Riparian Functional Assessment Phase Two Summary

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Abstract

In an effort to assess the response of degraded riparian buffers to the cessation of the main disturbance regime (mowing) and the facilitated succession approach to riparian restoration, the City of Austin implemented phase 2 of the Riparian Functional Assessment (RFA) which consisted of sampling degraded buffers after 1 year with no disturbance. Only degraded sites were included in this phase and their functional scores were compared with those of reference sites from the initial sample year representing healthy riparian function. A total of 9 degraded sites were added to the initial 16 degraded sites from phase 1 for this assessment. Results suggest that degraded buffers lacked the necessary time to show a response in riparian function after only one year of recovery. Sampling design changes are recommended to better assess the growing number of buffer site locations tracked in this project, including reinstituting reference site sampling and shifting to a biannual sampling regime. Based on analysis of phase 2 data, changes to the assessment tool include the following: substitute organic soil carbon for direct soil moisture measurements, coalesce the hardwood demography and recruitment parameters into woody community dynamics, and upgrade soil compaction instruments for higher accuracy and reliability.

Introduction

Riparian zones are widely recognized as functionally unique and dynamic systems that provide a suite of essential ecosystem services (Fischer and Fischenich 2000). Healthy riparian buffers can function to provide pollutant removal, protection from stream bank erosion, slowing of floodwaters, increased groundwater infiltration, temperature buffering, carbon sequestration, and plant and animal habitat (Fischer and Fischenich 2000, Stacey et al. 2006, Richardson et al. 2007, Woolsey et al. 2007). In general, increasing degradation of an ecosystem fundamentally alters the basic services provided by that system (Hobbs and Cramer 2008). Riparian zone restoration is a commonly applied method for improving the ecological function of a degraded site. A vast majority of current restoration endeavors involve either removal of vegetation, planting, or both, without measuring essential ecosystem processes that may be affected. A Riparian Functional Assessment tool was developed in 2012 (Richter and Duncan 2012) to quantitatively measure how these restoration projects strengthen the environmental functionality of the riparian zone. This assessment tool provides information for adaptive management of degraded sites and helps ensure that the trajectory of the vegetation succession is moving towards an achievable minimally-impacted reference condition. Previous studies by the City of Austin have identified a methodology for diagnosing and monitoring the improved ecological function of urban riparian systems following restoration activities including the identification of specific metrics that respond to changes in management as well as represent a broad suite of ecological function (Duncan 2012). The objective of phase 2 of this study is to conduct an assessment of the response to restoration, active or passive, on degraded sites after one year since the cessation of mowing. This study will help guide current and future riparian restoration efforts for the City of Austin.

Methods

Data collection
Phase 2 of this project included only degraded sites. A total of 25 sites from various watersheds and drainage areas were sampled. The site list was composed of 16 sites previously sampled in Phase 1 of the study in 2012, in addition to 9 new sites (Appendix 1). Sites were sampled from April 16-30, 2013.

At each site, a 100 m transect was run along the creek center-line. Transect starting points were marked by tree tags, or associated permanent marker. The direction (upstream or downstream) of each transect was denoted on data sheet as reference for future evaluations and matched the transect direction from previous sampling. As dictated by protocol, photographs were taken at the upstream and downstream transect ends as well as at the 50 m mark on the transect tape looking both downstream and upstream. Additional photos were taken at various other locations within a site that were considered as valuable for future comparisons. Sampling 10x10 m quadrats were established along the left and right banks of each transect when possible and centered at 5, 50, and 95 m on the transect tape. The edge of the quadrat closest to the creek began at bankfull channel edge. Within each 100 m^2 riparian quadrat, the following parameters were recorded (Appendix 2):

1. **Soil compaction** was measured as close to the center of the quadrat as possible with a penetrometer and recorded in pounds per square inch. Three measurements were recorded in each quadrat at a depth of 3 inches of soil.
2. **Soil moisture** was recorded as close to the center of the quadrat as possible with a soil probe tester. The probe was chemically cleaned prior to each quadrat sampling and inserted into the ground for approximately two minutes prior to taking a reading to allow the probe to stabilize. In instances where the soil probe would not activate

due to a lack of moisture in the soil, a zero was recorded for soil moisture. Three measurements were recorded in each quadrat.

