1967; Pielou, 1977) and the species-abundance relationship is a fundamental attribute of plant and animal communities. Typically, one finds that singleton species (those represented by one individual) are numerous, often the most numerous. Species with successively more representatives, doubletons with 2, trebletons with 3, and so on, are usually progressively less numerous.

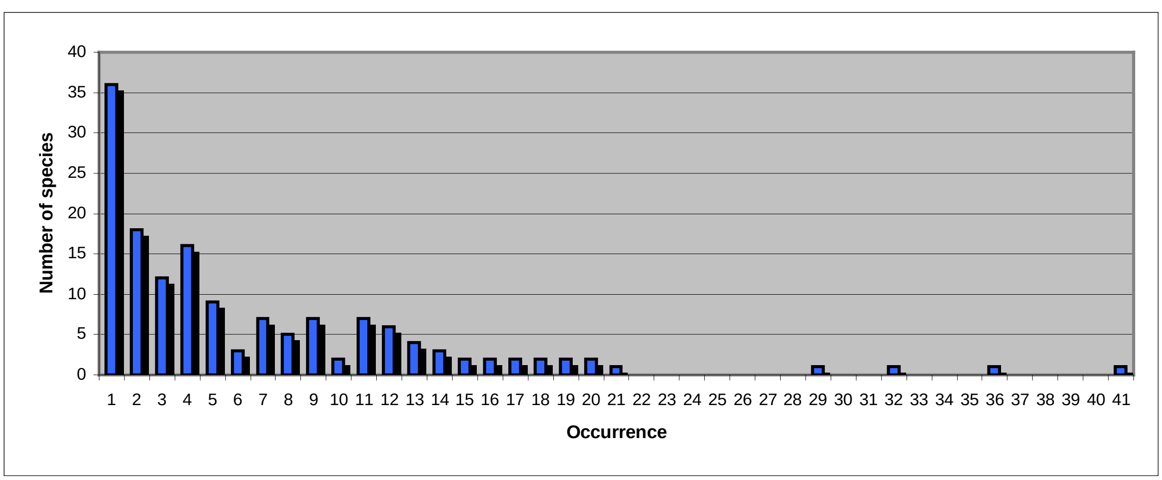

Figure 14. Species occurrence frequency among the 152 species found in the releve plots used in this study.

This study did not measure individual plant abundance in the plots, rather presence or absence and these data also follow this general pattern of many uncommon and a few common species (Figure 14). The underlying reasons for this pattern are complex, site-specific, and beyond this discussion. Thirty-six species occurred only once and 91 species, representing 60% of the total number of species observed in this study, occurred in five or fewer plots. On the other end of this abundance spectrum, five species (3% of total) occurred in 20 or more of the 50 releve plots and these are shown in Figure 15. The two most commonly encountered species in the plots are non-native species: smilo grass (*Pipatherum miliaceum*) and giant reed (*Arundo donax*).

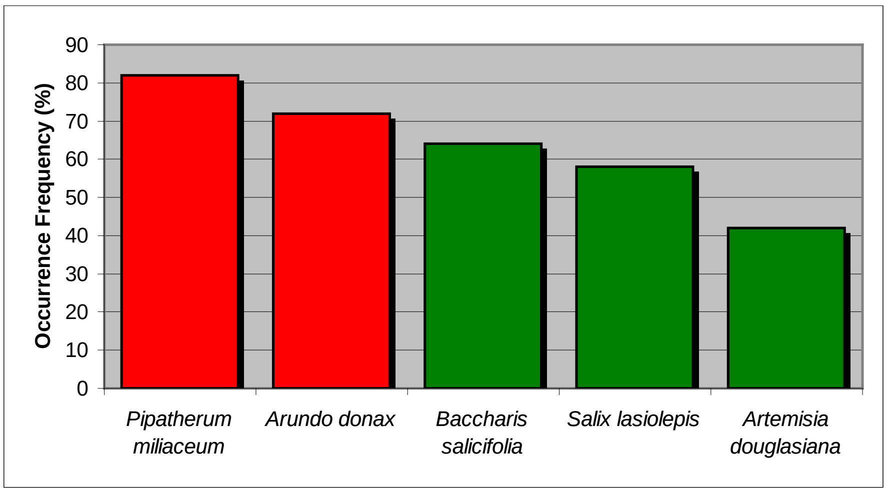

Figure 15. Top five recurring plant species in the plots.

