Riparian reference condition: Using regional plant composition to guide functional improvements in the City of Austin

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Abstract

As a result of an expanding and rapidly urbanizing metropolitan area, the riparian vegetation communities of Austin-area streams continue to diverge further from their natural state. In an effort to maintain the ecological function and the natural character of Austin watersheds, the City of Austin Watershed Protection Department has identified a need to characterize an archetype, or background condition of Edwards Plateau and Blackland Prairie riparian communities for use as a template for both benchmarking and target for stream restoration projects. Species composition, spatial arrangement and physical attributes of vegetation communities for 12 sites located in both smaller and larger watersheds were characterized using multiple belt-transects. Multivariate analyses including detrended correspondence analysis (DCA), analysis of similarity (ANOSIM), and similarity percentage (SIMPER) were performed by Community Analysis Package software (Seaby and Henderson 2007). Results show that there was a significant difference in plant community composition in all compared drainage areas and ecoregions for both ground cover and overstory communities ($p<0.05$). The analysis of similarity showed that the samples should be grouped by ecoregion and location within the watershed for overstory and ground cover communities. Recommended vegetation templates are presented as a guide for comparison to other riparian communities in the Austin area, and also a reference point for restoration of degraded systems. These quantitative species distribution lists are an important resource for riparian ecologists in this region.

Introduction

Restoration of native riparian habitat is a commonly accepted method for improving the health and function of degraded stream systems. Often passive restoration, the reduction or elimination of activities causing the degradation or prevention of natural recovery, is all that is needed to restore function and improve water quality (Kauffman *et al.* 1997, Richardson *et al.* 2007). However, in highly urbanized systems where reducing the perturbation is not feasible, restoration efforts should be designed to match the scale of degradation while reducing the connectivity between impervious surfaces and the stream system (Walsh *et al.* 2005). Restoration efforts focused at the watershed or landscape scale have the greatest potential for success (Kauffman *et al.* 1997). Poor post-project evaluation, usually as a result of insufficient funding, is one of the greatest challenges to a successful riparian restoration effort (Follstad *et al.* 2007). Without being able to prove success, there is a great risk that public support for restoration projects will decline (Woolsey *et al.* 2007). Often, restoration success is evaluated by comparing a group of indicator values before and after project implementation (Woolsey *et al.* 2007). Establishing clearly defined project objectives and evaluation guidelines is necessary prior to restoration implementation (Woolsey *et al.* 2007). Currently there are no such guidelines for riparian restoration in the City of Austin for use in municipal capital projects and required private commercial/residential development mitigation. The differences in vegetation, geology, soils, flow, and historic land-use patterns between the two ecoregions of Austin (Blackland Prairie and Edwards Plateau) have resulted in the need for individualized riparian restoration templates. The focus of this study was to maximize efforts to control flooding, prevent erosion, improve water quality, and provide habitat for native species by defining what a model riparian zone consists. The model zones are used to generate guidance templates for restoration work done in Austin. While focusing largely on restoring stream function through the restoration of native plant species the COA will help define what a healthy riparian zone vegetation community should consist of in the two Austin ecoregions. Templates are also generated by drainage area location within watersheds (upper reaches and lower reaches, also called in this report respectively, headwaters and bottomlands). The aim is to determine vegetation differences between ecoregions and drainage area locations and to design specific guidelines from those analyses.

Methods

Riparian Vegetation List

The Edwards Plateau and the Blackland Prairies riparian vegetation lists developed for this project (Appendix I) combine information from a variety of published books, databases and local expertise (Corell 1979, Lynch 1981, Vines 1984,USDA 2011 and others) including the following information:

- Plant growth type: Trees, shrubs, vines, sedges and rushes, ferns, forbs, grasses
- Taxa information: common name, scientific name, genus, species
- Expected growth zone: zone 1, zone 2, zone 3 (Figure 1)
- Location: Edwards Plateau, Blackland Prairies, or Edwards Plateau and Blackland Prairies

For this study, stream banks have been classified in three hydric zones according to soil hydrology. Zone 1 is the saturated or wetland area, zone 2 is mesic area, with periodic inundation and zone 3 corresponds to upland or floodplain with infrequent inundation (Figure 1). This variation in moisture helps determine the type of vegetation community present. Between each zone, there is usually a change of slope, or transition, on each side of the bank (Figure 1).

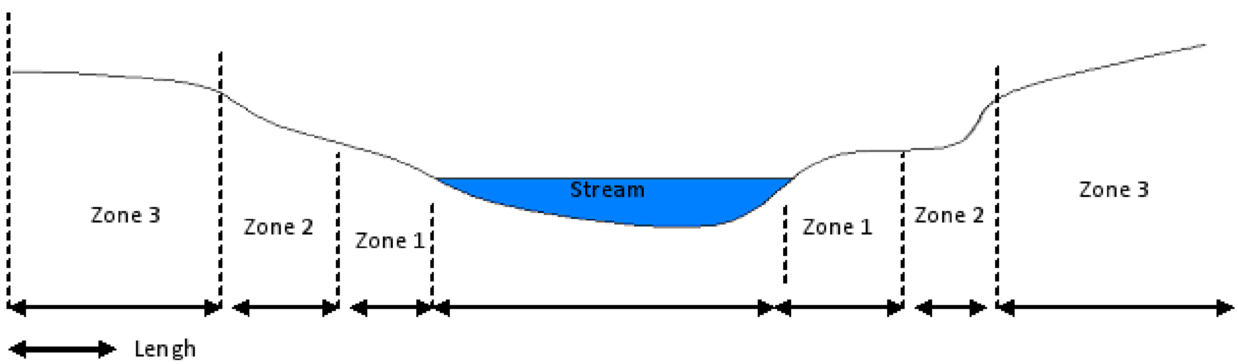

Figure 1: Cross-section stream view of hydric zones. Zone 1 is the saturated or wetland area, zone 2 is mesic, with periodic inundation and zone 3 corresponds to upland with infrequent inundation.

Reference sites

Sites were selected from previously defined reference areas with high Environmental Integrity Index (EII) scores or from aerial imagery and site visits denoting streams with significant riparian buffer widths. The EII score is a combination of a water quality, sediment, contact recreation, non-contact recreation, physical integrity, and aquatic life assessments. The basis of a healthy "riparian site" was the presence of established vegetation from the desired native riparian vegetation list (Appendix I). Three sites were chosen as replicates from four “treatments”: upper and lower watershed areas from the two ecoregions, comprising a total of twelve sample sites (Figure 2).

