City of Austin
WATERSHED PROTECTION

Sapling Survival Assessment: Examining Success of One Urban Riparian Restoration Tool in Austin, Texas

SR-14-13, March 2014

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Abstract

Through a partnership with the City of Austin Parks and Recreation Department Urban Forestry Program and the local non-profit organizations Tree Folks and Austin Parks Foundation, more than 6,200 tree saplings were planted in January and February of 2013 in eight riparian buffers as part of the City of Austin Grow Zone Program. In order to quantify the survival and growth rate of the planted saplings, a Sapling Survival Assessment protocol was established at four of the sites by setting up 16 m^2 plots (average of 25 saplings per plot) at the time of planting and assessing survival and growth of the saplings within each plot in October 2013. Species, relative light level, location, height and diameter were measured, and whether the plant was alive or dead was recorded. The overall survival rate of the saplings sampled (n=381) was 13.4% and the probability of surviving varied significantly among species, sites and light levels (open vs. shade). On average, saplings grew at a rate of 0.015 mm/day (5.75 mm/yr) in diameter and 0.073 mm/day (26.6 mm/yr) in height. The diameter and height growth rate varied significantly among species but not among sites or light levels. These results will provide guidance on sapling planting to help achieve target canopy densities and species composition at future restoration locations.

Introduction

The ability to restore ecosystem services provided by functional riparian buffers depends on the successful establishment of structurally and biologically diverse vegetation. Because species with limited seed dispersal are unlikely to colonize urban areas, active planting of saplings may increase woody species diversity in urban riparian forests. Planting woody saplings instead of large containerized trees can constitute a valuable tool in the urban riparian restoration toolbox, particularly in arid and semi-arid regions where water restrictions and drought are problematic. Compared to containerized trees, saplings require less water to establish, are often available in a more diverse species palate, have fewer root problems often associated with poor growing practices in commercial nurseries, and cost less to purchase and install. Information about survival rates for woody saplings planted in urban riparian buffers is scarce, although Duncan and Richter (2012) reported an overall survival rate of 37% of saplings planted in urban undeveloped parks in Austin, Texas. Growth rates for the species planted in Austin in degraded urban creek buffers was unknown.

Relative light levels and distance from a water body can greatly affect available soil moisture, and thus sapling survival. In semi-arid areas, the most important cause of sapling mortality is water stress and desiccation (Selter, Pitts and Barbour 1986; Frazer and Davis 1988; Padilla and Pugnaire 2007). In addition, different plant species respond differently to various levels of light and moisture (Bazzaz and Carlson 1982; Frazer and Davis 1988; Beckage and Clark 2003). Prior studies, however, evaluated survival in saplings emerging from natural recruitment from the seed bank. Information on the survival and growth of planted saplings is lacking for arid and semi-arid areas. Without species-specific survival and growth rates for planted saplings, little guidance is available for selecting appropriate species or adequate sapling densities to achieve canopy restoration goals. In order to guide riparian restoration projects in Austin, this project measures survival and initial growth rates of different woody sapling species planted in creek buffers at different light conditions.

Methods

Plot Design

Four creek buffer areas (Grow Zones) where mowing has ceased and that are being managed through a facilitated plant succession approach were selected for this study. Bartholomew is a Grow Zone providing a 2.23 hectare buffer to a 1,000 m section of Tannehill Creek within Bartholomew Park. Dottie Jordan is a Grow Zone providing a 0.36 hectare buffer to a 457 m segment of Little Walnut Creek within Dottie Jordan Park. Lady Bird Lake is the longest Grow Zone providing a buffer of almost 5 km along the shoreline of Lady Bird Lake and encompassing about 4.73 hectares of riparian buffer. Shoal Creek is a Grow Zone along 572 m of Shoal Creek providing a buffer of about 1.46 hectares through the Shoal Creek greenbelt (Figure 1).