Smilo is not only common throughout the Matilija Creek and Ventura River watersheds and occurred in over 80% of the plots, but also had relatively high cover values (mean 6.8%, 12.3%, range 0-75% cover), especially in plots established in floodplain scrub habitats that formerly were covered with giant reed. Live giant reed (re-sprouts) occurred in over 70% of the plots. Both of these species were spatially highly variable in occurrence and cover. The high recurrence of live giant reed in the plots is partly an artifact of study design (control plots are included in Figure 15), but also reflects its abundance in the project area as re-sprouting, live vegetation (82% of 28 treatment plots contained live giant reed that varied in cover from 0 to 25%). Despite non-natives comprising the two most commonly occurring species, native shrubs make up 10 of the 15 next most commonly encountered species in this study.

Giant reed re-sprouting was positively associated with pre-treatment infestation. Consequently, Reaches 7a and 7b support some of the highest re-sprout rates and cover of live giant reed in this study. Re-sprouting is recurring vegetatively and underscores the need for multi-year re-treatment efforts to continue. It is highly unlikely that giant reed can be completely eradicated from the project area, but it may be consigned to a rather minor component of riparian woodland and floodplain scrub habitat if periodic control efforts continue until native vegetation has been established in areas formerly infested by this species. Giant reed thrives on disturbance and two disturbance factors: lowering water levels in Matilija Reservoir, coupled with occasional severe storms that mobilize floodplain substrates and remove native vegetation, allowed this species to form extensive, nearly monotypic stands of vegetation in Reaches 7a and 7b and contributed to the high level of infestation in the upper Ventura River below Matilija Dam.

The major finding of this study is that native species are recolonizing the woodland and scrub treatment plots at a 2:1 ratio over non-native species following treatment (65% cover and 58% cover, respectively). This result is surprising given that exposed, disturbed substrates typically favor non-native species that frequently out-compete native species in terms of reproductive output and growth rates. However, once giant reed was removed and controlled, these exposed substrates have been rapidly colonized by native plants that proliferated in the absence of competition with the exotics. One reason may be that, at least in the project area upstream of Matilija Reservoir, giant reed infestation was more or less restricted to the floodplain and along these reaches the floodplain is bordered by stream terraces that support intact, native riparian woodland and alluvial scrub habitats that provide a ready seed source for propagules to colonize areas once giant reed has been removed. Other non-native vegetation present in the plots is composed of species that do not appear to inhibit native species colonization or growth.

There is a clear trend in total and native species richness and cover: infestation by giant reed depresses total species richness and especially native species richness and cover (Figures 11 and 12). Treated woodland plots were more speciose than untreated woodland plots, but treated and untreated scrub habitats did not differ significantly in total species richness because this metric was so spatially variable (Figure 12). However, native plant cover dominated treated scrub habitat plots (and treated woodland plots).

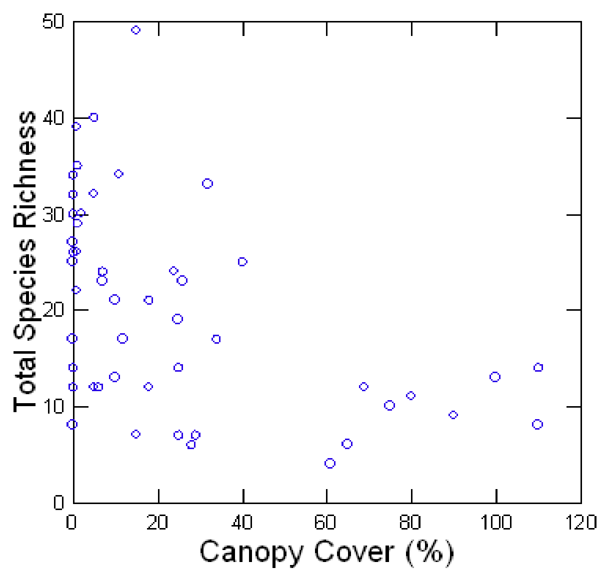

Figure 16. Relationship between species richness and canopy cover (r = -0.497).**

An important pattern observed among the 50 releve plots was the control that canopy cover had on species richness and composition and its implications for community structure and the nature of non-native plant infestation, especially giant reed (Figure 16). Although total species richness declines significantly with increased canopy cover, this inverse pattern is borne disproportionately by non-native vegetation (r = -0.352**). Native species richness showed no relationship to canopy cover (r = 0.108). This means that the relative contribution of non-native vegetation to woodland communities depends strongly on canopy cover and where woodland canopies remain intact, non-native species remain a minor component of overall species richness. This was certainly the case in Reaches 7a and 7b where giant reed was able to thoroughly infest riparian woodland habitat following disturbance that destroyed or reduced tree canopy cover. Once established an uniform stands of vegetation, giant reed was able to maintain dominance by repressing native plant recruitment and survivorship.

