Response of riparian vegetation to mechanical removal of invasive plants, RMRS Middle Rio Grande Fuels Reduction Study (FRS): Progress to date

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Introduction

The following provides a brief summary of progress to date on the vegetation portion of the Middle Rio Grande Fuels reduction project. The overarching goals of vegetation monitoring and analyses are to: 1) characterize responses of herbaceous and woody vegetation to fuels reduction treatments in the context of site landscape and environmental characteristics and land-use history, 2) monitor re-sprouts of treated exotic species in fuels reduction treatments, and 3) monitor transplant success (survival) in replanted sites. Our vegetation evaluations consider each fuel reduction treatment and control at the North, Middle and South sites. A secondary component of this project was evaluation of the efficacy of ETGages™ as a means of estimating evapotranspiration in a range of cover types along the MRG.

Specific tasks completed in 2005 towards meeting the above goals include, 1) completion of ground cover and litter measurements, 2) monitoring and removal of climate sensing instruments, 3) monitoring of exotic resprouts and survival of planted native species, 4) assembly of a GIS (geo)database for geomorphic/landscape analysis, 5) completion of the field components of monitoring of ETGages, and relative humidity and air temperature instruments at associated researchers' eddy covariance towers and sap flux stations along the Middle Rio Grande, and 6) preliminary analysis of ecological data.

Integrated Project Progress Overview

The following provides a brief overview of study methods, current results and preliminary findings.

Task 1 – Description of Vegetation Patterns

<u>Placing sites and treatments in a landscape context</u>

Current treatment, historical land use, and landscape/environmental setting all interact to create the ecological dynamics of MRG riverine ecosystems. Extensive vegetation surveys in experimental treatment plots initiated in 2004 and completed in 2005 form our baseline vegetation data set (Merritt and Johnson 2005). These data are being used to track site succession following fuels reduction treatments relative to untreated control plots. Since treatment blocks span a latitudinal gradient and blocked plots possess differing geomorphic positions and land use histories, the first phase of our analyses concerns quantification of site differences and similarities within and among experimental blocks. Using these analyses in conjunction with a Geographic Information System (GIS) data, we are seeking to understand how these historical and landscape factors affect vegetation dynamics and response to experimental treatment.

To this end, we reviewed published reports, historic accounts, and data sources regarding the chronology of water development and vegetation change along the Rio Grande River. We also obtained digital orthographically-corrected aerial photographs and other available GIS data of the entire study reach and examined valley attributes, fluvial landscape, and current structure of the dominant woody vegetation at the sites. In our final analyses, we will use this information to statistically partition ecological variation into its component parts to evaluate the results of fuels reduction treatments after accounting for inherent site differences.

Summary of Vegetation Analyses

What follows is a brief synopsis of preliminary vegetation analyses to date. These analyses explore the broad vegetation characteristics and patterns occurring in the study region and lay the necessary groundwork for future statistical modeling and time-series analysis. Here, we are particularly concerned with describing inter-site and inter-block differences in species richness, composition, and associated environmental factors, and initial responses to fuels reduction treatments.

These data were obtained in our 2004 and 2005 surveys, during which we gathered vegetation data from all nine study sites.

Species Richness in Control and Fuels Reduction Treatments

In total, 99 vascular plant species were identified in our vegetation surveys, 40 percent of which were exotic, introduced plants. We compared plant species richness, species composition, and environmental characteristics of the sites.

Irrespective of experimental block, average *plot-level* (2x2 m^2) herbaceous *species richness* was highest in the control sites followed by fuels reduction plus revegetation ("Fuels Red-Veg") and fuels reduction only ("Fuels Red"), respectively (Figure 1). This result was expected since data were obtained the first growing season after the intensive site alteration that is part of fuels reduction treatments. Similarly, we also found significant differences in *species composition* between treatment and control sites, however, most species in control sites are still represented at treatments sites, indicating that there is a high likelihood of re-colonization and establishment of species richness at the treated sites.