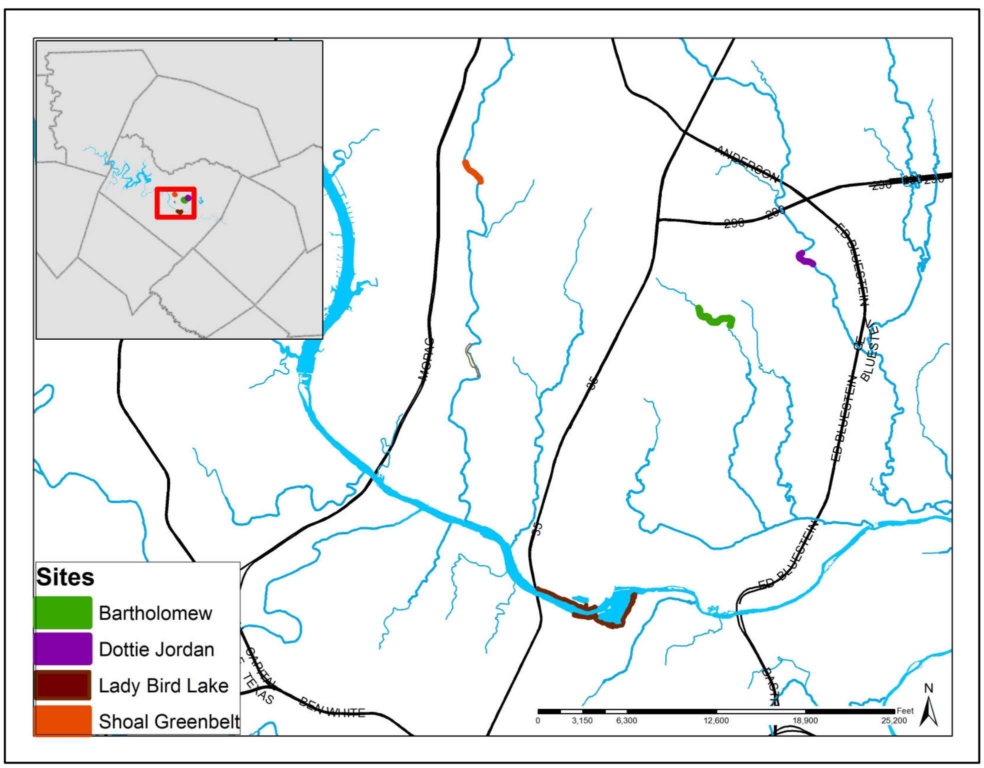

Figure 1: Map of Grow Zone sites included in the study.

Within each of the four Grow Zones included in this study, four 16 m^2 planted plots were randomly located within the area where a sapling planting took place in January and February of 2013. An attempt was made to have all four planted plots within each Grow Zone with the same number and species of saplings. However, this was not always possible due to sapling availability. Four 16 m^2 passive plots were randomly located within the area where no sapling planting was conducted. Plots ran 4 meters perpendicular to the stream inland starting at bankfull depth and 4 meters parallel to the stream (Figure 2). The precise locations of all 4 corners of each of the plots were recorded by GPS coordinates and by triangulation from witness trees or other prominent features benchmarked in the field. Galvanized nails 1 ft long were driven into the ground on the two corners of each plot closest to the stream bank leaving about 2 in of the nail exposed as permanent benchmarks (Figure 2, black dots) to help relocating sampling locations in the future site visits using a metal detector.