The picture that emerges from this study is that removal and control of exotics opened up substrates that were rapidly colonized by a mixture of native and non-native species. Native colonists appear to be dominant, both in terms of species richness and percent cover in the treatment plots. Overall, removal and control of the target exotics appears to have been very successful as the first step in restoring these floodplain habitats to their former uninfested condition. Repression of giant reed to a minor component of woodland and scrub habitats in the project area appears to hinge on two factors: a) establishing a dense canopy of riparian trees in woodland habitats and; b) establishing dominance of native shrubs in scrub habitats. Future monitoring of these releve plots is necessary to document if the patterns reported herein persist.

6.0 Literature Cited

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Appendix 1. Plot Location and Characteristics.

Appendix 1. Plot Location and General Characteristics. The following table gives the project area reach of the releve plots or, if plots were located outside of the project area, the general location (maps of plot locations follow this table. UTM coordinates are taken from the data sheets for each plot. Photographs of plot conditions are found on a CD attached to this report.

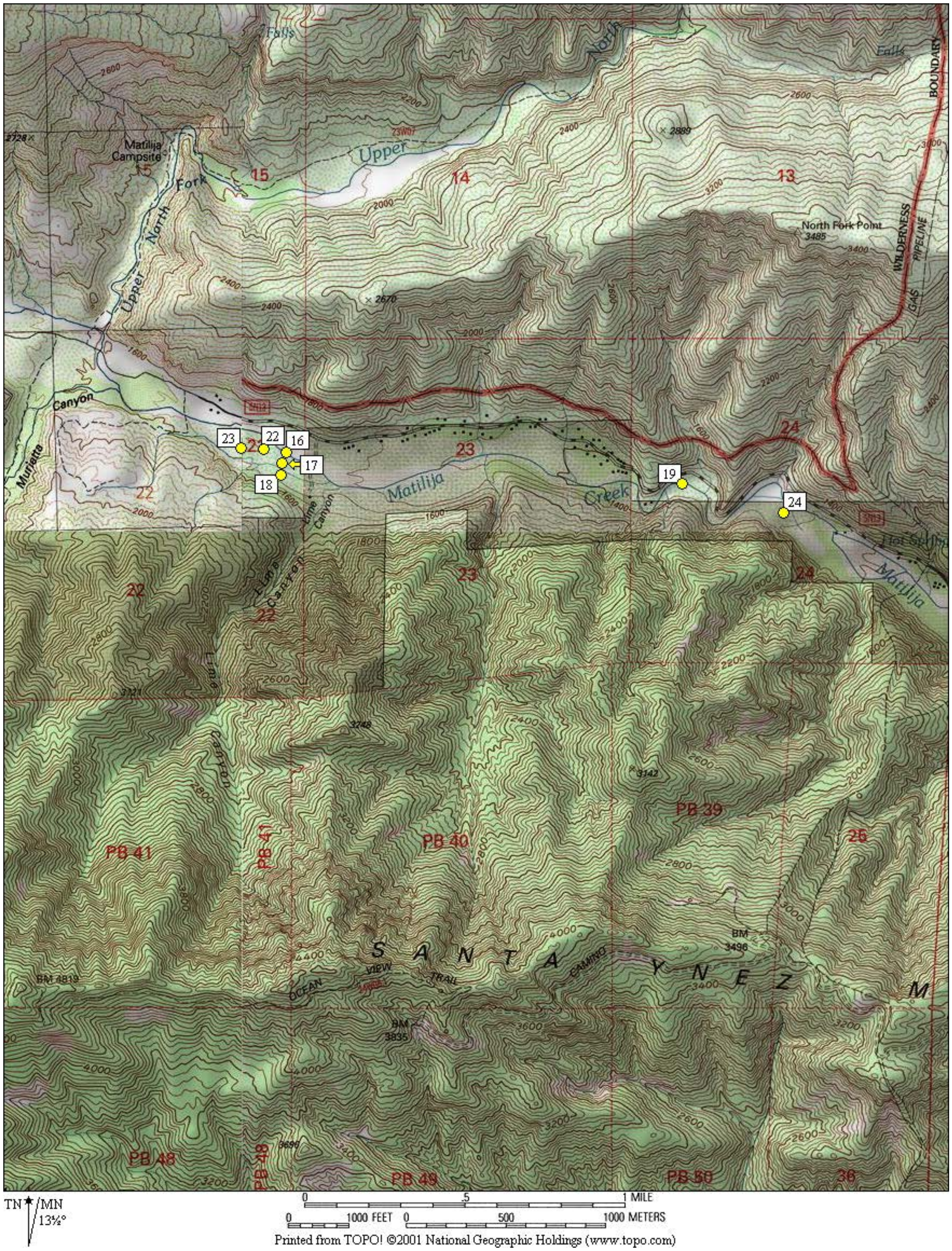
Releve Field Number	General Location	Mapped Polygon Number and Infestation *	UTM Coordinates**	Stand	Treatment
MATI 0001	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	286704 E 3819032 N	Woodland	Spray-Shred
MATI 0002	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	286799 E 3819182 N	Scrub	Spray-Shred
MATI 0003	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	286911 E 3819109 N	Scrub	Spray-Shred
