RIPARIAN PLANT COMMUNITY PATTERNS: A CASE STUDY FROM SOUTHEASTERN ARIZONA

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ABSTRACT

There is concern about the preservation and, when necessary, restoration of riparian areas in semi-arid regions. Understanding patterns of plant species composition and distribution within riparian corridors is helpful in planning for the management and protection of buffer strips that reduce the delivery of sediments to stream systems, maintain streambank stability, and filter excess nutrients that occur in runoff water. To determine how plant community patterns varied along environmental gradients in a semi-arid riparian ecosystem, 192 quadrats located on transects radiating away from a mixed perennial and intermittent stream system were sampled for woody and herbaceous plants. Principal Components Analysis (PCA) was used to display community patterns based on species composition and distribution. Three communities of woody plants were observed across hydrologic and elevational gradients: a shrub-dominated *Mimosa biuncifera* community; a woodland community dominated by *Prosopis velutina*; and a riparian community dominated by *Platanus wrightii*. Patterns of herbaceous plants were not related to these gradients.

Riparian ecosystems are the link between aquatic and terrestrial ecosystems. They spread laterally across floodplains onto adjacent near-slopes that drain directly into the stream water and vertically from the groundwater aquifer to the top of the vegetation canopy (DeBano and Baker 1999, Ilhardt et al. 2000). Riparian ecosystems often encompass distinctive environmental gradients and a variety of plant communities (Naiman et al. 1993, Shaw and Finch 1996, Cartron et al. 2000). One prerequisite for the management of riparian ecosystems, therefore, is knowing how plant community patterns are affected by environmental gradients.

We collected data within the riparian corridor of a watershed in southeastern Arizona to evaluate plant community patterns across environmental gradients associated with a semi-arid riparian ecosystem, and to formulate hypotheses on the processes responsible for the observed patterns. We initially thought that plant species composition and distribution might change along environmental gradients of distance to the main stream channel and elevation above the main stream channel.

Plant community patterns within riparian ecosystems differ markedly from patterns of the surrounding hillslopes in response to increased availability of moisture in these ecosystems (Reichenbacher 1984, Johnson and Lowe 1985, Tellman et al. 1993, Shaw and Finch 1996). We, therefore, collected information on the compositions and distributions of woody and herbaceous plants to determine if plant community patterns varied between floodplains and adjacent hillslopes, and to determine potential differences in species composition and distribution might be attributable to the same environmental gradients regardless of their life form.

STUDY AREA

The study was conducted along Paige Creek in Happy Valley, Arizona, on the eastern side of the Rincon Mountains, about 50 km east of Tucson, Arizona (Jemison 1989, Snyder 1995). This area was selected because it has a plant community that is representative of other riparian areas in southeastern Arizona (Table 1). Paige Creek is a stream system with a perennial main stem and intermittent reaches that drains an area of about 25 km^2. Average elevation of the stream system studied is approximately 1,250 m. Annual precipitation in the general area averages 325 mm (Sellers et al. 1985). Precipitation (mostly rainfall) during the study period of October 1, 1993 to September 30, 1994 was 430 mm and bimodal in its distribution. Over 50% of the rainfall occurring from July to September originated as high intensity convective thunderstorms with the remainder occurring as winter storms in mostly November through February.

The soil bordering the reach of Paige Creek studied is a Comoro — gravelly sandy loam (sandy, mixed, thermic, ustic Torrifluvent), ranging in depth from 25 to 100 cm (USDA Soil Conservation Service 1979, Hendericks 1985) with an average slope of 3%. This soil extends upslope from the main stream channel to 30 m onto the adjacent hillslopes (Jemison 1989). North of the main channel is

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Table 1. *Taxa of plants at Paige Creek, Arizona. Table includes species found in greater than 5% of quadrats. Nomenclature follows Lehr (1978).*