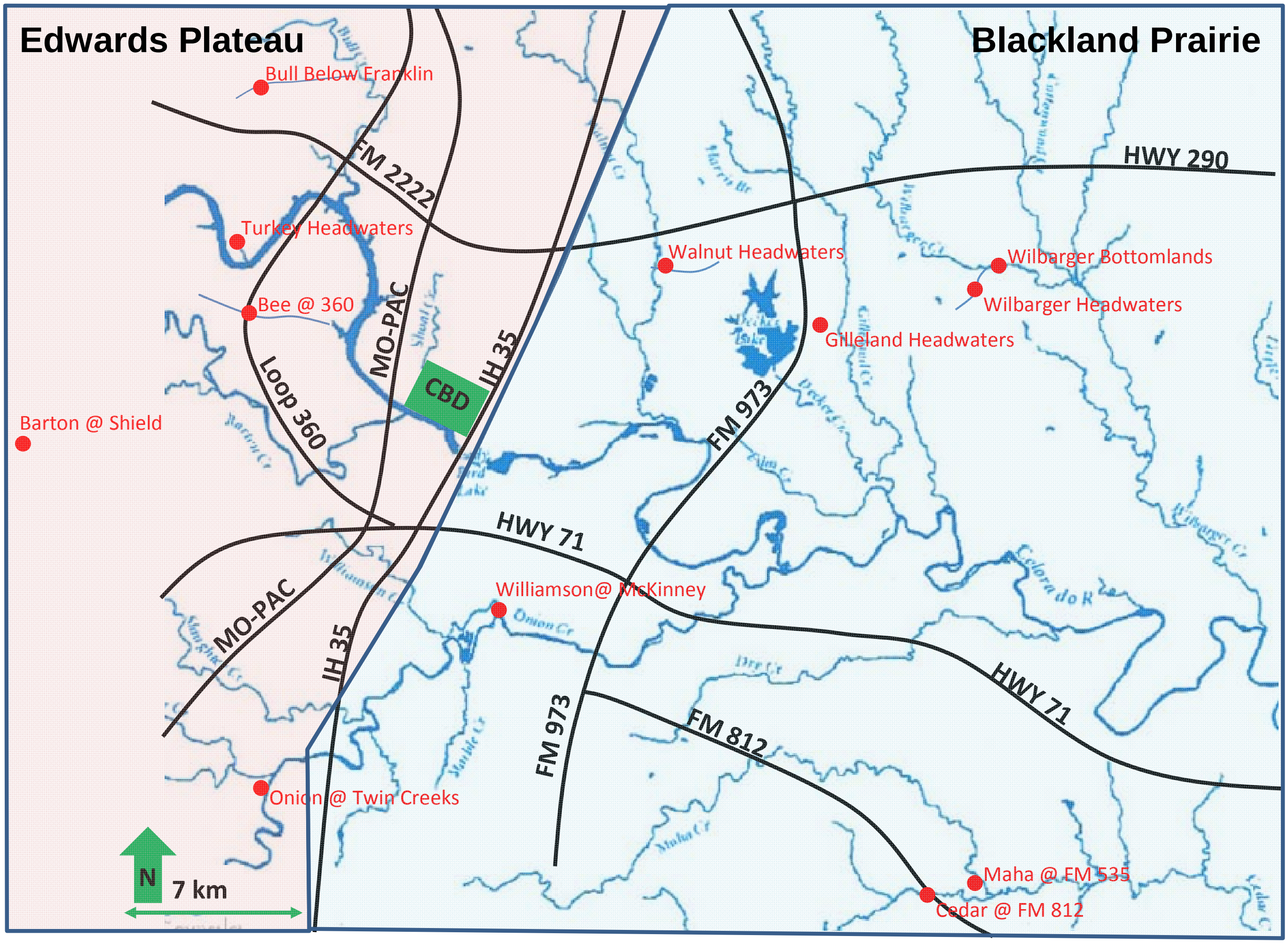

Figure 2: Reference sites for the ecoregions of Austin, the Edwards Plateau and Blackland Prairies

Vegetation transects

The vegetation sampling method employed was modified from the belt transect technique (Coles-Ritchie *et al.* 2004, Tazik *et al.* 1992). The transect method was designed to capture the change in vegetation communities of the riparian area from the lower banks to the floodplain. Each belt transect extended from the creek thalwag to the normal high-water mark (Zone 1), extended through the intermittently flooded bench (Zone 2) and terminated in the portion of the floodplain that was characterized by upland plant communities (Zone 3). At each site, three transects were established perpendicular to the stream on alternating stream banks from downstream to upstream. The margins of each 2-meter wide transect were established by the placement of a 2 meter long rope centered on the tape measure at 1 meter intervals. The identification and enumeration of plant communities was organized into three categories; ground cover, understory and canopy. Plants were recorded using a designated USDA four letter abbreviation of their Latin names. The abbreviation consisted of the first two letters of the genus name and the first two letters of the species name. A number was designated as a suffix in cases where similar Latin names presented redundancy of abbreviation nomenclature. For example: *Aster texanus* and *Ascelepias texanus* were designated ASTE and ASTE2 respectively (Appendix I). Groundcover plants (grass, forbs) were recorded by indicating the Latin name and the percent area covered within the 1m square quadrat. Understory plants (vines, shrubs) were recorded by indicating both the Latin name and the number of stems. Canopy plants (small and large trees) were recorded with greater detail by indicating both the Latin name, the maturity (mature or sapling) and the specific location of the trunk within the transect. Tree seedlings were counted as groundcover or understory, depending on their size. Data for all three categories were recorded on a single field sheet (Appendix II).

Cross sections

Cross sectional measurements were also used to determine the zones and associated slope breaks. These values are used to assess the morphological differences among and between eco-regions and catchment size (upper reaches vs. lower reaches). Bankfull width is proportional to catchment size and often indicates the 1-2 year flood frequency of a natural system. Width/depth ratio (w/d) is a relative index of channel shape and indicates the severity of stream incision and bank gradient. Channels with high w/d ratios tend to be shallow and wide while channels with low w/d ratios tend to be narrow and deep. In general, upper reach streams have lower w/d than lower reach streams. These values will be incorporated in templates for ideal channel shape for each eco-region and location within the catchment. Graphical representations of cross sections containing drainage area and w/d ratios are included in Appendix III.

Canopy cover

Canopy cover is the average density of the overstory measured at the thalweg, top of bank, and 5 meters from top of bank using a handheld densiometer (Lemmon 1956). A dense riparian canopy is important not only in moderating stream temperatures, but as an indicator of bank stability and sediment and organic matter input potential. A functioning mature riparian zone will have high canopy cover. Low canopy densities can indicate an unhealthy riparian zone or one that is in an earlier successional stage.

Data analysis methods

All collected data was entered into an Oracle database by sample site and quadrat. Ground cover species were entered as a percentage while shrubs/vines/trees were entered as stem counts. Quadrat size and hydric zone were also denoted in the database. Basic statistics were computed in SAS software, in order to find densities of shrubs, vines, and trees. The Community Analysis Package software was used to perform various multivariate analyses of the data including detrended correspondence analysis (DCA), analysis of similarity (ANOSIM), and similarity percentage (SIMPER). First, a detrended correspondence analysis was used to examine the difference in plant community structure between ecoregions, locations, and hydric zones. DCA is an exploratory test to analyze community structure where greater distance between the sample points in the ordination indicates larger plant community differences (Hill and Gauch 1980). Analysis was performed on the density of overstory species and percent cover of ground cover species separately in order to compensate for the scale used in the data collection. Rare species were not down weighted in the analysis. Sample points were then grouped by ecoregion and an analysis of similarity was performed to determine if there was a significant difference between the plant communities within each ecoregion. An ANOSIM tests whether the samples within a group are more similar in composition than samples in other groups (Clarke and Warwick 1994). The null hypothesis defined in an ANOSIM is that there is no difference between samples from various groups, thus a p-value less than $\alpha=0.05$ implicates that there is evidence that the samples within a group are more similar than would be possible by random chance. The sample statistic can range from -1 to 1 with -1 indicating that samples are outside the defined groups, 0 representing random patterns of similarity, and 1 representing tight clustering within each group. Samples were grouped *a priori* by ecoregion, location within the watershed (upper or lower), and hydric zone. Following the analysis of similarity, a similarity percentage (SIMPER) was computed on groups that were found to be significantly different from the ANOSIM. This procedure defines the contribution of each species to the similarity within groups and the dissimilarity between groups (Clarke 1993). Following these comparisons, representative species of each unit and rare species within each unit were chosen to be added to the template plant list by overstory (trees/shrubs/vines) and ground cover categories.

Results

Cross sections

Cross section data for each site (n=3) was averaged to make inferences about ecoregion differences and watershed drainage. As expected, bankfull widths for upper reach sites were considerably smaller when compared to lower reach sites (Table 1). Blackland Prairie sites were substantially dryer when compared to Edwards Plateau sites (Table 1). This difference in wetted width between ecoregions demonstrates the variability in groundwater influences among sites. Variations in width/ depth ratios (w/d) indicate different erosion patterns. As predicted, upper reach sites for the Edwards Plateau had a lower w/d indicating higher incision and steeper channels. W/d for Blackland Prairie lower reach sites were significantly lower than expected resulting in steeper channels and reduced hydric zone connectivity. The canopy cover was dense, greater than 84.3% cover for 9 of 12 sites, indicating a mature riparian overstory. The lower canopy cover at Barton at Shield and at Wilbarger upper reaches sites could be explained by the larger channel and reduced canopy at the thalweg. The low canopy cover results at Maha at 535 were due to the position of one transect in a large point bar on the bend of the creek that contained minimal overstory vegetation. Graphical representations of cross sections containing drainage area and w/d are included (Appendix III).