MATI 0004	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	286767 E 3819086 N	Woodland	Spray-Shred
MATI 0005	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	286788 E 3819099 N	Woodland	Spray-Shred
MATI 0006	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	286827 E 3819061 N	Scrub	Spray-Shred
MATI 0007	Reach 7a Plan Sheet 13	R7A-27 (50-100%)	286694 E 3819226 N	Scrub	Spray-Shred
MATI 0008	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	287476 E 3819133 N	Scrub	Spray-Shred
MATI 0009	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	287540 E 3819052 N	Woodland	Spray-Shred
MATI 0010	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	287516 E 3819011 N	Woodland	Spray-Shred
MATI 0011	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	287455 E 3819027 N	Woodland	Spray-Shred
MATI 0012	Reach 7b Plan Sheet 14	R7B-1 (50-100%)	285966 E 3819446 N	Woodland	Spray Shred
MATI 0013	Reach 7b Plan Sheet 14	R7B-1 (50-100%)	285912 E 3819457 N	Woodland	Spray Shred
MATI 0014	Reach 7a Plan Sheet 13	R7A-27 (50-100%)	286626 E 3819222 N	Scrub	Spray-Shred
MATI 0015	Reach 7a Plan Sheet 13	R7A-15 (11-24%)	286543 E 3819201 N	Scrub	Cut-Daub
MATI 0016	Reach 7b Plan Sheet 16	R7B-48 (< 1%)	282088 E 3820553 N	Scrub	None (Control)
MATI 0017	Reach 7b Plan Sheet 16	R7B-43 (1-10%)	282067 E 3820490 N	Scrub	None (Control)
MATI 0018	Reach 7b Plan Sheet 16	R7B-50 (< 1%)	282059 E 3820445 N	Scrub	None (Control)
MATI 0019	Reach 7b Plan Sheet 15	R7B-49 (< 1%)	284075 E 3820349 N	Woodland	Cut-Daub
MATI 0020	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	287017 E 3819241 N	Woodland	Spray-Shred
MATI 0021	Reach 7a Plan Sheet 13	R7A-26 (50-100%)	287460 E 3819084 N	Woodland	Spray-Shred
MATI 0022	Reach 7b Plan Sheet 16	R7b-50 (< 1%)	281975 E 3820577 N	Scrub	None (Control)