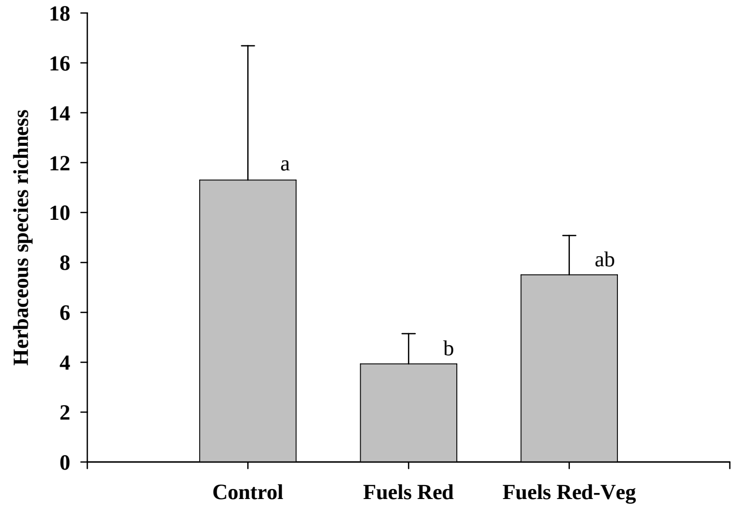

Figure 1. Mean (+/-1 standard error) herbaceous species richness at the plot level in control, fuels reduction, and fuels reduction-revegetation treatments. Different inset letters indicate significant ($p < 0.05$) differences in means from Tukey's test following analysis of variance.

Site-level species richness was calculated by first accounting for differences in sampling intensity and site size. These calibrated species richness values were generated by first fitting sample-based species accumulation curves to the plot-level species data from each site. The curves were generated by randomly entering samples from a site (without replacement) and plotting new species added to the list with each added sample. These randomizations were repeated 50 times to generate species accumulation curves and to estimate standard deviations. We conducted the randomizations using the Bootstrap Method. We then compared richness for similar numbers of plots sampled to account for species-area relationships. These calibrated species richness values were used to compare the *site-level* species richness between sites within blocks and between treatments.

Site-level species richness calculated from species-areas curves is shown in Figure 2. The richest sites were the fuels reduction-revegetation treatment in the North block and the control in the south block. The three most species poor sites were the fuels reduction treatments in the North and South Blocks and the fuels reduction-revegetation site in the Middle block. These results suggest that inherent differences in species richness exist among sites within blocks as well as among the blocks themselves.

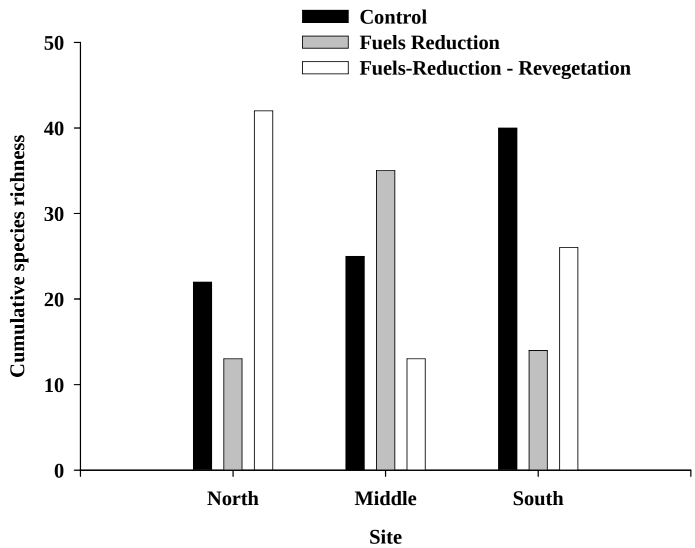

Figure 2. Site-level differences in cumulative species richness by site and treatment. Cumulative richness was calculated using species accumulation curves.

Aggregating *site-level* species richness data by treatment showed that in the year following fuels reduction treatment there were no detectable differences in species richness between treatments and controls (Fig. 3). This result is, of course, confounded by inter-block differences in species richness, however, it does suggest that fuels reduction treatments do not have an unduly severe affect on species richness (at least in the short term). Future vegetation analyses will parse out the portion of variation caused by inter-block differences, to provide a better understanding of the specific effects of fuels reduction treatments, regardless of regional trends.