Table 1: Cross sectional data averaged from 3 transects for each site. EPH = Edwards Plateau Headwaters, EPB = Edwards Plateau Bottomlands, BPH = Blackland Prairie Headwaters, and BPB = Blackland Prairie Bottomland

Site	Name	Region	Catchment (acres)	Bank Full Width (ft)	Wetted Width (ft)	w/d (ft)	Canopy Cover (%)
349	Bull below Franklin	EPH	1,705	37.3	8.0	5.6	90.3
1104	Bee @ Loop 360	EPH	388	18.4	7.0	6.7	95.0
5294	Turkey Creek Upper reaches	EPH	1,216	44.8	10.0	7.9	94.2
236	Onion @ Twin Creeks	EPB	109,979	83.0	41.8	15.4	98.6
223	Williamson Cr. @ McKinney	EPB	18,426	79.3	31.6	14.6	92.8
46	Barton @ Shield	EPB	39,658	86.4	42.7	11.0	63.9
5298	Wilbarger Upper reaches	BPH	564	39.7	0.0	13.8	73.2
5296	Gilleland Upper reaches	BPH	493	27.3	0.0	8.7	96.1
5295	Walnut Upper reaches	BPH	104	28.6	0.0	6.5	97.8
5300	Cedar @ FM 812	BPB	22,946	50.0	8.6	3.9	85.6
5299	Maha @ 535	BPB	24,375	43.6	1.9	6.7	75.7
5297	Wilbarger Lower reaches	BPB	29,015	59.5	23.7	5.7	84.8

Region Comparison

Detrended correspondence analysis (DCA) found limited groupings in overstory/woody and groundcover vegetation between sampling regions (Figure 3). Edwards Plateau Headwaters was the only sampling region (Fig 3, light blue squares) to show distinct vegetation groupings for both strata. For the remaining sampling regions, overlap of the vegetation community can be explained by several ubiquitous generalist plant species. Woody species such as Hackberry, Roughleaf Dogwood, Fraxinus sp., Smilex sp., and Ilex sp. along with groundcover of Poison Ivy, Virginia creeper, Drummond's aster, Straggler daisy, Slender yellow woodsorrel, and Carex sp. were found in all sampling regions. Although essential for healthy central Texas riparian areas, these generalists plant species dilute the importance of region specific taxa that define the unique functional differences associated with hydrologic and geomorphic variation.

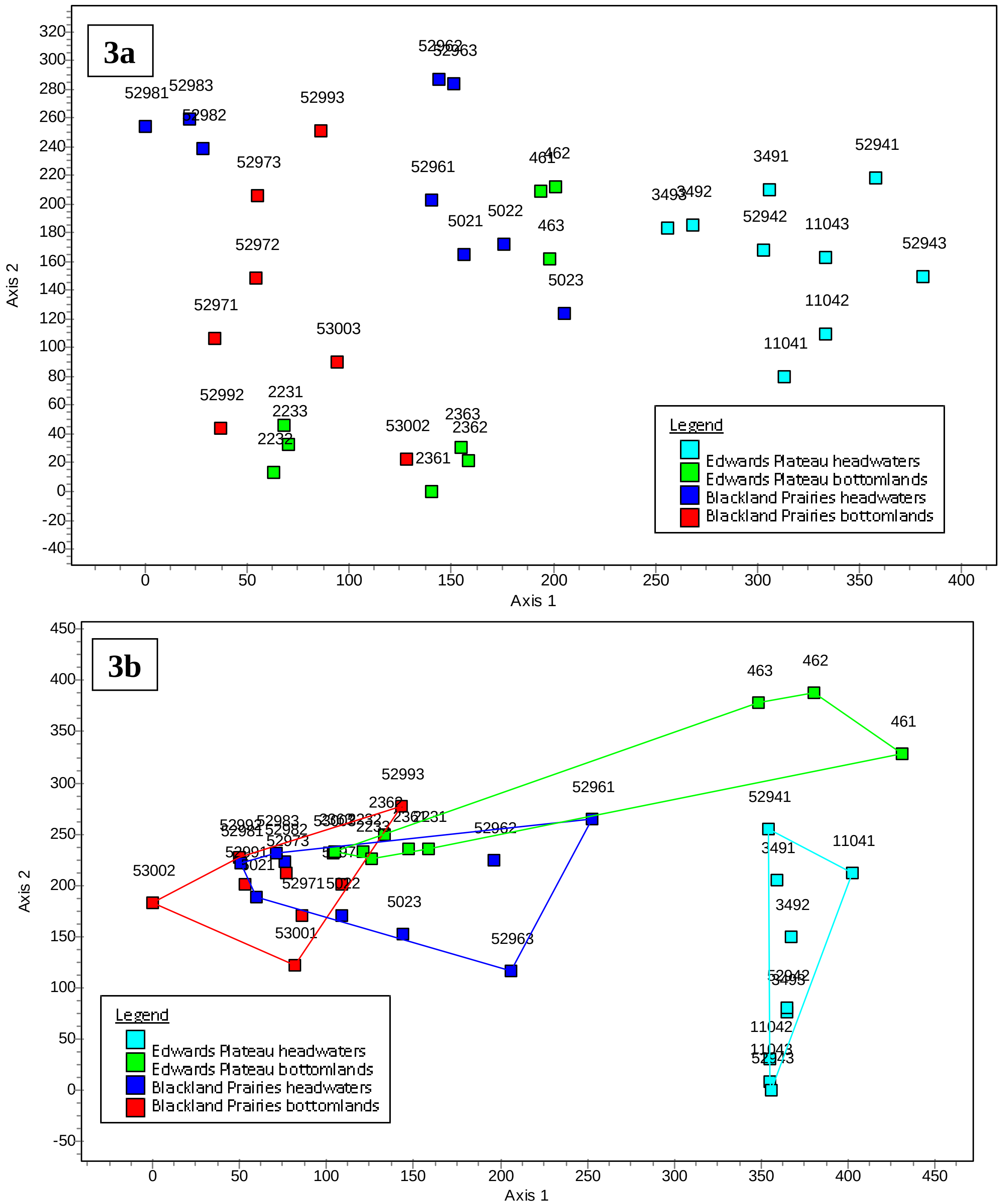

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Figure 3: Ordination of Detrended Correspondence Analysis (DCA) for overstory density (3a) and percent ground cover (3b) in Edwards Plateau upper reaches, Edwards Plateau lower reaches, Blackland Prairie upper reaches, and Blackland Prairie lower reaches. Each point represents each hydric zone of every sampling site (N=3). The numerical notation refers to the site number followed by the hydric zone.

Although results of the analysis of similarity show that there was a significant difference in plant community composition in all compared drainage area and ecoregions for both ground cover and overstory/woody communities ($p<0.05$) (Table 2 a-d), the groupings are weakly defined with patterns more closely distributed at random (sample statistic = 0.175-0.389). A sample statistic ranging closer to 0 indicates random distribution patterns, whereas 1 indicates tight clusters. However, smaller spatial resolution that combines region and drainage area reveals tighter clusters with distinct vegetation composition (Table 2 e-f). For example, Blackland Prairie Headwater (BPH) sites when compared to Edwards Plateau Headwaters (EPH) (a total of 9 samples each, 3 transects x 3 sites) display almost no statistical similarity in their vegetation composition for the groundcover layer (sample statistic = 0.943). Understanding the unique vegetation associated with our sampling regions (Edwards Plateau upper reaches, Edwards Plateau lower reaches, Blackland Prairie upper reaches, and Blackland Prairie lower reaches) will help managers design restoration plans that maximize ecosystem function. Additionally, the ANOSIM results also showed that samples could not be significantly grouped by hydric zone for ground cover or overstory communities ($p>0.05$).