3. **Plant cover and structural diversity:** The percent cover of vegetation in the canopy (greater than 5 m high), understory (0.5 to 5 m high), and groundcover (less than 0.5 m high) layers for each quadrat was visually estimated.
4. **Woody demography**: The dominant hardwood species with the highest percent cover was noted for each quadrat and its presence or absence in each of the size classes was recorded (seedlings, saplings, mature, snags). Seedlings were defined as hardwoods with a height of less than 30 cm and having sprouted within the last year, saplings were defined as hardwoods with a height greater than 30 cm but less than half of the potential mature height, mature individuals were defined as hardwoods approaching their maximum height and displaying full developed canopy, and snags were defined as dead trees with little to no leaves.
5. **Seedling recruitment/succession**: The hardwood species with the highest number of seedlings in each quadrat was recorded.
6. **Riparian Zone width**: At the center of each quadrat, a measuring tape was run perpendicular to the in-stream transect starting at the bankfull channel edge and ending at the edge of the riparian zone buffer. This distance was recorded in meters.
7. **Instream canopy cover** was estimated at the center point of the creek at 5, 50, 95 meters along the 100 m transect. This was done by holding a densiometer level, 12" – 18" in front of the body so the operators head was just outside of the grids. The number of quarter squares occupied by vegetation was counted at each location and recorded as percent cover. Instream canopy cover photographs were taken at each point with a Canon EOS 60D camera (18-135 mm lens). The camera lens was directed to the sky to capture a representation of the observed canopy. These photographs were used to verify the densitometer measurement.

Data Analysis

The Riparian Functional Assessment (RFA) score and parameter sub-indices scores were calculated following Richter and Duncan (2012). Student's t-tests and Wilcoxon sign rank tests were used to determine if there was a difference between scores calculated from degraded buffers sampled in 2012 and the scores calculated from the same degraded buffers in 2013. In addition, the Wilcoxon rank-sum test was used to determine if any significant difference existed between scores calculated from degraded sites added to the list of City of Austin Grow Zones in 2013 and the scores calculated from reference sites sampled in 2012.

Results and Discussion

The overall RFA score was not significantly different between 2012 and 2013 in the 16 sites that had been sampled in both years (t-test, $p = 0.6327$; sign rank, $p = 0.6286$) (Figure 1). The main management change in these sites was a cessation from mowing within a riparian buffer 5 to 10 meters from the edge of the creek. Although most sites are expected to respond to this change with an increase in herbaceous cover and seedling recruitment from opportunistic tree species, no significant functional changes were expected to be detectable from this assessment after only one growing season.

The RFA scores for the new Grow Zones sampled in only 2013 had significantly lower scores than the 2012 reference sites ($p<0.0001$) (Figure 1). In addition, the canopy cover, recruitment, riparian width, compaction, and structural diversity scores were significantly lower in the added degraded sites when compared to the reference sites ($p<0.05$). The soil moisture and hardwood demography scores were not significantly different between the two groups.