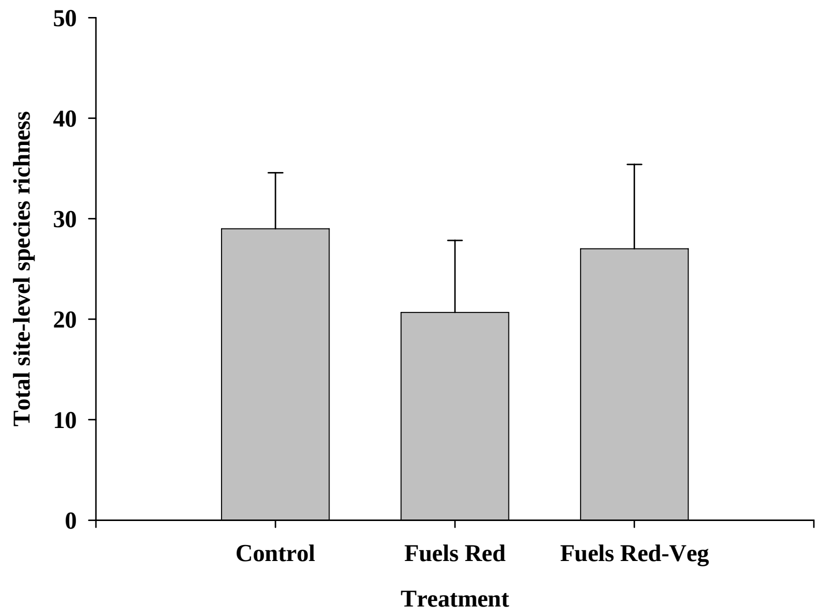

Figure 3. Mean (+/-1 standard error) cumulative species richness by treatment. There were no significant differences in species richness between treatments (ANOVA: $p > 0.05$).

Comparison of Species Composition in Control and Fuels Reduction Treatments

We conducted analysis of similarity (ANOSIM) to test for differences in species composition between fuels reduction treatments and control sites in the first year following treatment. These analyses were conducted on data aggregated by transect. The ANOSIM procedure is initiated by constructing a Bray-Curtis similarity matrix for all pairwise comparisons of transects. Bray-Curtis similarity index incorporates shared species abundances between transects and calculates similarity ranging from 0 (no shared species) to complete similarity 100 (same species in the same proportions). ANOSIM tests the null hypothesis of no difference between factors (treatments) by calculating an R statistic. R of 0 indicates that the average similarity of transects within treatments is no different than the average similarity of transects between treatments; $R = 1$ indicates that the similarity of transects within the treatments are considerably higher than between treatments. The closer R is to 1 the stronger the compositional differences between factors. ANOSIM is then conducted on 999 random assignments of transects to each of the factor (treatment) levels. The number of times that the R calculated for randomly assigned transects exceeds that for the actual data is used to calculate a p-value (proportion of Rs higher by chance).

The first ANOSIM tested for vegetation differences between blocks. The hypothesis of no vegetation differences between the blocks was rejected (Global $R = 0.25$, $p = 0.001$) and all pairwise differences were significant. Thus, from a vegetation standpoint, blocks were not true replicates and aggregating data by treatment was inappropriate for this type of analysis. All remaining analyses were conducted to test for differences between treatments within each block.

In the North block, there were significant differences between treatments ($R = 0.30$, $p = 0.016$). The control was marginally different from the fuels reduction–revegetation treatment ($R = 0.20$, $p = 0.056$), but not significantly different from the fuels reduction only treatment ($R = 0.21$, $p = 0.079$). The biggest difference in vegetation between North treatments was between the fuels reduction and fuels reduction–revegetation treatment ($R = 0.65$, $p = 0.008$).

At the Middle site there were also significant differences between treatments (Global $R = 0.31$, $p = 0.005$). All treatments differed significantly: control and fuels reduction only ($R = 0.42$, $p = 0.016$), control and fuels reduction–revegetation treatment ($R = 0.43$, $p = 0.024$), and fuels reduction and fuels reduction–revegetation treatment ($R = 0.23$, $p = 0.063$).

All treatments at the South block were likewise significantly different (Global $R = 0.64$, $p = 0.001$). All pairwise comparisons between treatments were significantly different: control and fuels reduction ($R = 0.41$, $p = 0.024$), control and fuels reduction–revegetation treatment ($R = 0.56$, $p = 0.005$), and fuels reduction and fuels reduction–revegetation treatment ($R = 0.99$, $p = 0.029$).