Woody plants	Herbaceous plants
Arctostaphylos pungens	*Acalypha neomexicana*
Brickellia grandiflora	*Aristida ternipes*
Celtis reticulata	*Bidens leptocephla*
Isocoma tenuisecta	*Boerhaavia coccinea*
Mimosa biuncifera	*Bouteloua aristoides*
Nolina microcarpa	*Bouteloua curtipendula*
Platanus wrightii	*Bouteloua rothrockii*
Prosopis velutina	*Bracharia arizonica*
Quercus arizonica	*Bromus rubens*
Quercus emoryi	*Cenchrus pauciflora*
Vitis arizonica	*Commelina erecta*
	Conyza canadensis
	Cyperus pringleii
	Desmodium procubens
	Digitaria sanguinalis
	Dioda teres
	Eragrostis intermedia
	Eriochloa gracilis
	Eriogonum abertianum
	Eriogonum wrightt
	Euphorbia albomarginata
	Euphorbia hyssopifolia
	Evolvulus arizonica
	Heterotheca psammophila
	Leptochloa dubia
	Machaeranthera spinulosus
	Monarda austromontana
	Oenotherea hookeri
	Oxalis albicans
	Panicum capillare
	Panicum obtusum
	Paspalum stramineum
	Physalis hederaefolia
	Portulaca umbractiola
	Setari grisebachii
	Sitanian hystrix
	Sporobolus cryptandrus
	Talinum spp.

Carolompi—very gravely sandy loam (sandy to coarse, loamy, mixed, thermic, cumlic Haplustoll). On the south side is a steep granite rock-land with small pockets of soil and slopes ranging from 25 to 75%.

METHODS

Six sites with differing hydrologic regimes were selected along a 2.4-km reach of Paige Creek (Snyder 1995). Sites A and F, located in the proximity of the perennial stream, were the most mesic sites. The other sites were situated along intermittent reaches of the stream. Sites A, B, and D were floodplain sites, while sites C, E, and F were established on hillslopes that were characterized by steeply rising slopes (25 to 40%) along an alluvial wedge above the main channel. Four transects were established perpendicular to the stream-flow on each of the six sites. The transects were spaced 5 m from the edge of the stream channel to avoid being eroded downstream and 9 m apart from each other. Eight sample plots were spaced 9 m apart on each 63 m transect to provide a total of 192 sample plots.

Diameters of woody plants within 67-m^2 circular plots were measured in the summer of 1994 and the basal area (the measure of woody plant abundance) calculated for each stem and totaled for multi-stemmed plants. Herbaceous plants were sampled by estimating percent basal cover for each species found within circular 0.9-m^2 quadrats (Bonham 1989) at the end of the cool season growing period in May and at the end of the warm season growing period in October of 1994. Other information recorded at the sample plots were the horizontal distance to the main stream channel; the height above the average depth of the main channel referred to as the "relative elevation"; and the geomorphic surface of the plot, that is, floodplain, secondary terrace, overflow channel, hillslope, or old road surface.

Principal Components Analysis (PCA) was used to identify and analyze the plant community patterns. PCA ordinates quadrats and species by synthesizing plant species information for all quadrats and projecting this information onto a low dimensional space (Gauch 1982). Species that occurred on fewer than 5% of quadrats were eliminated from the analysis because of the "strong effect" that rarely observed species have on a PCA. Eleven tree and shrub species were sampled and analyzed. Thirty herbaceous species were sampled in May and 35 species in October. Separate analyses were conducted for the woody plants, the herbaceous plants sampled in May, and the herbaceous plants sampled in October. Pearson's product-moment correlation coefficients were calculated between PCA axes and measured environmental variables.

This study was primarily concerned with the composition and distribution of plant species across the riparian areas adjacent to the stream reach sampled. Therefore, a PCA was conducted on the correlation matrix, because we felt that the differences in distribution of species are more important than the differences in abundance of dominant species (Noy-Meir et al. 1975). The correlation matrix de-emphasizes differences in abundance and accentuates differences in species distributions (Gauch 1982).

RESULTS

Woody Plants

The ordination diagram of the basal area of woody plants demonstrated three distinctive community patterns. First, quadrat scores appeared to ordinate along the first principal component due to changes in relative elevation (Fig. 1). Hillslope quadrats ordinated apart from low-lying floodplain quadrats, indicating that the first axis represented a relative elevation gradient that influenced plant species composition. The correlation coefficient between the first principal component and relative elevation further was significant (r=-0.54, P<0.0001).

The second pattern observed was that the second principal component appeared to be influenced by site location. This pattern was evident when the quadrat scores were labeled with site identifiers on the ordination diagram (Fig. 2). Quadrats at sites A and F, the most mesic sites, generally ordinated negatively on the second axis; those from sites E and C, the hillslope sites, ordinated positively on the second axis; and sites B and D, located on floodplains, ordinated near the origin. The correlation coefficient of the second axis and site location was significant (r=0.39, P<0.0001).