MATI 0023	Reach 7b Plan Sheet 16	R7B-43 (1-10%)	281865 E 3820575 N	Scrub	Cut-Daub
MATI 0024	Reach 7b Plan Sheet 15	R7B-41 (1-10%)	284577 E 3820189 N	Scrub	None (Control)
MATI 0025	Reach 7a Plan Sheet 13	R7A-21 (25-49%)	287335 E 3819155 N	Woodland	Spray-Shred/C-D
MATI 0026	Reach 5a Plan Sheet 10	R5-22 (1-10%)	289486 E 3815362 N	Scrub	Cut-Daub
MATI 0027	Reach 5a Plan Sheet 10	R5-64 (11-24%)	289480 E 3815226 N	Scrub	Cut-Daub
MATI 0028	Reach 5a Plan Sheet 10	R5-42 (25-49%)	289417 E 3815211 N	Scrub	Cut-Daub
MATI 0029	Reach 7a Plan Sheet 13	R7A-32 (50-100%)	286411 E 3819167 N	Scrub	Spray-Shred/C-D
MATI 0030	OVLC parcel, S of San Antonio Creek and E of main stem Ventura River, E of Ventura River Trail	Downstream of Project Area (< 1%)	287981 E; 3806576 N	Woodland	None (Control)
MATI 0031	OVLC parcel, S of San Antonio Creek and E of main stem Ventura River, E of Ventura River Trail	Downstream of Project Area (0%)	287943 E 3806606 N	Woodland	None (Control)
MATI 0032	OVLC parcel, S of San Antonio Creek and E of main stem Ventura River, E of Ventura River Trail	Downstream of Project Area (75%)	287863 E 3806720 N	Woodland	None (Control)
MATI 0033	Main stem Ventura River floodplain, W of confluence San Antonio Creek	Downstream of Project Area (30%)	287772 E 3806753 N	Scrub	None (Control)
MATI 0034	Main stem Ventura River floodplain, W of confluence San Antonio Creek	Downstream of Project Area (50%)	287731 E 3806749 N	Scrub	None (Control)
MATI 0035	E edge main stem Ventura River, W of confluence San Antonio Creek	Downstream of Project Area (98%)	287721 E 3806796 N	Woodland	None (Control)
MATI 0036	W edge main stem Ventura River, S of confluence San Antonio Creek, W of Ventura River Trail	Downstream of Project Area (99%)	287870 E 3806703 N	Woodland	None (Control)
MATI 0037	Reach 5a Plan Sheet 10	R6-7 (1-10%)	289736 E 3816584 N	Woodland	Cut-Daub
MATI 0038	Reach 5a Plan Sheet 10	R6-7 (1-10%)	289746 E 3816591 N	Woodland	None (Control)
MATI 0039	Reach 5a Plan Sheet 10	R6-7 (1-10%)	289731 E 3816640 N	Woodland	Cut-Daub
MATI 0040	Reach 6b Plan Sheet 12	R6-15 (11-24%)	289021 E 3818099 N	Woodland	Cut-Daub
MATI 0041	Reach 6b Plan Sheet 12	R6-18 (25-49%)	289166 E 3818029 N	Woodland	Cut-Daub
MATI 0042	North Fork Matilija Creek at jct Hwy 33 x Matilija Cyn Rd	East of Project Area (0%)	288272 E 3819286 N	Woodland	None (Control)
MATI 0043	E side main stem Ventura River floodplain, W of Ventura River Trail,	Downstream of Project Area (98%)	288264 E 3803376 N	Woodland	None (Control)