After performing ANOSIM, we then tested for the influence of each species on dissimilarity between factors by performing similarity percentage analysis (SIMPER). SIMPER provides the subset of all species that contribute to 90% of the total measured differences between treatments. This provides the subset of the whole species list that best discriminates between (or are sensitive to) the treatments. Species driving the differences between the control and treatments at the North sites included *Acroptilon repens*, *Anemopsis californica*, and *Parthenocissus quinquefolia*, which were all more abundant in the control than in the treated sites. *Muhlenbergia aperifolia*, *Ailanthus altissima*, and *Ipomoea leptophylla* were among those species that were more abundant in the treated sites compared to the control in the North block.

In the Middle block *Panicum obtusum, Muhlenbergia aperifolia*, *Sporobolus airoides*, *Distichlis spicata*, *Ratibida tagetes*, *Elymus elymoides*, *Chamaesyce serpyllifolia*, and *Apocynum androsaemifolium* collectively explained 73% of the difference in species composition between the control and fuels reduction treatment; all were more abundant in the control. *Anemopsis californica* was markedly more abundant in the treated sites than in the control. In the South block *Chloris* spp., *Ipomoea leptophylla*, *Gutierrezia sarothrae*, *Senecio riddellii*, *Sphaeralcea* spp., *Muhlenbergia asperifolia*, and *Aristida purpurea* var. *longiseta* collectively explained 71% of the distinction between plant communities between the control and treatments, all being abundant in the control but absent or sparse in the treatments. Species in the treatments but not the control in the South block include *Anemopsis californica, Amaranthus hybridus*, *Sisymbrium altissimum, Panicum obtusum*, and *Helianthus ciliaris.*

Factors Influencing Herbaceous Vegetation

Documenting patterns of herbaceous vegetation is fundamental to understanding the ecological effects of fuel reduction treatments. Herbaceous species populations tend to be much more immediately responsive to environmental change, including alteration of canopy structure, than long-lived woody species. As such, patterns in herbaceous species abundance can be particularly informative indicators of short-term changes in ecosystems.

Our initial statistical analyses are focused on characterizing “baseline” conditions in control sites and determining the primary factors influencing herbaceous species composition under “natural” conditions. Redundancy Analysis (RDA) was used to visualize patterns in control site herbaceous vegetation and relate them to environmental factors. RDA uses a reciprocal averaging algorithm to order samples (e.g., plots, transects, or sites) according to similarities or differences in their species compositions. RDA then constrains site scores to be linear combinations of environmental variables. This procedure is analogous to multiple regression of site scores on environmental variables.

The end result of this analysis is a RDA diagram in which proximity of sample points in the diagram implies similarity in vegetation and environmental characteristics. Vectors in the diagram indicate the maximum direction of change for that factor. The order of sites relative to any given vector provides a ranking of the site with regard to that environmental factor. The further from the origin a site is in the direction a vector is pointing, the greater the value for the environmental factor (stronger positive association). The converse applies to sites oriented in the direction of the vector tail. The relative lengths of the vectors indicate the strength of the correlation between vegetation and that environmental factor.

Figure 4 is the RDA diagram of samples (plots) from control sites for which soil chemistry data were available. Environmental factors included in this analysis were chosen on the basis of a step-wise forward selection process using Monte Carlo permutations to test for significance. All included factors had significance (p) values lower than 0.05. As is evident from the diagram (Fig. 4), differences in soil factors (P, NO_3, Ca, and Clay), ground cover/litter (total ground cover, fine wood litter, and leaf depth*leaf cover), and exotic woody cover were all strongly associated with control site vegetation.

It is unclear how fuels reduction treatments could affect soil chemistry, however, such treatments without question have a strong effect on exotic woody cover and ground cover/litter composition. Field observations suggest that in treated sites, on-site chipping of cut exotics and mulching with those chips has a marked affect on herbaceous vegetation cover. We noted that in areas with a deep and/or continuous mulch of chips vegetation cover and to a lesser degree species richness appeared suppressed compared to non-mulched areas of the same site.