The third pattern was the existence of three woody plant communities on the study site (Fig. 3). These communities appeared to be associated with differences in the environmental gradients that were associated with the respective quadrats (see Figs. 1, 2, 3). The three communities consisted of a shrub-dominated *Mimosa biuncifera*, *Nolina microcarpa*, *Arctostaphylos pungens*, and *Isocoma tenusiceta* community found on the high relative-elevation (>5 m) quadrats on relatively xeric sites; a woodland community with *Prosopis velutina* and *Celtis reticulata* on the intermediate relative-elevation (1-5 m) quadrats on relatively xeric sites; and a riparian community with *Platanus wrightii*, *Quercus emoryi*, *Quercus arizonica*, *Brickellia grandiflora*, and *Vitis arizonica* on the low relative-elevation (<1 m) quadrats on relatively mesic sites.

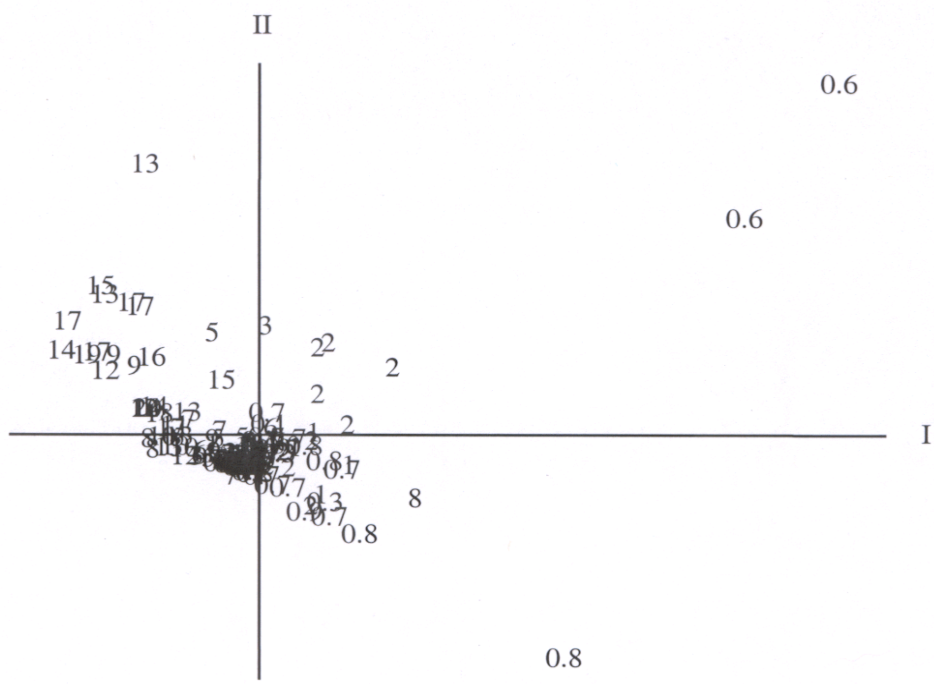

Figure 1. *Principal components analysis ordination of quadrat scores for woody plants at Paige Creek, Arizona. Relative elevations above the streambed (m) are used for labels.*