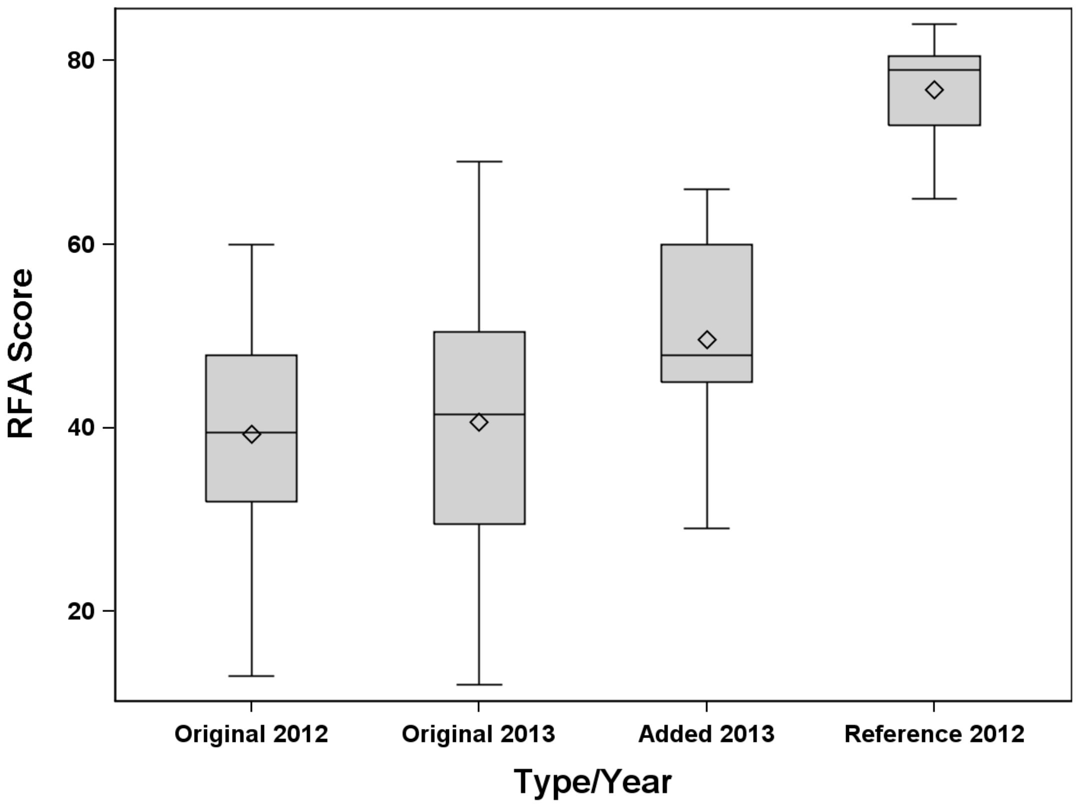

Figure 1: Riparian Functional Assessment score comparison for 16 Grow Zones sampled in 2012 and 2013, 9 Grow Zones added in 2013, and 12 reference sites sampled in 2012.

Two parameter scores were significantly different between the original degraded sites sampled in 2012 and the same sites sampled in 2013: instream canopy score and riparian width score (Figures 2 and 3, respectively). The instream canopy score was lower in 2013 than in 2012 Wilcoxon signed rank, p-value 0.0281). Although substantial changes in the canopy were not expected, the effects of the extreme drought conditions in 2011 may not have been evident in early 2012 but may have been captured in the 2013 data. Tree crowns receded substantially in some species like *Carya illinoinensis* (pecan) and *Salix nigra* (black willow), and high mortality was observed in other species like in *Ulmus crassifolia* (cedar elm) and *Celtis occidentalis* (common hackberry).

The riparian width was larger in 2013 than in 2012 for the 16 sites that were sampled in both years, shown by the significantly higher riparian width score for the 2013 sampling event (Wilcoxon signed rank, p-value < 0.0001). This change could be attributed to the successful implementation of the No-Mow policy within Grow Zones.

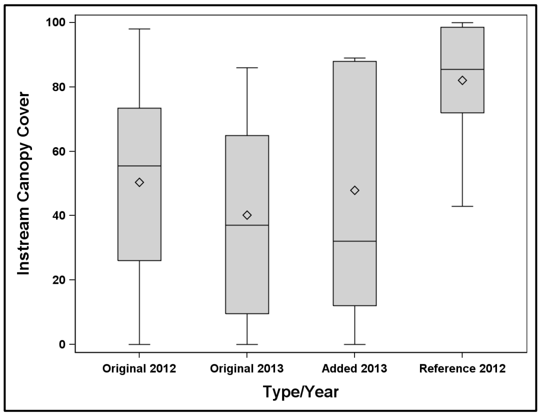

Figure 2: Instream Canopy Cover score comparison for 16 Grow Zones sampled in 2012 and 2013, 9 Grow Zones added in 2013, and 12 reference sites sampled in 2012.