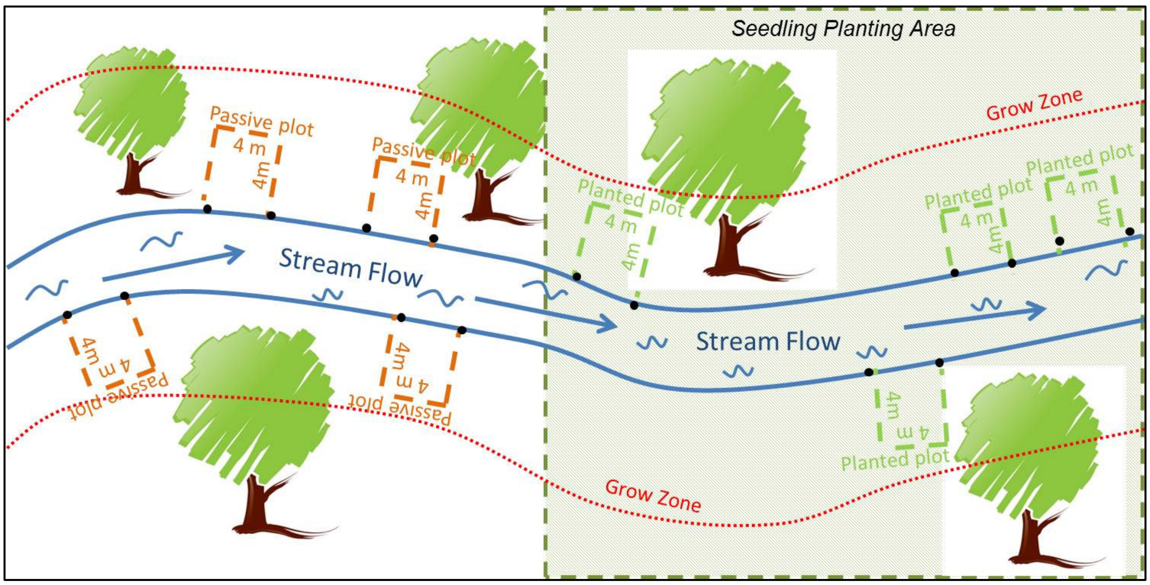

Figure 2: Example of randomly selected plots within planted and passive areas in a Grow Zone.

Sapling Measurements

Following sapling planting events (Ready, Set, Plant!) in January and February of 2013, active and passive plots were established and benchmarked at each of the 4 Grow Zones. All saplings were flagged within each plot making sure that the planted saplings were distinguishable from established "volunteer" saplings (non-planted saplings established within the last growing season that were > 0.5 ft high). The following parameters were collected for all saplings within each plot (including non-planted plants in active plots) immediately after planting and in November 2013:

- Species Identity
- If plant is alive or dead
- Diameter (cm) taken at 2.5 centimeters above the soil
- Height (cm)
- Relative Light Level (RLL)
- Distance (m) from upstream benchmark nail (US)
- Distance (m) from downstream benchmark nail (DS)

Saplings were considered alive if they contained any living parts (leaves and buds) or if the trunk felt firm and flexible. Trunks that did not bend and/or felt hollow when squeezed were considered dead. Diameter was measured to the nearest 0.5 mm using Vernier calipers. Height was measured to the nearest 0.1 cm, starting from the soil surface to the top of the apical meristem on the main stem, but ignoring any limbs or leaves that may protrude above the apical meristem. RLL was divided into Low (<33% canopy cover), Medium (33%-66% canopy cover), and High (>66% canopy cover) and were visually estimated.

Data Analysis-Survival

Logistic regression was performed on sapling data in order to determine if the Grow Zone (site effect), Species Identity, and/or RLL played a significant role in sapling survival. Species that were recorded in the primary event as having greater than two individuals were used in the analysis (Table 1). Incorporating the three main effects with all interactions led to a total of 25 models to analyze sapling survival. The model with the lowest Akaike Information Criterion (AIC) was chosen to be used in further analysis and then used to compare the survival of saplings between site locations, species, and RLL through the use of the ESTIMATE statement in the LOGISTIC procedure in SAS 9.2.

Data Analysis-Growth Rate

For each live individual in the second sampling event, growth rate for height was calculated in cm/day and diameter growth rate was calculated in mm/day. Height growth rate and diameter growth rate were input as response variables in two separate unbalanced ANOVA models. All species found within the plots were given numerical dummy variables prior to being input into the model. Only species where growth rates could be calculated on more than two individuals were used for analysis (Table 1). Independent variables for each model included: Grow Zone (site effect), RLL, and Species Identity. Type III sum of squares were used for inferences due to the unbalanced dataset.

Table 1: Assigned species number and the common name for each species in analysis. The number of individuals of each species is listed for each analysis.

Species Number	Species Common Name	Survival Analysis	Growth Analysis
1	American beautyberry	15	6
3	American sycamore	13	1**
4	aromatic sumac	35	13
5	bald cypress	15	3
6	bodark	9	4
7	Carolina buckthorn	25	7
8	catclaw	14	0**
9	cedar elm	8	3
11	cottonwood	8	0**
12	elderberry	29	1**
15	honey locust	15	5
18	glossy privet	0*	6
19	live oak	16	7
21	Mexican buckeye	28	0**
22	mountain laurel	23	2**
24	pecan	14	6
27	red mulberry	8	3
28	red oak	16	2**
29	redbud	0*	4
30	roughleaf dogwood	23	5
32	spicebush	22	0**
33	Texas persimmon	28	1**
34	western soapberry	15	2**

*Not used in survival analysis (seedlings not planted but that had emerged from natural recruitment).
**Not used in growth rate analysis.