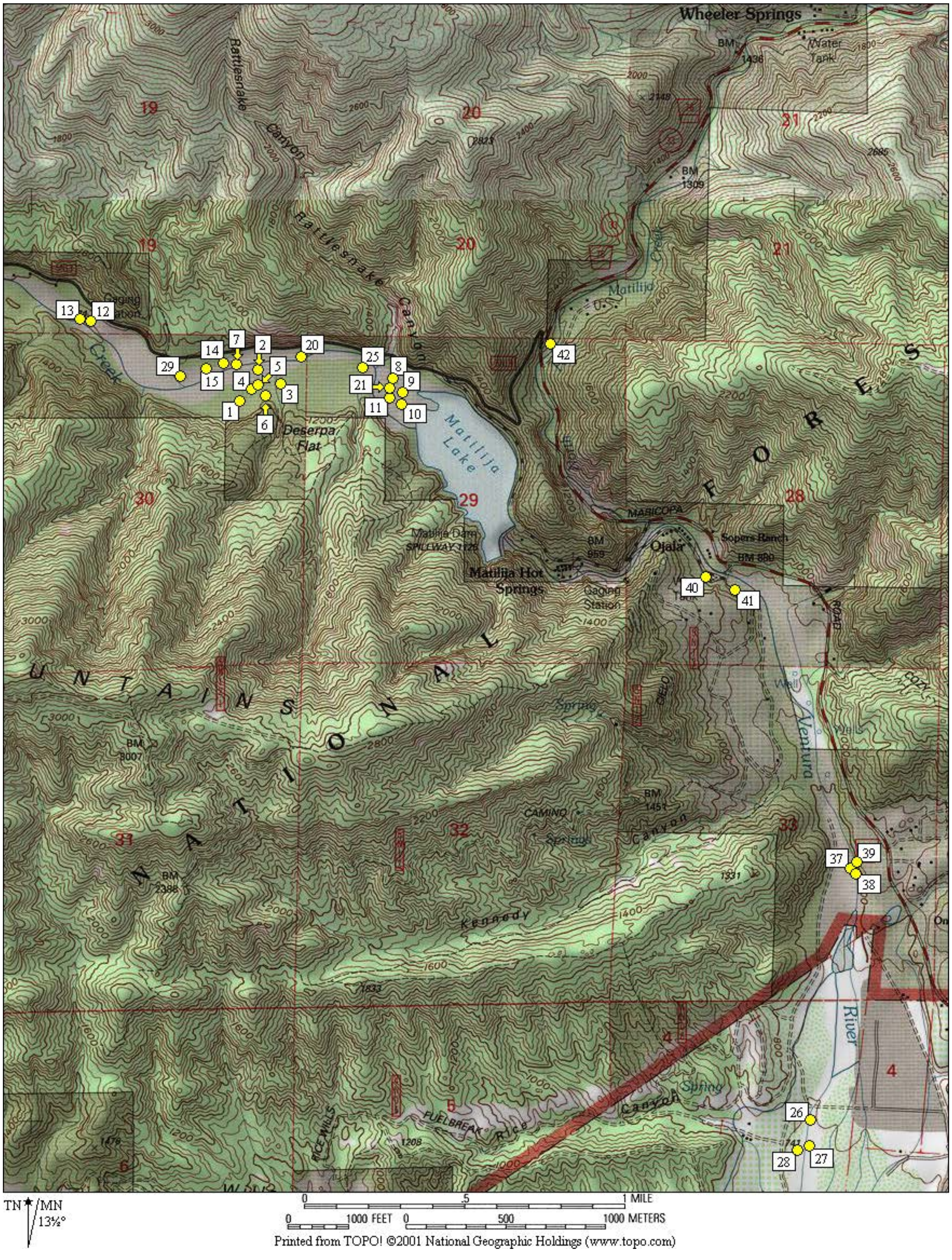
	downstream of Foster Park				
MATI 0044	E side main stem Ventura River floodplain, W of Ventura River Trail, downstream of Foster Park	Downstream of Project Area (99%)	288288 E 3803360 N	Woodland	None (Control)
MATI 0045	E side main stem Ventura River floodplain, W of Ventura River Trail, downstream of Foster Park	Downstream of Project Area (99%)	288143 E 3803437 N	Scrub	None (Control)
MATI 0046	E side main stem Ventura River floodplain, W of Ventura River Trail, downstream of Foster Park	Downstream of Project Area (65%)	288119 E 3803454 N	Scrub	None (Control)
MATI 0047	E side main stem Ventura River floodplain, W of Ventura River Trail, downstream of Foster Park	Downstream of Project Area (45%)	288087 E 3803476 N	Scrub	None (Control)
MATI 0048	E side main stem Ventura River floodplain, W of Ventura River Trail, downstream of Foster Park	Downstream of Project Area (0%)	288021 E 3803530 N	Woodland	None (Control)
MATI 0049	E side main stem Ventura River floodplain, W of Ventura River Trail, downstream of Foster Park	Downstream of Project Area (50%)	287990 E 3803522 N	Woodland	None (Control)
MATI 0050	E side main stem Ventura River floodplain, W of Ventura River Trail, downstream of Foster Park	Downstream of Project Area (40%)	288336 E 3803254 N	Scrub	None (Control)

* Polygon number is mapped on VCWPD plan maps dated 1 June 2007 (County of Ventura, 2007). "Infestation" is an estimate of total cover of target exotics in mapped polygon. Estimates were made prior to start of initial treatment, which began in September 2007 (Ecosystems Restoration Associates, 2007).