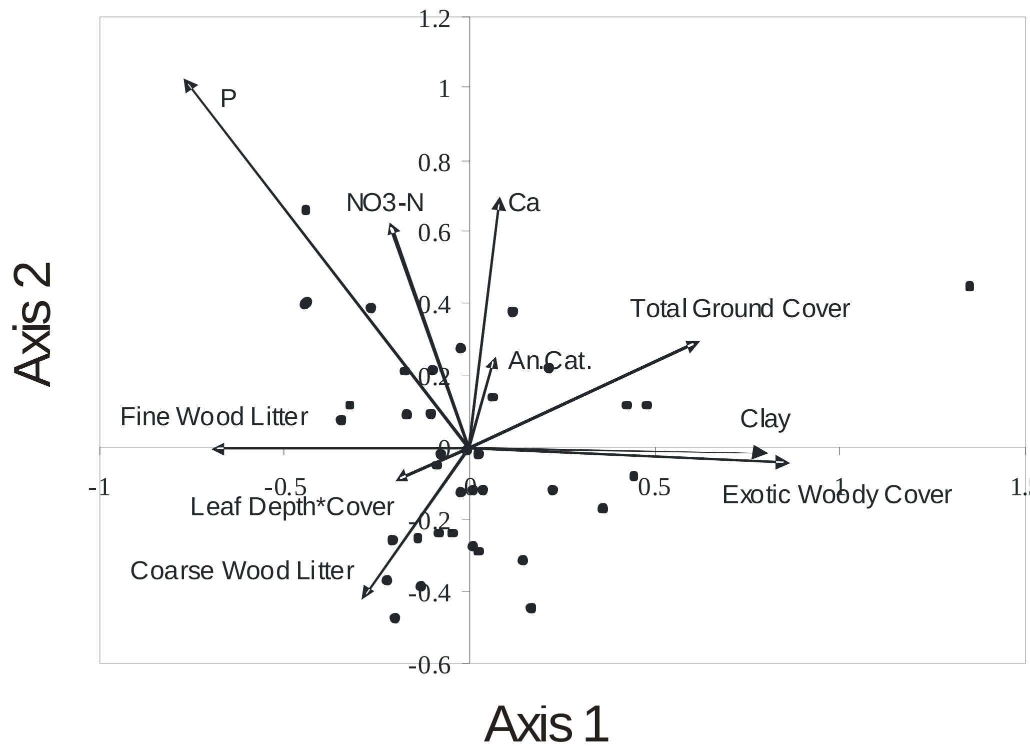

Figure 5. RDA diagram of plots in control sites possessing soil data. Points indicate sample location. These have been left unlabled for clarity. An.Cat. Is the anion/cation ratio. See text for additional details.

Our analyses of treatment site vegetation dynamics encompass many facets, but one of our primary foci at this point is investigating how chip mulch affects herbaceous vegetation. The process of fuels reduction essentially obliterates all surface components of the herb layer. Thus, in our modeling we assume that herbaceous species abundance was essentially zero at t_0 in 2003. Our data collected during 2004 – 2005 is representative of the initial successional state of treatment sites (t_1).

As part of our exploratory research on the t_1 herbaceous data, we assembled bar graphs of herbaceous species richness and total cover versus chip depth and percent cover (Fig. 5). These charts include the aggregation of data from all treatment sites and all blocks, thus considerable natural variation is included. Despite the inclusion of such natural variation, this analysis was informative. Plots show a gradual decrease in species richness and a marked decrease in herbaceous coverage with increasing chip depth. In both cases, the increase in vegetation parameters in the deepest chip class resulted from a just a few unusually well vegetated plots at site M3. It is also interesting to note that the vast majority of species cover and diversity arose from plants with predominately stoloniferous, vegetative growth such as *Anemopsis californica, Muhlenbergia asperifolia*, and *Distichilis spicata*.

The extent of chipping appears to have less of an effect on herbaceous vegetation than chip depth, although there could be a slight tendency for herbaceous vegetation cover to be reduced by increased extent of chips (Fig. 5). We speculate that chip