Tables 2a – 2f: Analysis of Similarity: Edwards Plateau vs. Blackland Prairies - Groundcover (2.a), Edwards Plateau vs. Blackland Prairies - Overstory (2.b), Upper reaches vs. Lower reaches - Groundcover (2.c), Upper reaches vs. Lower reaches - Overstory (2.d), and Edwards Plateau upper reaches, Edwards Plateau lower reaches, Blackland Prairie upper reaches, and Blackland Prairie lower reaches comparison for groundcover (2.e) and overstory (2.f).

2.a Edwards Plateau vs. Blackland Prairies - Groundcover

ANOSIM	
Sample Statistic	0.389
P Value	0.001

Pairwise Tests		
1st Group	2nd Group	P Value
BP (18)	EP (18)	0.001

2.b Edwards Plateau vs. Blackland Prairies - Overstory

ANOSIM	
Sample Statistic	0.249
P Value	0.001

Pairwise Tests		
1st Group	2nd Group	P Value
BP (18)	EP (18)	0.001

2.c Upper reaches vs. Lower reaches - Groundcover

ANOSIM	
Sample Statistic	0.175
P Value	0.006

Pairwise Tests		
1st Group	2nd Group	P Value
Bott (18)	Head (18)	0.006

2.d Upper reaches vs. Lower reaches - Overstory

ANOSIM	
Sample Statistic	0.254
P Value	0.001

Pairwise Tests		
1st Group	2nd Group	P Value
Bott (18)	Head (18)	0.001

2.e Region comparison - Groundcover

ANOSIM	
Sample Statistic	0.526
P Value	0.001

2.f Region comparison- Overstory

ANOSIM	
Sample Statistic	0.451
P Value	0.001

Tables 2a – 2f (continued)

2.e Region comparison - Groundcover

Pairwise Tests

1st Group	2nd Group	P Value	Sample Statistic
BPB (9)	BPH (9)	0.003	0.310
BPB (9)	EPB (9)	0.008	0.193
BPB (9)	EPH (9)	0.001	0.844
BPH (9)	EPB (9)	0.001	0.446
BPH (9)	EPH (9)	0.001	0.943
EPB (9)	EPH (9)	0.001	0.558

2.f Region comparison- Overstory

Pairwise Tests

1st Group	2nd Group	P Value	Sample Statistic
BPB (7)	BPH (9)	0.003	0.376
BPB (7)	EPB (9)	0.084	0.141
BPB (7)	EPH (9)	0.001	0.729
BPH (9)	EPB (9)	0.001	0.355
BPH (9)	EPH (9)	0.001	0.609
EPB(9)	EPH (9)	0.003	0.471

Templates

The analysis of similarity showed that the samples should be grouped by ecoregion and location within the watershed (Edwards Plateau upper reaches, Edwards Plateau lower reaches, etc.) for overstory and ground cover communities. A similarity percentage (SIMPER) was performed with the samples grouped in this manner in order to determine which plants characterized each grouping. Plant species that the SIMPER analysis defined as similar within each grouping or unit were used to characterize each region. In addition to the similar species within a region, plant species that were found at all sites or exclusively in an ecoregion or drainage area were added to the plant template (Table 3). Species that define an ecoregion are characterized as being both abundant and widespread in their associated sampling region (Table 3).

Table 3: Template of overstory (3a) and groundcover (3b) vegetation for City of Austin riparian evaluation. Nomenclature of + indicates species presence and x indicates species that define the region (both abundant and widespread in the associated sampling region).

Overstory (3a)

Common Names	Scientific Name	EPH	EPB	BPH	BPB
Box Elder	ACER NEGUNDO		x		
Peppervine	AMPELOPSIS ARBOREA		x		+
Trumpet Vine	CAMPSIS RADICANS	x			
Hackberry	CELTIS SPP.	+	+	+	+
Roughleaf Dogwood	CORNUS DRUMMONDII	+	+	+	+
Texas Persimmon	DIOSPYROS TEXANA	x		+	+
Elbow Bush	FORESTIERA PUBESCENS	+	+	x	+
Ash	FRAXINUS SPP.	+	+	+	+
Silktassel	GARRYA LINDHEIMERI	x			
Possumhaw	ILEX DECIDUA	+	+	x	x
Yaupon Holly	ILEX VOMITORIA	x	x	+	
Ashe juniper	JUNIPERUS ASHEI	x	+		
Virginia creeper	PARTHENOCISSUS QUINQUEFOLIA	+	+	+	+
	RUBUS SPP.	+	+	+	+
Soapberry	SAPINDUS SAPONARIA VAR. DRUMMONDII			x	x
	SMILAX SPP.	+	+	+	+
Coralberry	SYMPHORICARPOS ORBICULATUS			x	x
Poison ivy	TOXICODENDRON RADICANS	+	x	+	x
Ceder elm	ULMUS CRASSIFOLIA	+	+	x	x
Sweet mountain grape	VITIS MONTICOLA	+	+	+	+
Mustang Grape	VITIS MUSTANGENSIS	+	+	+	+

Table 3 (continued)

Groundcover (3b)					
Common Names	**Scientific Name**	**EPH**	**EPB**	**BPH**	**BPB**
Maidenhair fern	ADIANTUM CAPILLUS-VENERIS	x	x		
Annual ragweed	AMBROSIA ARTEMISIIFOLIA		+	x	x
Drummond's aster	ASTER TEXANUS	+	+	+	+
Straggler daisy	CALYPTOCARPUS VIALIS	+	+	+	+
Sedges	CAREX SPP.	+	+	+	+
Hackberry	CELTIS SPP.	+	+	+	+
Ash	FRAXINUS SPP.	+	+	+	+
Poaaumhaw	ILEX VOMITORIA	x			
Ashe juniper	JUNIPERUS ASHEI	x	+		
Yellow wood sorrel	OXALIS DILLENII	+	+	+	+
Virgina creeper	PARTHENOCISSUS QUINQUEFOLIA	+	+	+	+
Texas red oak	QUERCUS TEXANA	x			
	RUBUS SPP.	+	+	+	+
Ceder Sage	SALVIA ROEMERIANA	x	+		
Johnsongrass	SORGHUM HALEPENSE			+	+
spreading hedgeparsley	TORILIS ARVENSIS		x	+	x
Ceder elm	ULMUS CRASSIFOLIA	+	+	+	+
White crownbeard	VERBESINA VIRGINICA	+	+	+	+

Discussion

Cross sections

Streams and rivers exhibit a decreasing downstream gradient from headwaters to the mouth. Slopes are characterized as steep in the headwaters and more gradual towards the mouth resulting in a concave longitudinal profile (Allen 1995). The width to depth ratio (w/d) we documented followed an inverse trend in the Blackland Prairie sites: becoming more incised further downstream. This increased channel incision could be largely explained by historic land use activities. Unlike the Edwards Plateau region, the Blackland Prairie has a long history of agricultural degradation. The Blackland Prairie has rich deep, alluvial clay soils, and is much flatter in gradient, resulting in a history of intensive agricultural use and minimal protection of the riparian buffer zone (Harmel *et al.* 2006). High agricultural use has been associated with increased surface runoff and channel erosion. Watersheds in northeastern Puerto Rico, where land use patterns have shifted from forest to agriculture, have experienced an approximate 50 % increase in surface runoff (Clark and Wilcock 2000). Changes to width and depth of a stream system can often result from a shift in discharge or flowrates (Clark and Wilcock 2000). Agricultural degradation within the Blackland Prairie region has limited the amount of pristine riparian habitat with the bulk of extant vegetation consisting of secondary growth communities. In addition, Blackland Prairie streams tended to be drier with smaller wetted widths, and in many cases, dry streambeds, compared to the Edwards Plateau streams. This could have been simply a result of the streams chosen, but is also due to the long-term degradation of the Blackland Prairie region by agriculture and the lack of deep aquifer groundwater that feeds many of the Edwards Plateau streams. Understanding historical land use and local climate variability is vital for restoration planning.