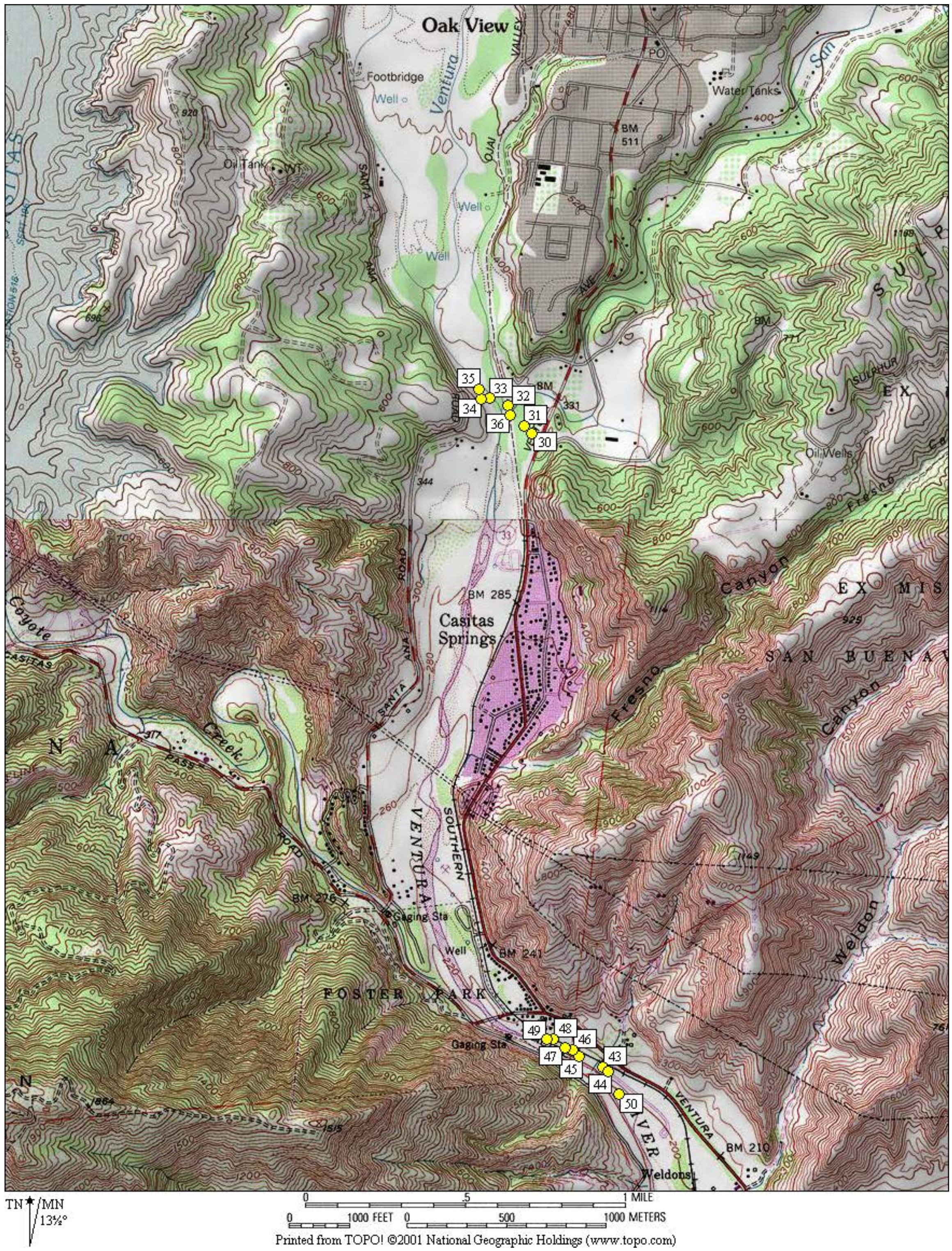
** GPS coordinates taken at SW corner of each releve plot in November-December 2009. GPS accuracy is +- 7 to 12 feet, generally +- 9 ft.



Map 1 of 3. Upstream end of releve plot locations, Project Area Reaches 7a and 7b.



Map 2 of 3. Releve plot locations in Project Area Reaches 5, 6, and 7a,b.



Map 3 of 3. Releve plot locations downstream of Project Area.

Appendix 2. Plot Summary Data.

Appendix 3. Plant Species Found in Plots.