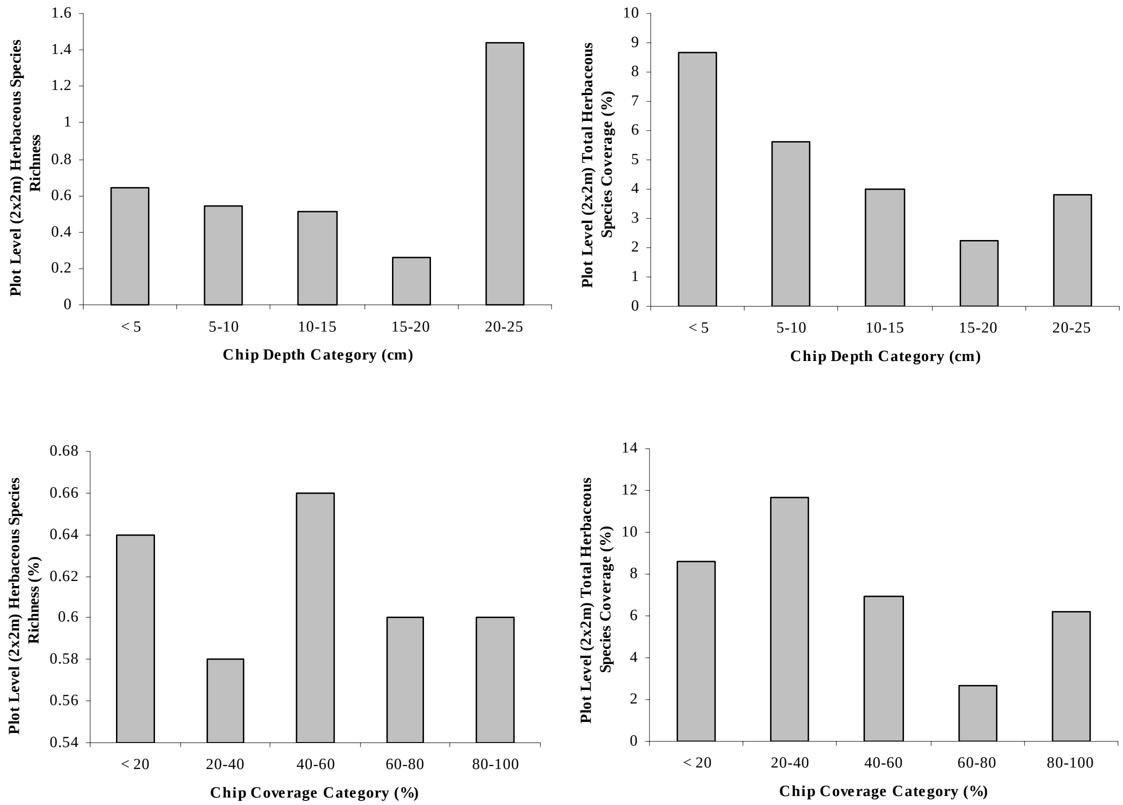

Figure 6. Bars graphs relating herbaceous species richness and cover to wood chip depth and percent cover. Data are aggregated from all treatment sites.

coverage does not appreciably retard herbaceous species, and that any apparent reduction results from the inter-correlation of chip coverage and depth (i.e., areas with a high coverage of chips also tend to be those with greater chip depths).

<u>2006 Vegetation Evaluation Goals</u>

The approximately two thousand vegetation plots established by Merritt and Johnson in 2004 will be re-inventoried in 2006 to characterize short-term successional trends in herbaceous and woody plant species composition. Linkages between plant community dynamics and physical site characteristics (including patterns of chipped fuel application and disturbance associated with equipment access roads) will be used to provide recommendations for conducting fuels reduction activities to enhance rapid recovery of plant communities. These data will be evaluated in the context of the historical landscape-scale analysis of the MRG following the 2006 inventories.

Task 2: Monitoring of re-sprouting and re-growth of treated exotic trees and shrubs and survivorship of transplanted native species.

<u>Resprouts</u>

A total of 837 cut stems of non-native woody species were evaluated for resprouting at the treated sites (North 2, North 3, Middle 1, Middle 3, South 2, and South 4). These resprouts were measured along transects established for the vegetation inventories. Russian olive (*Elaeagnus angustifolia*), tamarisk (*Tamarix ramosissima*), Siberian elm (*Ulmus pumila*), and mulberry (*Morus alba*) resprouts were inventoried along the transects.

The overall resprout rate for the 837 stems measured was 16%. Resprout rate was highest for Siberian elm (50%) and lowest for Russian olive (3%). *Tamarix* and *Morus* each had resprout rates of 18% (Fig. 4).