Region Comparison

In general, our analysis showed significant vegetation groupings by region. Relatively small changes in geographic location and drainage area resulted in distinct shifts in plant species composition. Understanding these trends as well as which species define a specific region can help managers identify when a restored site has improved functional characteristics or when a degraded site requires some level of restoration. Typically, changes in riparian function occur with shifts in vegetation composition (Richardson *et al.* 2007). For example, a riparian restoration project on a headwaters stream in the Edwards Plateau region could be deemed to have improved ecosystem function when species such as Trumpet vine, Silktassel, Yaupon holey, Maidenhair fern, etc, (Table 3) have successfully established (reproduced with multiple age classes). When a site can successfully support these defining plant species restoration practitioners can assume some level of hydrological and geomorphologic functional improvement (Richardson *et al.* 2007). Conversely, sites where these defining species are absent could be an indication of disturbance indicating restoration may be appropriate. Often a passive approach, which removes anthropogenic site disturbance, is sufficient to improve function and facilitate establishment of defining plant species (Kauffman *et al.* 1997, Richardson *et al.* 2007). Additional research and monitoring of pilot projects is needed to evaluate the potential of passive restoration techniques for restoring ecosystem function in the highly degraded urban riparian environments of Austin.

Although plants in riparian areas are generally grouped by moisture, slope, soil chemistry and topography (Clinton *et al*. 2010), our study found no significant effect within the three hydric zones sampled. This could be due to the drought-conditions in which the survey was conducted, or the method we used to identify the three zones. More work needs to be done with this component of the study to further test the hydric zone hypothesis, preferably with seasonal/climate variation.

Templates

The Riparian Template: Streamside Planting Guide (Appendix 1) encompasses both the common and defining riparian vegetation encountered in this study as well as information from published plant books and local knowledge to create a list characterizing basic structure of riparian areas in the Austin area. This guide provides information for landowners and developers as well as City of Austin capital project managers interested in improving the integrity of the riparian zone. Recommendations for native grasses, forbs, shrubs and trees as well as appropriate region and hydric zone for planting are provided in Appendix 1. The results of the analysis in this paper detail further information on specific plant communities that can help to define the unique regional differences of Austin (Table 3). This information gives resource managers insight on when site disturbance has altered ecosystem function and provides indicators for when those functions may have been restored. These templates are the most robust product generated by this study, as they provide a guide for comparison to other riparian communities in the Austin area, and also a reference point for restoration of degraded systems. By providing quantitative species lists for these reference sites, and density/cover values, the templates provide an objective and well documented resource for riparian ecologists in this region.

Recommendations

Due to the expense and historical record of failure of active or manipulated stream and riparian restoration efforts, additional research is needed on the functional improvements associated with passive riparian restoration. Understating the likely successional trajectory in urban riparian areas following disturbance removal is necessary prior to designing future restoration projects that maximize functional improvements at the lowest effective cost. Obtaining monitoring data on both passive and active restoration projects in the Austin area should be a priority for determining the best option for each specific site.

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Notes:

RIPARIAN TEMPLATE

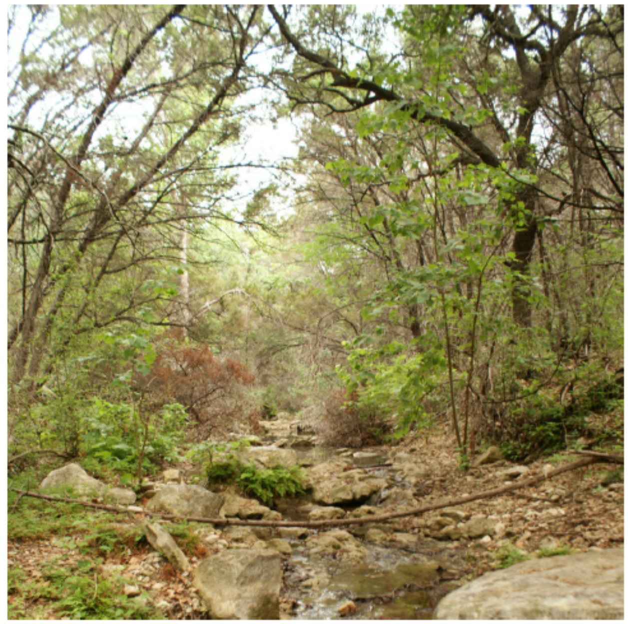
STREAMSIDE PLANTING GUIDE

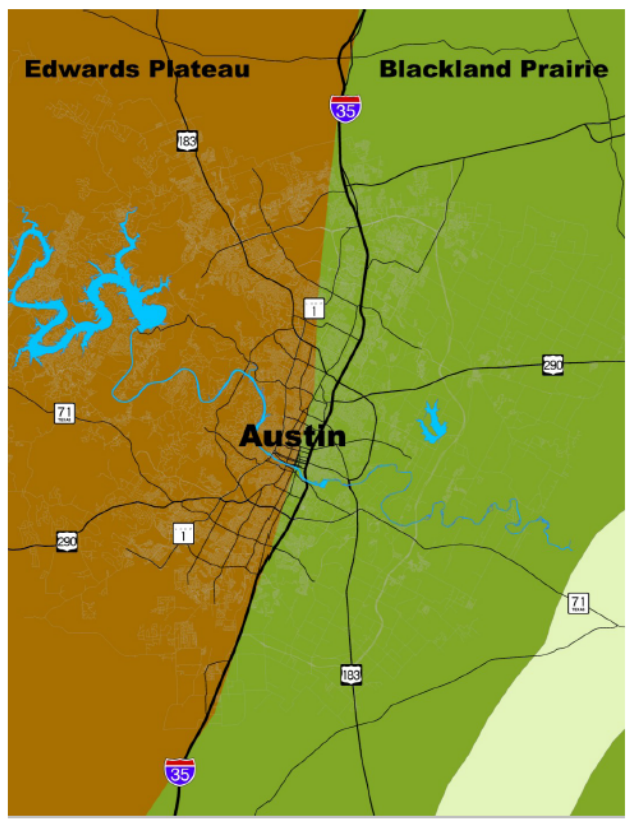
The land alongside a stream, the riparian zone, plays a critical role in maintaining the integrity of the stream. Mature plants in the riparian zone help maintain water quality in the stream. They also function structurally to prevent erosion and flooding downstream.

This template provides guidance for landowners and developers interested in improving the integrity of the riparian corridor of their waterways. Recommendations for native grasses, forbs, shrubs and trees are provided for large and small drainage areas in both Edwards Plateau and Blackland Prairie riparian zones.