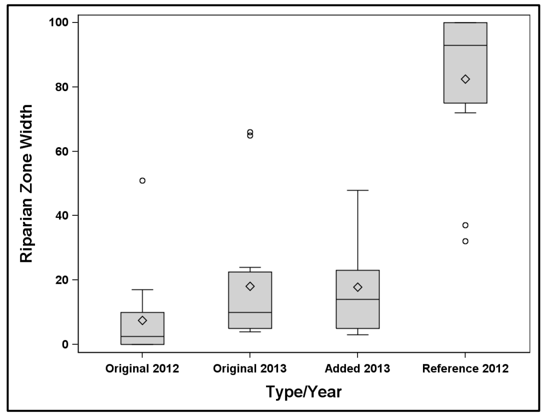

Figure 3: Riparian Width score comparison for 16 Grow Zones sampled in 2012 and 2013, 9 Grow Zones added in 2013, and 12 reference sites sampled in 2012

Soil moisture was not significantly different between years 2012 and 2013 for the 16 sites sampled in both years. Inherent variation in instantaneous soil moisture values is very high, affected by time of year and day as well as temporal distribution of rainfall events. Although data collection was scheduled during a similar time of year and similar time of day for each site, year to year variation can be difficult to address using only a single instantaneous data point throughout the year. This was the most cost effective method for obtaining information about the moisture in the soil with the added benefit of requiring little effort to collect; however, the natural variation in instantaneous soil moisture readings is likely to make detecting meaningful changes too difficult.

Soil compaction was not significantly different between years 2012 and 2013 for the 16 sites sampled in both years. This result was not surprising after only one growing season between data collection events. However, there were concerns noted in the field regarding the accuracy of the cone penetrometers used in the study. Two consecutive soil compaction measurements were taken with two different penetrometers and the results of the measurements were substantially different. It was determined that one of the penetrometers had seen extensive use in the field in the previous year and was no longer properly calibrated. Furthermore, the precision of the penetrometers was to the nearest hundred psi with a measurement maximum of 300 psi; this prevented detection or changes in compaction below this precision level.

Conclusions and Recommendations

Continuous soil moisture monitoring is cost prohibitive for this study. We recommend measuring total soil organic carbon from soil samples collected in each plot and each site as a surrogate to directly measuring soil moisture. The underlying assumption is that organic carbon retains water and thus organic carbon content and long-term soil moisture are positively correlated (Rawls et al. 2003).

We recommend upgrading the soil compaction instruments to penetrometers that can be calibrated and zeroed. Staff concluded that soil compaction measurements taken during 2013 were strongly affected by instrument error.

The number of Large Woody Debris (LWD) was dropped from the parameter list in the phase 1 of this study because there was a high number of reference sites with low LWD values even though reference sites were significantly different from degraded sites for this parameter. However, the functional contributions from LWD are well documented (Abbe and Montgomery 1996, Hyatt and Naiman 2001, Larson et al. 2001) and it is important to monitor progress in LWD presence in restoration sites. Given its importance and the fact that one potential source of variation in LWD, drainage area, is recommended to be explicitly incorporated in the sampling design in future iterations of this study, we recommend reinstating it as a parameter. This will allow examining if drainage area helps explain some of the variation in LWD in both reference and degraded sites.

The presence of hydrophytic vegetation was not included in the original list of functional parameters due to time and taxonomic constraints. Hydrophytic plants are indicators of high soil moisture and are sensitive to groundwater decline in semi-arid regions (Stromberg et al. 1996). We recommend including this functional parameter in the monitoring of riparian areas even though it will require additional time and training.

Although phase 2 of this project proposed to monitor only degraded sites, we recommend returning to the original sampling design of both reference and degraded sites. Reference sites represent functional riparian buffers that are used to evaluate restoration trajectory status at degraded sites. However, reference sites are not static; therefore, comparisons of degraded and reference sites during different years may be misleading and inclusion of reference sites may help control for factors related to annual climatic variation. In addition, since there have been changes recommended to the data collection methods, including parameters to be added, there is a need to obtain the reference values for these amended parameters.

Hardwood demography, which identifies whether or not the dominant hardwood species is present in all size classes (seedling, sapling, mature, snags), focuses only on one dominant species. There are limitations to this approach because it does not take into consideration multiple aspects that we have noted. Streams in early forest succession stages are likely dominated by light demanding species like *Salix nigra* (black willow)and *Populus deltoides* (eastern cottonwood). Once a full canopy of this species is developed, the seedlings and sapling of these same species are unlikely to survive and recruit into the next size class. However, seedlings and saplings of shade-tolerant species may be present and represent the potential canopy of the future forest. Therefore, a functional stream in which the mature trees are dominated by light-demanding species but with saplings and/or seedling dominated by different shade-tolerant species would be penalized as less functional. The current approach excludes even long-lived conifers, such as *Taxodium distichum* (bald cypress) from the parameter. In Austin streams, *T.*