The *fuels reduction treatment was effective in reducing exotic species at the fuels reduction sites*; mortality rate was 84% across all exotic species treated. These results suggest that Siberian elm is least sensitive to treatments, and perhaps should receive more intensive removal efforts during future fuels reduction treatments.

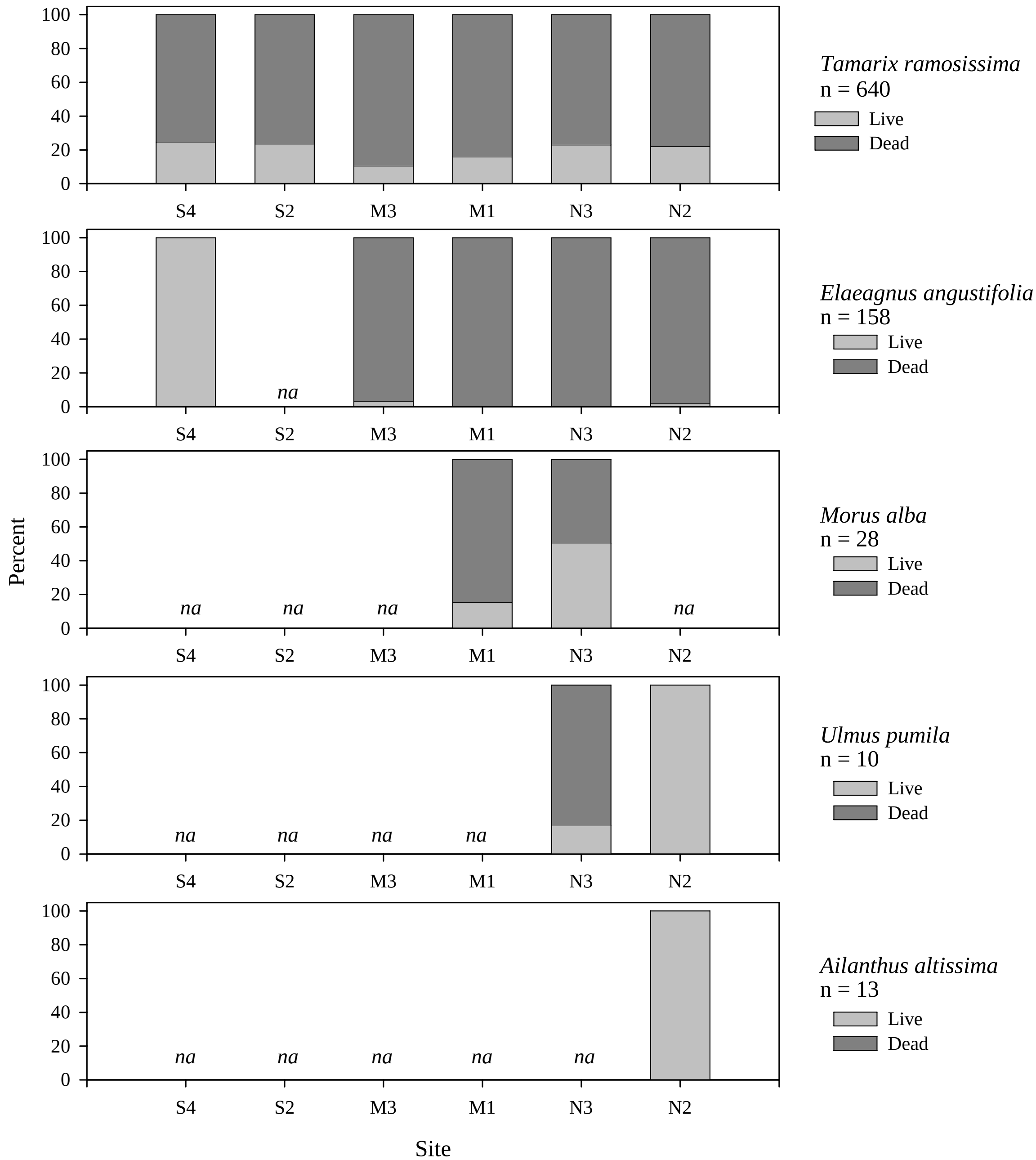

Figure 4. Resprout mortality at the treated fuels reduction sites along the Middle Rio Grande. The mortality rate of the 837 resprouts sampled was 84%.