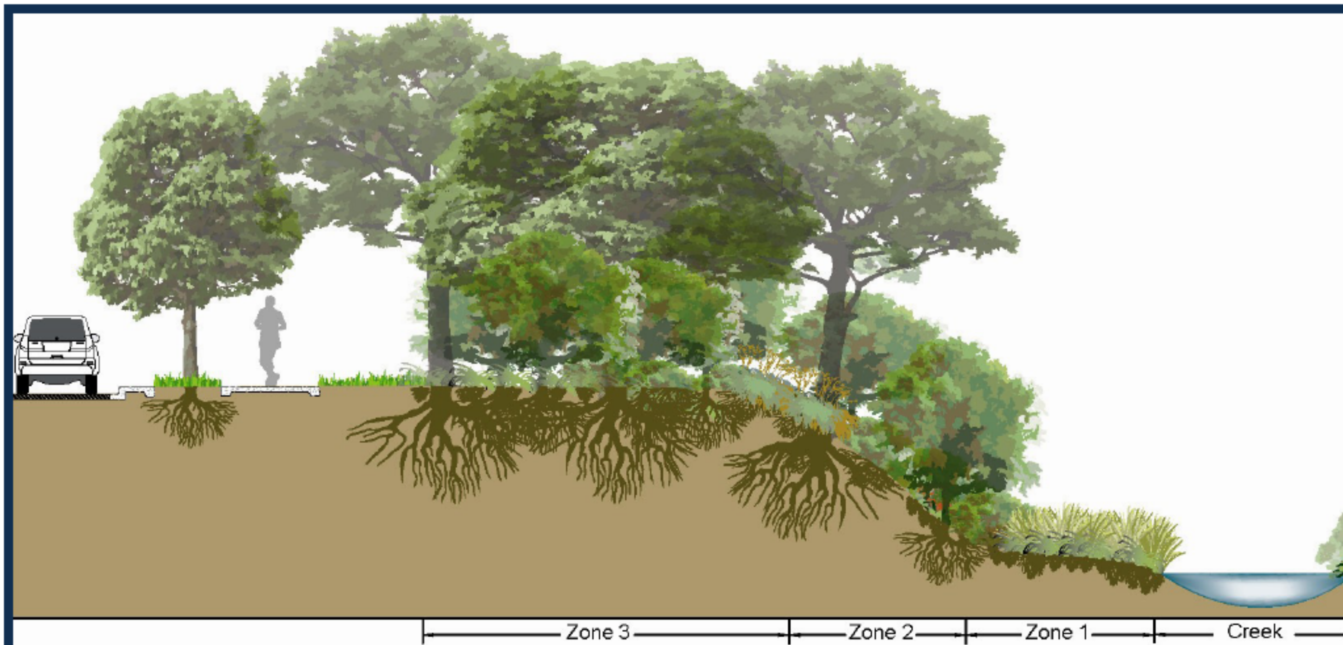
Although native plants are adapted to the extreme conditions of our local weather patterns, it is important to have an irrigation system in place for the first two years to help establish new plants. Placing 3"- 4" of mulch around the plants will keep soil moist and reduce weeds.

All of the plants listed here are found in the riparian areas of Austin's streams. When replanting a degraded riparian zone it is wise to increase plant density of the woody plants as well as the grasses and wildflowers. Maintaining a diverse vegetative community, comprised of plants in all tiers and zones will help combat aggressive and non-native plants.





WATERSHED PROTECTION



Mature Riparian Structure: Unique hydrologic conditions make different zones of the streamside suitable for distinct plant types. The soil in Zone 1 is always wet and frequently underwater. Zone 2 is underwater during most storm events but dries out afterwards. Zone 3 is a transitional area receiving its moisture from rainfall and large storm events.

Groundcover **Understory** **Upper Canopy**

Tiered Vegetation Scenarios: Wildflowers, grasses and other groundcover plants grow densely without canopy cover from trees and shrubs. In the presence of understory trees and shrubs, groundcover often thins out. When all three tiers of vegetation exist, grasses and forbs cover a very small percentage of area. It is recommended that trees, shrubs and groundcover be planted at increased densities to better facilitate success of the desired plant communities.

Additional Resources:

CoA Riparian Website http://www.cityofaustin.org/watershed/creekside.htm

Lady Bird Johnson Wildflower Center http://www.wildflower.org/plants/

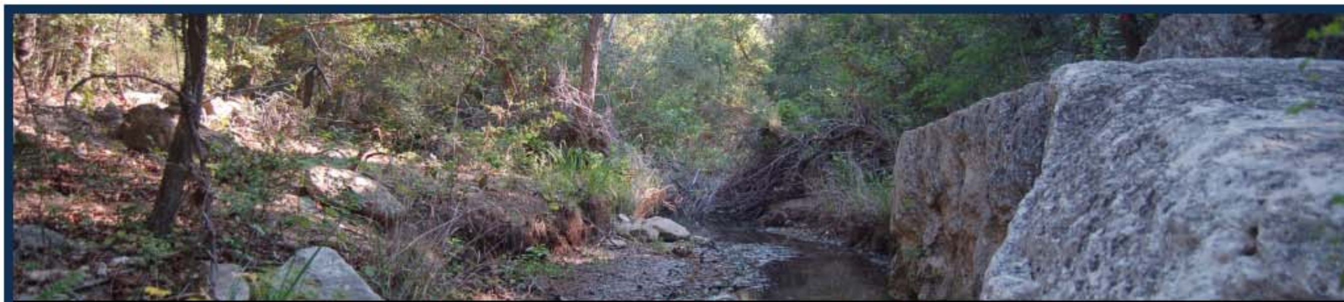
Texas Riparian Association http://www.texasriparian.org/

CoA Tree Encyclopedia http://www.ci.austin.tx.us/trees/en_spec.htm

National Plant Society of Texas http://npsot.org/wp/austin/

Improving Urban Streams http://www.msdlouky.org/insidemsd/wqstreams.htm

Tree Folks http://treefolks.org/



Edwards Plateau Small Drainage (<1800 acres)

	Growth	Common names	Scientific Name	Zones
Groundcover	Forb	Brown-eyed Susan	*Rudbeckia triloba*	2,3
	Forb	Cedar sage	*Salvia roemeriana*	2,3
	Forb	Frost weed	*Verbesina virginica*	1,2,3
	Forb	Plateau goldeneye	*Viguiera dentata*	2,3
	Grass	Arapaho muhly	*Muhlenbergia utilis*	1,2
	Grass	Cedar sedge	*Carex planostachys*	2,3
	Grass	Inland sea oats	*Hasmanthium latifolium*	1,2,3
	Grass	Lindheimer muhly	*Muhlenbergia lindheimeri*	2,3
	Grass	Little bluestem	*Schizachyrium scoparium*	2,3
	Grass	Scribner's panic grass	*Dichanthelium oligosanthes var. scribnerianum*	1,2,3
	Grass	Seep muhly	*Muhlenbergia reverchonii*	1,2
	Grass	Switchgrass	*Panicum virgatum*	1,2
Understory	Shrub	Agarita	*Mahonia trifoliolata*	3
	Shrub	Button bush	*Cephalanthus occidentalis*	1,2
	Shrub	Elbow bush	*Forestiera pubescens*	3
	Shrub	Silk tassel	*Garrya lindheimeri*	2,3
	Shrub	Turks Cap	*Malvaviscus drummondii*	2,3
	Tree/Shrub	Ashe juniper	*Juniperus ashei*	2,3
	Tree/Shrub	Escarpment black cherry	*Prunus serotina var. eximia*	2,3
	Tree/Shrub	Gum bumelia (Chittamwood)	*Bumelia lanuginosa*	2,3
	Tree/Shrub	Possum-haw (Deciduous holly)	*Ilex decidua*	1,2,3
	Tree/Shrub	Red Buckeye	*Aesculus pavia*	2
	Tree/Shrub	Texas persimmon	*Diospyros texana*	2,3
	Tree/Shrub	Yaupon	*Ilex vomitoria*	2,3
	Vine	Mustang grape	*Vitis mustangensis*	2,3
	Vine	Peppervine	*Ampelopsis arborea*	1,2,3
	Vine	Rattan Vine	*Berchemia scandens*	2
	Vine	Sweet mountain grape	*Vitis monticola*	2,3
	Vine	Virginia creeper	*Parthenocissus quinquefolia*	1,2
Overstory	Tree	Box elder	*Acer negundo*	1,2
	Tree	Cedar elm	*Ulmus crassifolia*	2,3
	Tree	Hackberry	*Celtis sp.*	2,3
	Tree	Texas ash	*Fraxinus texensis*	1,2,3
	Tree	Texas red oak	*Quercus buckleyi*	1,2,3

Notes:

These streams tend to have a rocky/bedrock substrate. The flow is intermittent, commonly occurring for only a short while after rain. A more comprehensive plant list can be found on the City of Austin's Riparian website.