distichum is an important riparian species that is present in mature riparian forests. Finally, the current method ignores species richness. Given these limitations, we recommend modifying the hardwood demography parameter by indicating the number of canopy species (woody species with mature trees height 40 ft or more) in three sizes classes: seedling, sapling, and mature. We recommend removing snags from this parameter given the difficulty of correctly identifying species in trees that have been dead for an extended period of time. However, snags provide important ecological services to riparian forests (Groffman et al 2003; Gurnell et al 2002) and represent a potential source of LWD for the stream and thus we recommend including the number of snags within the riparian buffer as a parameter in RFA.

While two parameters did show a change following one year of mowing cessation, it is thought to be unlikely that the majority of parameters, and thus the site, would show significant changes annually. Therefore, we recommend biennial data collection as follows:

- Twelve reference sites with sampling balanced across regulatory drainage area categories (0-64, 65- 320, 321-640, and 641-1280 acres) should be sampled annually for at least four more years. If data indicates that reference sites do not change substantially over one year to the next, sampling can be changed to a biannual schedule. Because drainage area affects hydrologic dynamics in streams, we recommend incorporating this explicitly in the study design with a balanced representation of sites across a range of drainage areas. The City of Austin has established drainage area categories that determine how individual stream segments are regulated, including the size of the protective buffers defined as the Critical Water Quality Zone (CWQZ) where development activities are restricted to protect the streams. One of the objectives of this study is to inform management practices and policy for riparian buffers. Utilizing regulatory drainage area categories provides a better link from the results of this study to policy and management recommendations.

- Half of the total number of degraded sites should be sampled on odd-numbered years with sampling balanced across regulatory drainage area, canopy cover (low, medium, high) and impervious cover (low, medium, high) levels.

- Half of the total number of degraded sites should be sampled on even-numbered years with sampling balanced across regulatory drainage area, canopy cover (low, medium, high) and impervious cover (low, medium, high) levels.

This recommended strategy maintains the ability to compare the degraded sites with reference sites within the same data collection period as well as gains the ability to maintain a relatively large sample size for degraded sites (n=24 in 2014). Although the goal of phase 2, as defined in the original City of Austin Quality Assurance Project Plan, was to track functional improvements of all riparian zone restoration degraded site locations over time, we recommend keeping a manageable but representative sample size and extrapolate results to make inferences about the non-sampled sites.

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Appendix 1: Degraded riparian zone restoration sites included in this study. Restoration Strategy is characterized as either passive or active. Active restoration refers to any active planting effort where plants/ seeds of woody vegetation was utilized within the monitoring transect. Passive sites have received no active planting but may have received grass seed and some weed management.

Site No.	Site Name	Drainage Area (Acres)	Watershed	Restoration Strategy	Banks Sampled
38	Waller Downstream of Cesar Chavez*	1280	WAL		L,R
116	Shoal Creek @ 24th street	1280	SHL	Passive	L,R
624	Waller upstream of 23rd street*	1280	WAL		L,R
3248	Lady Bird Lake VIP 35	1280	LBL		R
3255	Lady Bird Lake VIP 42	1280	LBL		R
4475	Waller Creek downstream 9th street*	1280	WAL		L,R
4835	Boggy @ Huisache Crossing	320	BOG	Active	L,R
5301	Tannehill @ Seabrook Spring	64	TAN	Active	L,R
5354	Boggy Creek @ Airport	128	BOG	Active	L,R
5556	East Bouldin @ Gabion in Gillis Park	320	EBO	Active	L,R
5580	Barton Creek Trib @ Lund and Robert EP. Lee	64	BAR	Active	L,R
5582	Blunn Creek @ Rosedale	640	BLU	Active	L,R
5584	Buttermilk Creek @ Buttermilk Park	320	BMK	Passive	L,R
5585	Boggy Creek @ 10th St	1280	BOG	Active	L,R
5586	Bull Creek 1600ft upstream Loop 360	1280	BUL	Passive	L,R
5589	Common Ford Trib ds xing in Common Ford Ranch	1280	CMF	Passive	L,R
5591	Johnson Creek in Tarrytown Park	320	TYN	Active	L,R
5592	Little Walnut Creek @ Dottie Jordan Park	1280	LWA	Active	L,R
5593	South Boggy @ Dittmar Park near Strickland	640	SBG	Active	L,R
5594	Shoal Creek @ Shady Oak Court	1280	SHL	Active	L,R
5595	Tannehill Creek @ Bartholomew Park near Berkman	640	TAN	Active	L,R
5596	Tannehill Creek upstream storm pipe in Givens Park	1280	TAN	Passive	L,R
5598	Taylor Slough South in Reed Park @ Footbridge	120	TYS	Active	L,R
5601	Walnut Trib @ North Star Greenbelt	64	WLN	Passive	L,R
5606	Williamson Creek in Battle Bend Park	64	WIL	Active	L,R
5809	Battle Bend Greenbelt	1280	WIL	Active	L
5810	Harper's Trib @ Heritage Oaks Park	64	HPP	Passive	L,R
5811	Shoal Trib @Crestmont Park	640	SHL	Passive	L,R