Transplant survival

We measured survival of transplants at each of the cleared and revegetated sites. Species sampled included *Amorpha fruticosa*, *Baccharis salicina*, *Forestiera pubescens*, *Lycium pallidum*, *Prosopis pubescens*, *Rhus trilobata*, and *Ribes aureum*. Survival of transplants ranged from 60-100% at the three sites (185 individuals were measured). Mortality rate was highest for skunkbrush (*Rhus trilobata*) in the North block (40% mortality), mesquite (*Prosopis pubescens*) in the Middle block (30% mortality), and for wolfberry (*Lycium pallidum*) in the South block (8% mortality). The primary cause of mortality for all species appeared to be drought stress and desiccation.

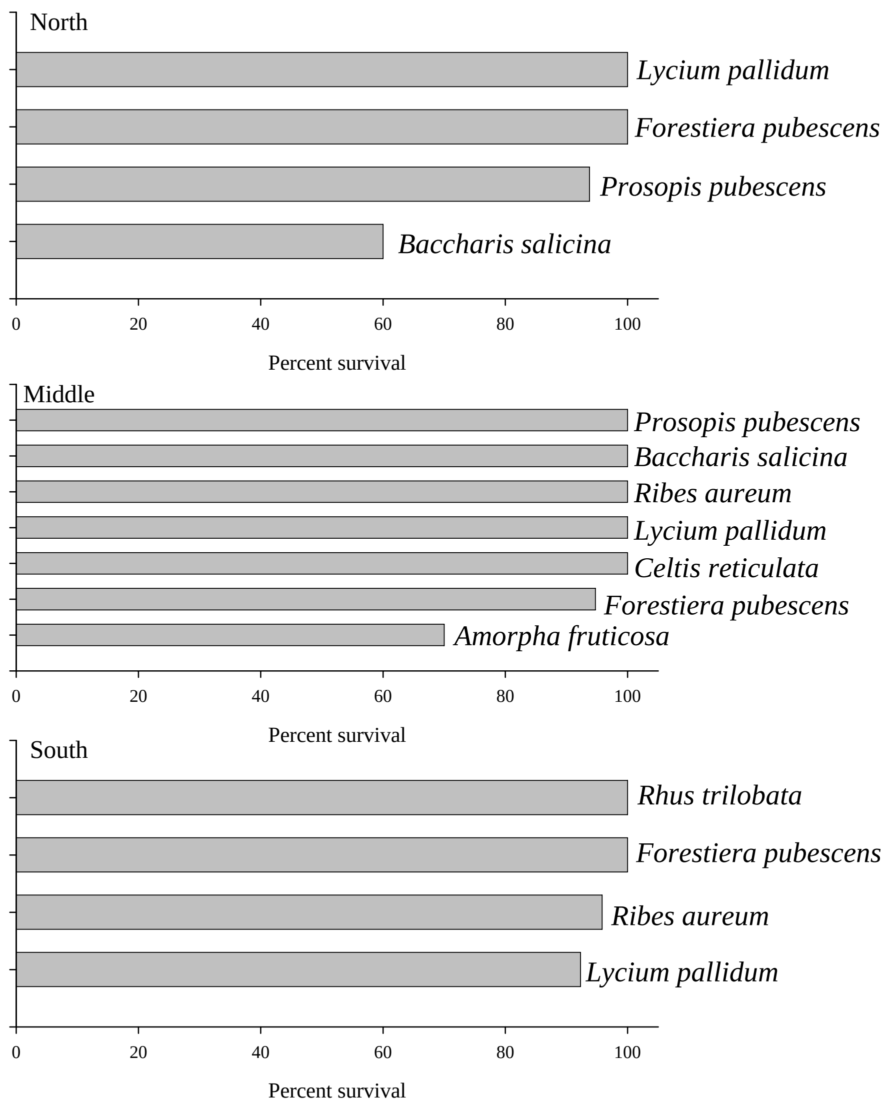

Figure 5. Survival rate of transplanted saplings of several native plants in the fuels reduction-revegetation treatments.

Task 3: Continued monitoring of ETGages, relative humidity, and air temperature at eddy covariance towers and sap flux stations.

ET gages were established this year at seven sites and data were gathered from June through September. We also gathered relative humidity and temperature data. These data will be compared to ET measured at each of the eddy covariance towers established by University of New Mexico.