Edwards Plateau Large Drainage (>1800 acres)

	Growth	Common names	Scientific Name	Zones
Groundcover	Forb	Frost weed	*Verbesina virginica*	3
	Forb	Maximillian sunflower	*Helianthus maximiliani*	2,3
	Forb	Rain lily	*Cooperia drummondii*	1,2
	Forb	Straggler daisy	*Calyptocarpus vialis*	1,2,3
	Grass	Curly mesquite	*Hilaria belangeri*	3
	Grass	Eastern gamagrass	*Tripsacum dactyloides*	2,3
	Grass	Inland saltgrass	*Distichlis spicata car. Stricta*	1,2,3
	Grass	Inland sea oats	*Chasmanthium latifolium*	1,2,3
	Grass	Lindheimer muhly	*Muhlenbergia lindheimeri*	2,3
	Grass	Little bluestem	*Schizachyrium scoparium*	2,3
	Grass	Sideoats grama	*Bouteloua curtipendula*	1,2,3
	Grass	Switchgrass	*Panicum virgatum*	1,2
	Grass	Virginia wildrye	*Elymus virginicus*	1,2,3
Understory	Shrub	Cat's-claw mimosa	*Mimosa biuncifera*	3
	Tree/Shrub	Ashe juniper	*Juniperus ashei*	3
	Tree/Shrub	Texas persimmon	*Diospyros texana*	3
	Tree/Shrub	Yaupon	*Ilex vomitoria*	1,2,3
	Vine	Dewberry	*Rubus sp.*	1,2,3
	Vine	Mustang grape	*Vitis mustangensis*	2,3
	Vine	Peppervine	*Ampelopsis arborea*	1,2,3
	Vine	Rattan vine	*Berchemia scandens*	1
	Vine	Virginia creeper	*Parthenocissus quinquefolia*	1,2,3
Overstory	Tree	American elm	*Ulmus americana*	2,3
	Tree	Boxelder maple	*Acer negundo*	1,2,3
	Tree	Cedar elm	*Ulmus crassifolia*	2,3
	Tree	Hackberry	*Celtis sp.*	1,2,3
	Tree	Roughleaf dogwood	*Cornus drummondii*	1,2,3
	Tree	Texas ash	*Fraxinus texensis*	2,3
	Tree	Texas red oak	*Quercus buckleyi*	3

Notes:

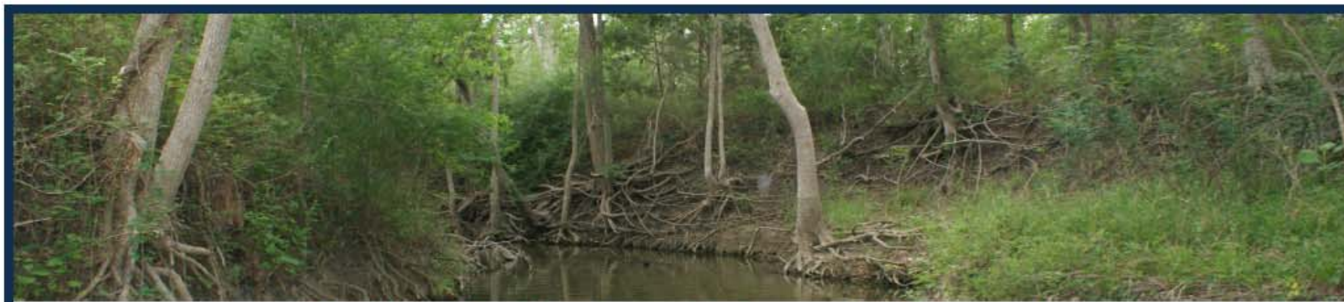
These streams tend to have a rocky/bedrock substrate. Large pools remain as aquatic habitat throughout the year. A more comprehensive plant list can be found on the City of Austin's Riparian website.

Blackland Prairies Small Drainage (<1800 acres)

	Growth	Common names	Scientific Name	Zones
Groundcover	Forb	Brown-eyed Susan	*Rudbeckia triloba*	1,2,3
	Forb	Gayfeather	*Liatris mucronata*	2,3
	Forb	Illinois bundleflower	*Desmanthus illinoensis*	2
	Forb	Maximillian sunflower	*Helianthus maximiliani*	1,2
	Forb	Texas aster	*Aster texanus*	2,3
	Grass	Big bluestem	*Andropogon gerardii*	3
	Grass	Blue grama	*Bouteloua gracilis*	3
	Grass	Estern Gamagrass	*Tripsacum dactyloides*	1,2
	Grass	Ryegrass	*Lolium perenne*	1,2,3
	Grass	Sideoats grama	*Bouteloua curtipendula*	1,2
	Grass	Switchgrass	*Panicum virgatum*	2,3
	Grass	Virginia wildrye	*Elymus virginicus*	1,2,3
	Grass	Yellow indiangrass	*Solrgum nutans*	3
Understory	Shrub	Cat's-claw mimosa	*Mimosa biuncifera*	3
	Shrub	Coralberry	*Symphoricarpos orbiculatus*	1,2,3
	Shrub	Elbowbush	*Forestiera pubescens*	1,2,3
	Shrub	Turk's Cap	*Malvaviscus drummondii*	3
	Tree/Shrub	Western soapberry	*Sapindus saponaria var. drummondii*	2,3
	Vine	Ivy treebine, Cow-itch	*Cissus incisa*	1,2,3
	Vine	Purple Bindweed	*Iponea triclocarpe*	2,3
	Vine	Virginia creeper	*Parthenocissus quinquefolia*	1,2,3
Overstory	Tree	Cedar elm	*Ulmus crassifolia*	1,2,3
	Tree	Green ash	*Fraxinus pennsylvanica*	1,2,3
	Tree	Hackberry	*Celtis spp.*	1,2,3
	Tree	Live oak	*Quercus fusiformis*	1,2,3

Notes:

These streams tend to have a silty or muddy substrate. The flow is intermittent to perennial, with small pools lasting through most of the year. A more comprehensive plant list can be found on the City of Austin's Riparian website.



Blackland Prairies Large Drainage (>1800 acres)

	Growth	Common names	Scientific Name	Zones
Groundcover	Forb	Frog fruit	*Phyla incisa*	2
	Forb	Frostweed	*Verbesina virginica*	2
	Forb	Late goldenrod	*Solidago altissima*	2
	Forb	Smartweed	*Polygonum sp.*	1,2
	Forb	Southern Dewberry	*Rubus trivialis*	2,3
	Forb	Swamp smartweed	*Polygonum hydropiperoides*	1
	Forb	Yerba de tago (False daisy)	*Eclipta alba*	1
	Grass	Bead grass	*Paspalum sp.*	1,2,3
	Grass	Big muhly	*Muhlenbergia lindheimeri*	2,3
	Grass	Devil's shoestring	*Nolina lindheimeriana*	3
	Grass	Dichanthelium	*Dichanthelium sp.*	1,2,3
	Grass	Emory's sedge	*Carex emoryi*	1,2
	Grass	Flatsedge	*Cyperus sp.*	2,3
	Grass	Inland sea oats	*Chasmanthium latifolium*	1,2,3
	Grass	Virginia wildrye	*Elymus virginicus*	1,2,3
	Grass	Walter's millet	*Echinochloa walteri*	1,2,3
Understory	Shrub	American beautyberry	*Callicarpa americana*	2
	Shrub	Coralberry	*Symphoricarpos orbiculatus*	1,2,3
	Shrub	Deciduous holly	*Ilex decidua*	1,2,3
	Shrub	Elbowbush	*Forestiera pubescens*	1,2,3
	Shrub	Pigeon Berry	*Rivina humilis*	2,3
	Shrub	Turk's Cap	*Malvaviscus drummondii*	2,3
	Tree/Shrub	Roughleaf dogwood	*Cornus drummondii*	2,3
	Tree/Shrub	Western soapberry	*Sapindus saponaria var. Drummondii*	1,2,3
	Vine	Virginia creeper	*Parthenocissus quinquefolia*	2,3
Overstory	Tree	Black Walnut	*Juglans nigra*	3
	Tree	Bois d' Arc	*Maclura pomifera*	3
	Tree	Bur Oak	*Quercus macrocarpa*	3
	Tree	Cedar elm	*Ulmus crassifolia*	1,2,3
	Tree	Cottonwood	*Populus deltoides*	1,2,3
	Tree	Eastern red cedar	*Juniperus virginiana*	3
	Tree	Hackberry	*Celtis spp.*	1,2,3
	Tree	Little Walnut	*Juglans microcarpa*	3
	Tree	Live Oak	*Quercus fusiformis*	3
	Tree	Pecan	*Carya illinoensis*	3
	Tree	Post Oak	*Quercus stellata*	3
	Tree	Sycamore	*Platanus occidentalis*	1,2

Notes:

These streams tend to have a combination of muddy and rocky substrates. Large pools remain as aquatic habitat throughout the year. A more comprehensive plant list can be found on the City of Austin's Riparian website.