Appendix 3. Plant Species Found in Releve Plots. The following list contains 152 non-native and native plant species were found in fifty 400m^2 releve plots measured between 4 November 2009 and 27 December 2009 along the main stem of Matilija Creek (26 plots), North Fork Matilija Creek (1 plot), and main stem Ventura River (23 plots).

Non-native species (n = 45 species or 30% of total sp richness):

Agrostis viridis
Arundo donax
Avena fatua
Bidens pilulosa
Brassica sp.
Bromus diandrus
Bromus madritensis subsp. *rubens*
Bromus mollis
Bromus sp.
Carduus pycnocephala
Centaurea solstitialis
Chenopodium album
Cirsium vulgare
Conium maculatum
Cynodon dactylon
Cynosurus cristatus
Erodium botrys
Euphorbia lathyris
Foeniculum vulgare
Galium aparine
Genista monspessulanus
Gnaphalium luteo-album
Hirschfeldia incana
Lactuca serriola
Malva nicaaensis
Marrubium vulgare
Melilotus alba
Nicotiana glauca
Picris echioides
Pipatherum miliaceum
Polypogon monspeliensis
Ricinus communis
Salsola tragus
Senecio mikanioides
Senecio vulgaris
Silybum marianum
Sonchus oleraceus
Taraxacum officinale
Vicia sp.
Vinca sp.
Vitis vinifera
Vulpia myuros
Washingtonia robusta

Native species (n = 107 species or 70% of total sp richness):

Achillea millefolium
Adenostoma fasciculatum
Agrostis exarata
Alnus rhombifolia
Ambrosia acanthicarpa
Ambrosia psilostachya
Arctostaphylos glauca
Artemisia californica
Artemisia douglasiana
Artemisia dracunculus
Aspidotis californica
Astragalus sp.
Baccharis pilularis
Baccharis salicifolia
Boykinia occidentalis
Brickellia californica
Calystegia macrostegia
Ceanothus crassifolius
Ceanothus megacarpus
Cercocarpus betuloides
Claytonia perfoliata
Clematis lasiantha
Conyza canadensis
Cyperus eragrostis
Datura wrightii
Dicentra ochroleuca
Encelia californica
Epilobium canum

Epilobium ciliatum
Equisetum sp.
Ericameria cuneata
Eriodictyon crassifolium
Eriodictyon traskiae
Eriogonum fasciculatum
Eriophyllum confertiflorum
Erodium macrophyllum
Euthamia occidentalis
Filago californica
Fraxinus dipetala
Galium angustifolium
Garrya veatchii
Geranium sp.
Gnaphalium californicum
Gutierrizia californica
Hazardia squarrosa
Heteromeles arbutifolia
Heterotheca sessiliflora
Hoita macrostachya
Juglans californica
Juncus xiphioides
Lepidospartum squamatum
Leptodactylon californicum
Lessingia filaginifolia
Leymus condensatus
Lotus purshianus
Lotus scoparia
Lupinus hirsutissimus
Lupinus sp.
Malacothamnus fasciculatus
Malacothrix saxatilis
Malosma laurina
Marah macrocarpus
Mentzelia laevicaulis
Mimulus aurantiacus
Nassella sp.
Paeonia californica
Pellaea mucronata
Pellaea andromedifolia
Pentagramma triangularis
Phacelia ramosissima
Platanus racemosa
Populus balsamifera
Populus fremontii
Prunus ilicifolia
Quercus agrifolia
Quercus chrysolepis
Rhamnus californica
Rhamnus crocea
Rhus integrifolia
Rhus ovata
Rhus trilobata
Ribes sanguineum
Ribes speciosum
Rubus ursinus
Rumex sp.
Salix lasiolepis
Salvia apiana
Salvia columbariae
Salvia leucophylla
Salvia mellifera
Sambucus mexicana
Scrophularia californica
Solanum douglasii
Solanum umbelliferum
Solanum xanti
Stachys albens
Stephanomeria cichoriacea
Toxicodendron diversilobum
Trifolium sp.
Turricula parryi
Typha latifolia
Umbellularia californica
Unid. native shrub A
Unid. native shrub B
Urtica holosericea
Venegasia carpesioides
Verbena lasiostachys
Xanthium strumarium
Yucca whipplei

Appendix 4. Releve Field Data Sheets