Data Analysis-Passive vs. Planted

Each plot in the experiment was marked as either 'Passive' or 'Planted'. Saplings were originally planted in the Planted plots whereas no initial planting was done for the Passive plots. Height growth rate and diameter growth rate were input as response variables in two additional unbalanced ANOVA models where the plot type was used as the independent variable. Type III sum of squares were used for inferences due to the unbalanced data

Sapling abundance was collected in each of the passive and planted plots during the initial sampling event and in the survival assessment visit in November 2013. Species diversity of saplings was calculated in each of the passive and planted plots for both sampling events using the Shannon-Wiener diversity index. Two separate repeated measure t-tests were performed using type of plot (passive or planted) as the independent variable and the number of the sampling event as a measure of time. The first t-test used sapling abundance as the response variable while the second used the species diversity index as a response variable.

Results and Discussion

SURVIVAL

The logistic regression model with the lowest AIC value included Grow Zone (site effect), species, and RLL main effects and the interaction between the Grow Zone (site effect) and RLL (Table 2). This model predicted the survival of an individual the best with a 0.857 *c-statistic*. The c-statistic is the area under a receiver operating characteristic curve (ROC curve) which is a curve that plots the fraction of predicted true "events" to total actual "events" against the fraction of predicted false positive "events" to total actual "non-events"(Hastie, Tibshirani and Friedman 2009). In this case an "event" would be classified as survival of a sapling. The c-statistic will range from 0.5 to 1.0 with a value of 0.5 corresponding to the model randomly predicting the response and a value of 1.0 corresponding to the model perfectly discriminating between a "events" or "non-events" (McNeil and Hanley 1984).

While this seemed to be the best predictive model, the RLL main effect and the interaction between the Grow Zone (site effect) and RLL were not significant in the model. In fact, removal of the RLL main effect and the interaction term from the model only increased the AIC slightly (Table 2) and the c-statistic dropped to a value of 0.848. It would appear that only Grow Zone and species impact the survival of saplings in this assessment. Thus, the model used for all further analysis in this report shall be the model that included the Grow Zone and species main effects even though this was not the model with the lowest AIC value.

Using the selected model, we compared the survival of saplings among Grow Zones and species. Survival was significantly different among Grow Zones. Survival at Shoal Creek was significantly higher than the other sites (Bartholomew p-value = 0.0041, Dottie Jordan p-value = 0.0003, Lady Bird Lake p-value = 0.0029) (Table 3). Sapling survival was not significantly different among Bartholomew, Dottie Jordan, and Lady Bird Lake sites. Both Bartholomew and Dottie Jordan seedling planting areas experienced severe water currents that tumbled the existing vegetation and covered the area with debris. Seedlings were difficult to find among the debris and some had been uprooted or fully covered with sand deposited during the storm event. In Lady Bird Lake, some areas experience high traffic that may have encroached in the seedling planting area. In addition, ragweed densities were high during 2012 after mowing ceased and may have affected seedling survival. It is unclear what site condition at Shoal Creek facilitated the higher survival rate. While the RLL was not a significant factor for sapling survival for this assessment and seemed to matter little to the survival of a sapling at Dottie Jordan or Lady Bird Lake, almost all surviving saplings at Shoal Creek were under medium light levels. In fact, the survival rate was 40% under the medium light levels at Shoal Creek and the survival rate was 11% under high light levels. The amount of available light may reduce water stress: sites with less available light, and thus more shade, may reduce soil water loss and air temperature. It may be that RLL facilitates higher survival rates but other environmental conditions must be present as well. We were not able to assess sapling survival under low available light conditions because no monitoring plots were planted under that light treatment.

Table 2: Terms of the logistic regression model and corresponding AIC values.