Appendix II

Belt Transect Field Sheet

Database No: ____________________ Tree Tag: __________

Site Name: ______________________________ Transect #: __________

Date: ______________________________ Lat.: ______________________________

Time: ______________________________ Long.: ______________________________

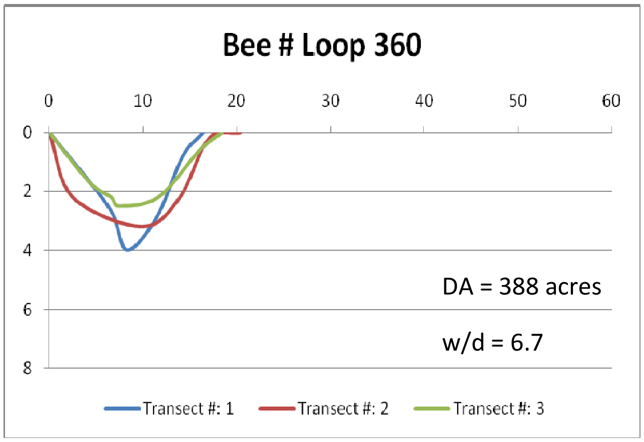
Personnel:

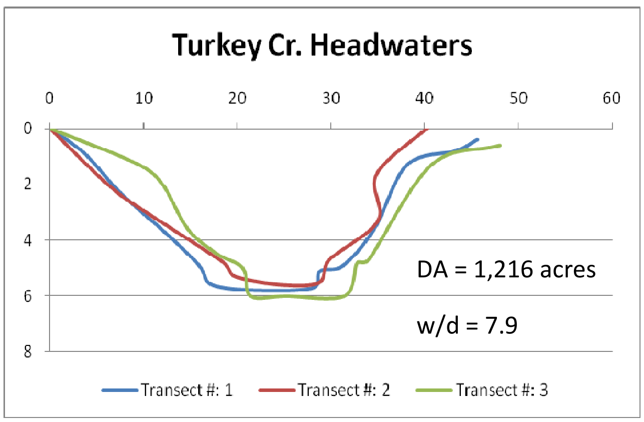
Groundcover %	Shrubs & Vines # Meters	Trees ○	Shrubs & Vines # Feet	Groundcover %
	12		39,4	
	11		36,1	
	10		32,8	
	9		29,5	
	8		26,2	
	7		23,0	
	6		19,7	
	5		16,4	
	4		13,1	
	3		9,8	
	2		6,6	
	1		3,3	
	0		Thalweg	
	1	0	1	

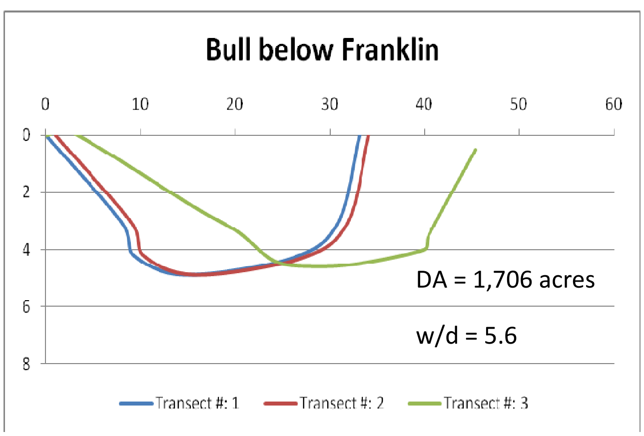
Groundcover %	Shrubs & Vines # Meters	Trees ○	Shrubs & Vines # Feet	Groundcover %
	27		88,6	
	26		85,3	
	25		82,0	
	24		78,7	
	23		75,5	
	22		72,2	
	21		68,9	
	20		65,6	
	19		62,3	
	18		59,1	
	17		55,8	
	16		52,5	
	15		49,2	
	14		45,9	
	13		42,7	
	1	0	1	

Appendix III

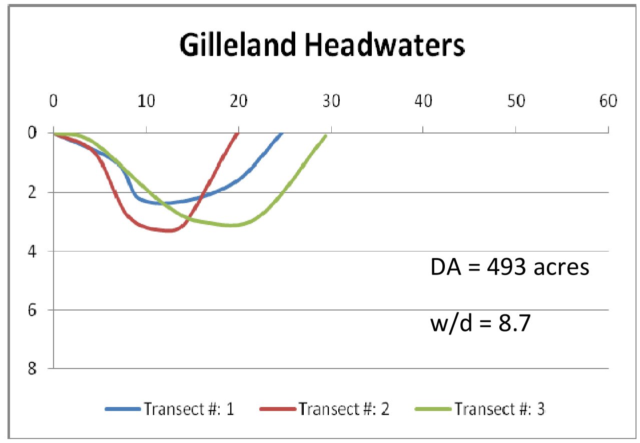
Edwards Headwaters

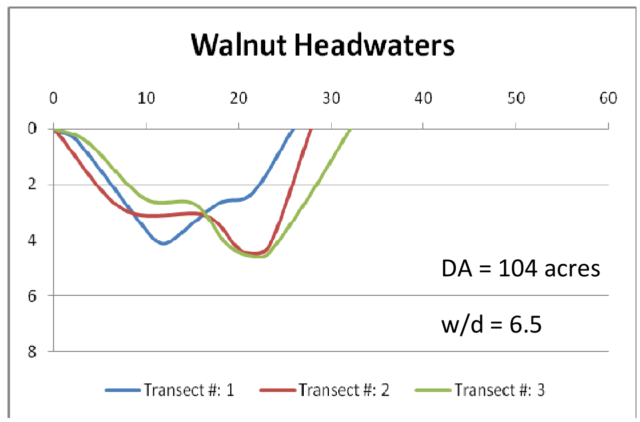


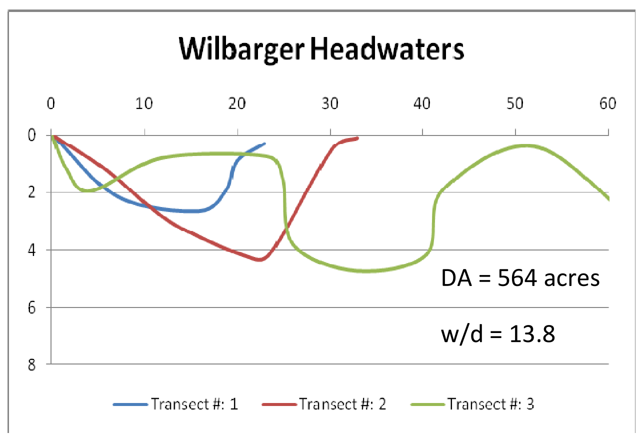




Blackland Prairie Headwaters







Edwards Bottomlands

Blackland Prairie Bottomlands