* These locations represent an upstream control, above the Waller Tunnel (#624) a location below the inlet structure but before the two side inlets (#1726) and below all effects of the tunnel before entering Ladybird Lake.

Appendix 2: City of Austin metrics for evaluating the functional condition of riparian zones.

Functional Metric	Rational
Soil Compaction	Soil compaction or bulk density is one of the most discerning variables separating forest cover from turf grass(Pouyat et al. 2007). Increasing soil compaction can reduce the soil's ability to function for structural support, water and solute movement, and restrict root growth(NRCS 2013). Compaction can result in shallow rooted plants and poor plant growth, reduced vegetative cover, increased erosion, and reduction in water infiltration(NRCS 2013). Improvements in soil compaction can be gained by reducing disturbance from vehicle and foot traffic and increasing soil organic matter content.
Soil Moisture	Soil moisture has been shown to be negatively correlated to urban land-use (Moffatt et al. 2004, Gift et al. 2010). Hydrologic changes associated with urbanization often result in lower water tables and drier more aerobic soil conditions (Gift et al. 2010). These changes can result in reduced denitrification and altered plant species composition (Gift et al. 2010, Sung et al. 2011). Increasing soil moisture can improve nutrient cycling and biomass production in riparian systems.
Plant cover and structural diversity	High cover and structural diversity of vegetation (groundcover, shrub, middle and upper canopy) indicates a productive plant community, high species diversity, adequate food resources and habitat for wildlife, and reduced flood impacts along banks (Stacey et al. 2006). Structural diversity is often absent in riparian areas that have been heavily damaged by human activities and can result in native wildlife species being extirpated from the area (Stacey et al. 2006). Patches of dense vegetation, both native and exotic, also play a key role in trapping sediment during periods of over-bank flow (Stacey et al. 2006).
Woody demography	Size and age class distribution of the dominant tree species indicates recruitment success and disturbance intervals. Missing age classes often result from disruptions to natural ecosystem processes and can induce successional changes and species loss (Stacey et al. 2006). Dominant species exert the most influence, and thus the greatest functional changes will occur if the abundance of these species is altered (Richardson et al. 2007).
Recruitment/ Succession	The understory (sapling) community reflects a habitat's current ecological condition; while overstory (tree) communities are reminders of past environmental condition (Woolsey et al. 2007). If the understory composition is different from the overstory, then a shift has occurred in the environmental conditions of a site either by anthropogenic or natural causes and may change the site's ecological function.
Riparian zone width	A wide riparian buffer has been shown to filter pollutants, control erosion, prevent flooding, and provide habitat and nutrient inputs into the (Barbour et al. 1999, Fischer and Fischenich 2000) Increased riparian zone width in restored systems has been shown to positively impact macroinvertebrate diversity in Austin streams (Chin et al. 2010). Riparian zone width is also the best predictor of nitrogen loading to water bodies when buffers are "relatively leaky" (Baker et al. 2007).
Instream Canopy Cover	Temperature heterogeneity within the stream channel is associated with increased aquatic species richness and ecosystem function (Woolsey et al. 2007). The amount of solar shading provided by adjacent and in stream riparian vegetation is critical for maintain temperature refugia. Decreased streambank vegetation cover, increased channel width, and reduced stream depth increases exposure, raises water temperatures and impacts aquatic life (Stacey et al. 2006).