Site	Species	Light	Site*Sp	Site*Light	Sp*Light	Site*Sp*Light	AIC
X	X	X		X			247.05
X	X	X					249.93
X	X						252.06
X		X		X			263.27
	X	X					266.97
X		X					270.06
X	X	X		X	X		271.71
	X						272.56
X							273.56
X	X	X			X		273.77
	X	X			X		289.42
		X					291.52
X	X	X	X	X			369.34
X	X	X	X		X		382.48
X	X		X				393.53
X	X	X		X	X	X	393.54
X	X	X	X				399.68
X	X	X	X	X	X		433.34
X	X	X		X		X	454.69
X	X	X	X		X	X	492.84
X	X	X	X			X	492.84
X	X	X	X	X	X	X	492.86
X	X	X	X	X		X	492.86
X	X	X				X	501.88
X	X	X			X	X	751.21

Table 3: Number of saplings planted at each Grow Zone and the percent of saplings at each site that survived after one year. *The number of saplings that survived at Shoal Creek was significantly higher than any other site.

Site	No. of saplings planted	Percent survival
Bartholomew	93	11
Dottie Jordan	98	5
Lady Bird Lake	100	11
Shoal Creek	88	28*

Survival was also significantly different among species. Aromatic sumac, red mulberry, Carolina buckthorn, American beautyberry, and cedar elm had significantly higher survival rates than mountain laurel, Texas persimmon, elderberry, Mexican buckeye, and spicebush (Table 4). Aromatic sumac also had significantly a higher survival rate than American sycamore and bald cypress. Only seven species had a survival rate of 20% or more: red mulberry, aromatic sumac, bodark, Carolina buckthorn, American beautyberry, cedar elm, and honey locust. All species that had less than 10% survival were species either requiring high moisture conditions (wetland indicator status of FAC, FAC+, FACW, or OBL), or were grown in small plastic sapling cones and had less than 6 months of growth prior the planting event. Grow Zones in this study are creek buffers with mostly disconnected floodplains and a low water table; saplings that require higher moisture levels would be expected to have higher mortality than those associated with upland habitats.

Table 4: Percent survival of assessed plant species at each Grow Zone.

Common Name	Site 1		Site 2		Site 3		Site 4		Overall	
	N	Survival (%)	N	Survival (%)	N	Survival (%)	N	Survival (%)	N	Survival (%)
aromatic sumac	11	27	8	38	8	25	8	63	35	37
red mulberry	1	0	NA	NA	4	25	3	67	8	38
Carolina buckthorn	4	0	4	0	9	11	8	75	25	28
American beautyberry	4	50	4	0	4	25	3	33	15	27
cedar elm	4	25	4	25	NA	NA	NA	NA	8	25
bodark	1	0	NA	NA	4	50	4	25	9	33
honey locust	4	0	3	33	4	0	4	50	15	20
live oak	4	25	4	0	4	0	4	50	16	19
roughleaf dogwood	4	0	4	0	8	13	7	43	23	17
pecan	3	0	4	0	4	50	3	0	14	14
red oak	4	25	4	0	4	0	4	25	16	13
western soapberry	6	17	8	0	NA	NA	1	0	15	7
cottonwood	4	0	4	0	NA	NA	NA	NA	8	0
catclaw	6	0	8	0	NA	NA	NA	NA	14	0
American sycamore	1	0	3	0	4	25	5	0	13	8
bald cypress	4	0	4	0	4	0	3	0	15	0
mountain laurel	3	0	4	0	9	0	7	14	23	4
Texas persimmon	7	14	8	0	8	0	5	0	28	4
elderberry	7	0	8	0	7	0	7	14	29	3
Mexican buckeye	7	0	8	0	7	0	6	0	28	0
spicebush	4	0	4	0	8	0	6	0	22	0

GROWTH RATE

In each model (height and diameter), the growth rate was not significantly different among Grow Zones (p=0.5740 Height, p=0.0846 Diameter) (Figure 4a,b). Similarly, both measures of growth rate were not significantly different between medium and high RLL (p=0.1794 Height, p=0.3648 Diameter) (Figure 5a, b).

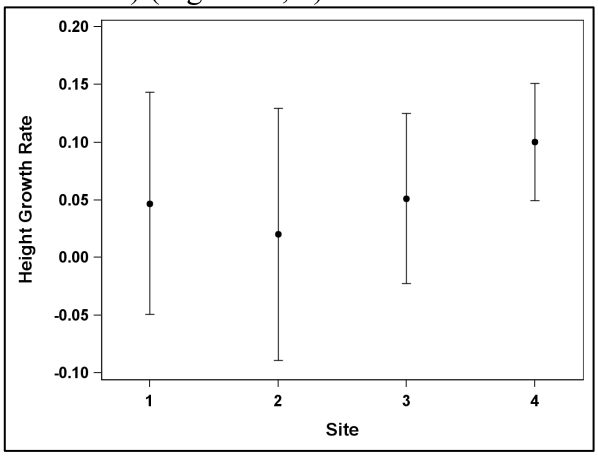

Figure 4a: Least Square Means (with 95% CI) of the height growth rate for saplings by site. There was no significant difference in the growth rate between sites.

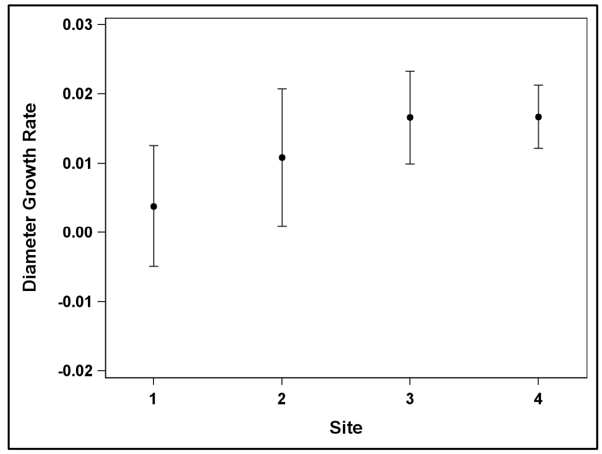

Figure 4b: Least Square Means (with 95% CI) of the diameter growth rate for saplings by site. There was no significant difference in the growth rate between sites.

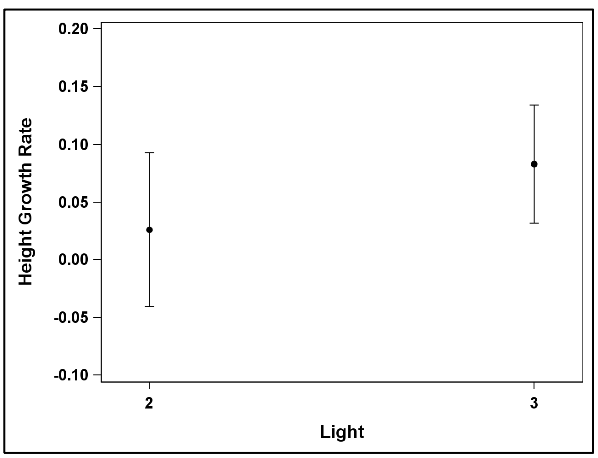

Figure 5a: Least Square Means (with 95% CI) of the height growth rate for saplings under medium or high RLL. There was no significant difference in growth rate between medium and high RLL.

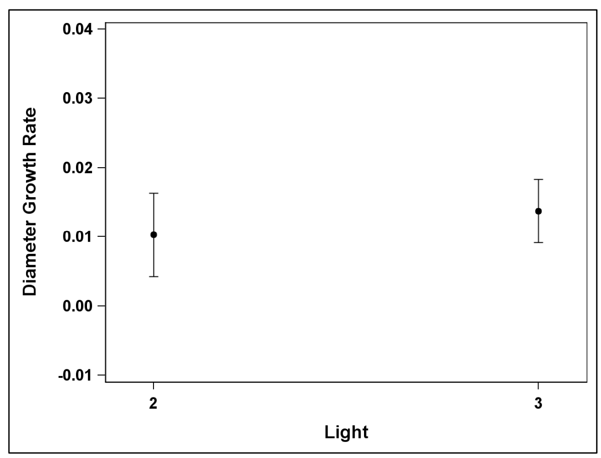

Figure 5b: Least Square Means (with 95% CI) of the diameter growth rate for saplings under medium or high RLL. There was no significant difference in growth rate between medium and high RLL.

A significant difference in height growth rate was found among species. The Tukey-Kramer multiple comparison test was used to examine which species were significantly different in growth rates. Bald cypress and redbud had a significantly higher growth rate in height when compared to aromatic sumac (Figure 6a). No significant difference was found among species for diameter growth rates (Figure 6b). Some of these species, including glossy privet, were not planted saplings and are non-native species considered invasive. Glossy privet (*Ligustrum lucidum*), in particular, is a very aggressive invader that dominates the canopy and understory, limiting recruitment by other woody species (Hoyos et al. 2010).

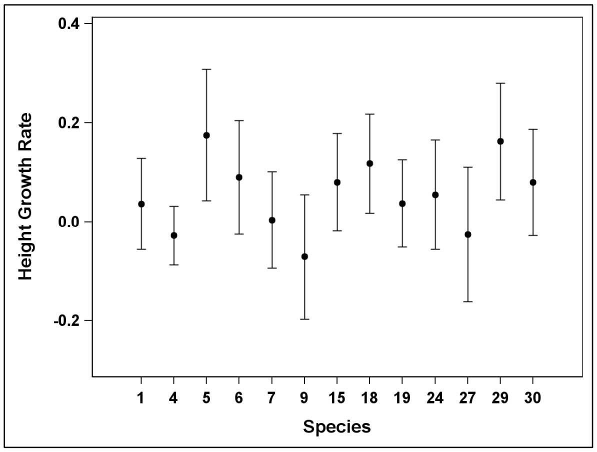

Figure 6a: Least Square Means (with 95% CI) of the height growth rate for saplings by the species of tree. See Table 1 for the tree species that matches each species number in the graph.

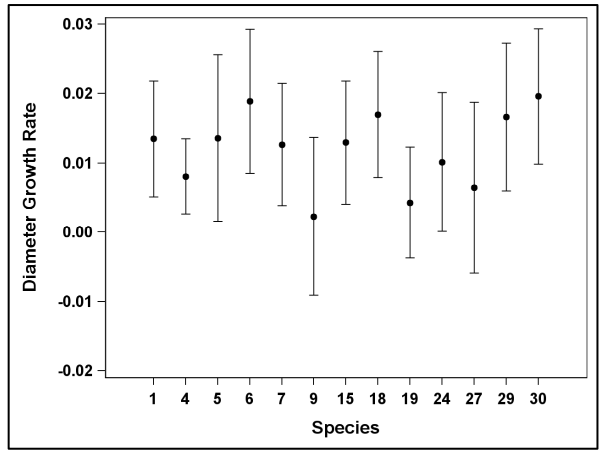

Figure 6b: Least Square Means (with 95% CI) of the diameter growth rate for saplings by the species of tree. See Table 1 for the tree species that matches each species number in the graph.

PASSIVE vs. PLANTED

There was no significant difference in the height growth rates between the passive (0.124±0.097 cm/day) and planted (0.073±0.139 cm/day) (p=0.0933) plots (Figure 7a). There was no significant difference in the diameter growth rates between the passive (0.020±0.013 cm/day) and planted (0.015±0.014 cm/day) plots (p=0.1074) (Figure 7b). Contrary to these results, it was expected that saplings from natural recruitment would grow significantly faster than planted saplings during the first growing season after the planting event because of transplant shock and the need of planted saplings to replace lost root biomass. Assuming that the first growing season is the most challenging for planted saplings, planted saplings that manage to survive may be able to keep growing at an equivalent pace with non-planted saplings. Longer term monitoring of the surviving saplings would be required to further assess this potential.

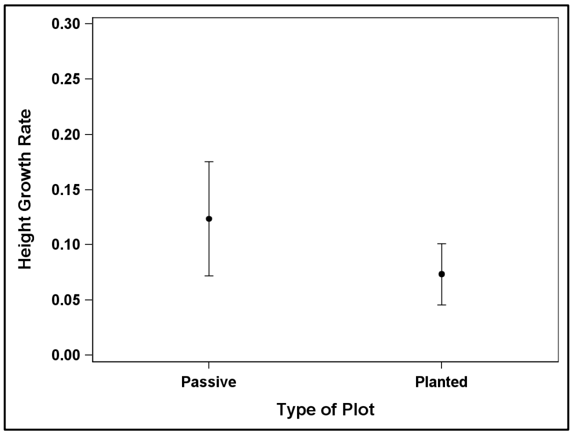

Figure 7a: Least Square Means (with 95% CI) of the height growth rate for saplings found in plots where saplings were planted and plots where saplings were not planted. There was no significant difference in height growth rate between passive and planted plots.

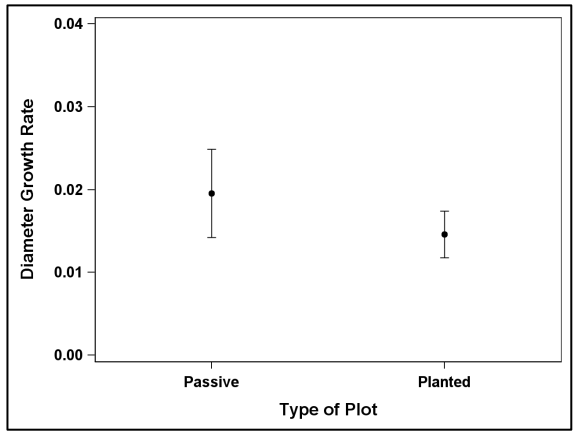

Figure 7b: Least Square Means (with 95% CI) of the diameter growth rate for saplings found in plots where saplings were planted and plots where saplings were not planted. There was no significant difference in diameter growth rate between passive and planted plots.

Sapling abundance was significantly higher in the planted plots than the passive plots after the initial planting (p<0.0001) and after the first year of the study (p=0.0375) (Table 5). There was a significant difference among the planted plot types between the site visits (p<0.0001) but not among the passive plot types (p<0.0001). The abundance of live saplings in passive plots was similar from year one to year two, but the abundance of live saplings in planted plots was less in year two. Therefore, although overall sapling survival was very low (13.4%), the contribution of sapling planting to the woody plant recruitment potential within the plots was still positive and significant.

Table 5: Least Square Means (with 95% CI) of sapling abundance in passive and planted plots for the first and second sampling event.

	Passive Plot		Planted Plot	
Sampling Event	**Mean Abundance**	**95% CI**	**Mean Abundance**	**95% CI**
First	2	0-3	24	23-25
Second	2	-1-4	5	3-8

Species diversity (Shannon-Weiner diversity index) in the planted plots was significantly higher than species diversity in the passive plots after the initial planting (p<0.0001) but not after the first year of the study (p=0.0865). There was a significant difference in species diversity between site visits (p=0.0013). There was also a significant interaction between the plot type (planted vs. passive) and site visits (planting = site visit 1, assessment = site visit 2) (p=0.0002). This indicates that the species diversity was significantly different between the initial and final site visits in the planted plots but not in the passive plots. The species diversity index in passive plots was similar from year one to year two, but the species diversity was lower in year two for the planted plots (Table 6).

Table 6: Least Square Means (with 95% CI) of the Shannon-Wiener diversity index in passive and planted plots for the first and second sampling event.

Sampling Event	Passive Plot		Planted Plot	
	Shannon-Weiner	**95% CI**	**Shannon-Weiner**	**95% CI**
First Visit (Jan/Feb 2013)	0.35	0.18-0.51	2.77	2.65-2.89
Second Visit (Nov 2013)	0.51	-0.12-1.13	1.17	0.73-1.61

While the species diversity decreased in the planted plots from year one to two and is not significantly different in the second year from species diversity in the passive plots, the species diversity is still slightly higher for planted plots than passive plots in the second year sampling and the contribution of the planting to the woody plant diversity can still be seen in the second year of the study. Long-term monitoring of these plots will indicate if the effects on woody plant diversity continue at a slightly higher index value or if they continue to drop to a point that is not only statistically insignificant but in fact equivalent to the diversity in the passive plots.

Conclusions

Overall sapling survival was low (13.4%). The probability of survival is affected by the Species Identity and the site (Grow Zone) where the sapling is planted. Sapling height growth rates were different among species but were not affected by the RLL or site (Grow Zone). Despite high sapling mortality, planting saplings as a restoration strategy has a significant effect on woody species sapling abundance and has the potential to accelerate riparian forest establishment. There was a noticeable, though not significant, positive effect on woody species diversity after one year of study by planting saplings.

Recommendations

Continue long-term monitoring to assess long-term effects of planting saplings in Grow Zones on the riparian vegetation through the Riparian Functional Assessment project.

Include assessment of species moisture requirements when planning the species composition of sapling planting events to enhance sapling survival.

Monitor the growth rate of individual species. Low survival precludes using these study plots to continue measuring growth rate for individual species. A follow up of this study is recommended to measure the growth rate of the different species included in sapling plantings. A balanced design is strongly recommended. This information will further contribute to restoration method enhancements and assist with projecting the expected carbon sequestration potential of the urban riparian restoration taking place in Grow Zones.

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