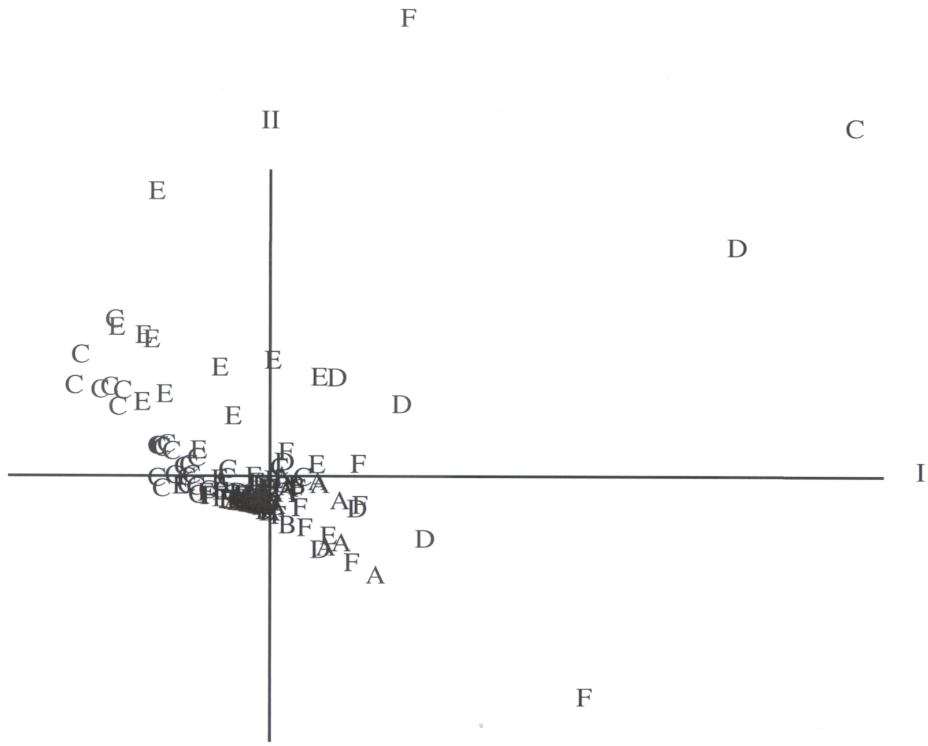

Figure 2. *Principal components analysis ordination of quadrat scores for woody plants at Paige Creek, Arizona. Site locations are used for labels, see Figure 1 for definitions.*

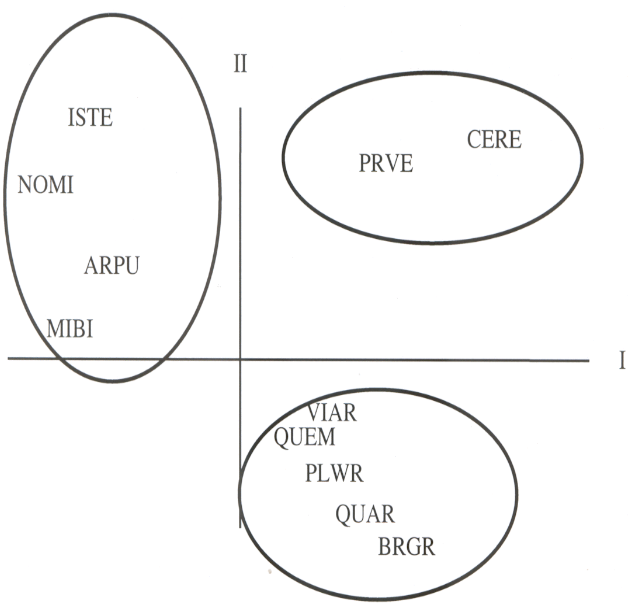

Figure 3. *Principal components analysis ordination of quadrat scores for woody plants at Paige Creek, Arizona. Species codes used for labels are Arpu (*Archostaphylos pungens*), Brgr (*Brickellia grandiflora*), Cere (*Celtis reticulata*), Iste (*Isocoma tenuisecta*), Mibi (*Mimosa biuncifera*), Nomi (*Nolina microcarpa*), Plwr (*Platanus wrightii*), Quar (*Quercus arizonica*), Quem (*Quercus emoryi*), and Viar (*Vitis arizonica*).*

Herbaceous Plants

Ordination of the percent basal cover of herbaceous plants sampled in either May or October did not indicate community patterns for either quadrat scores or species scores. Considering the cool-season plants, for example, the correlation analysis between the first and second principal components and environmental gradients indicated that relative elevation was correlated to the first axis ($r=-0.35$, $P<0.0001$), but the effect was not apparent in the ordination. Distance from the main stream channel was correlated with the second axis ($r=-0.26$, $P<0.0002$), but a community pattern was again not evident in the ordination. However, the species scores did indicate that dominant grasses were more frequently associated with other grasses than with forbs.

DISCUSSION

Woody Plants

Relative elevation had the greatest effect on the composition and distribution of the woody plants. Sites A and F were relatively flat sites located near the perennial stream reaches of Paige Creek, while the other sites were situated on intermittent reaches with less groundwater recharge. Sites C and E were steeper sites with less annual streamflow than sites

A and F, and, therefore, represent more xeric sites. Sites B and D, which generally ordinated near the origin, were relatively flat sites also on intermittent reaches of Paige Creek. If site locations are used as proxies for the hydrologic regime, the hydrologic character of the stream (perennial or intermittent flow) is important but likely moderated by surrounding geomorphic surface. If water is available on a continuous basis but plants cannot access it because of the geomorphic surface, relative elevation might have had a "stronger effect" on the composition and distribution of woody plants than the hydrologic regime of the site. Steep hillslopes raise the distance above the water table, and, therefore, plant-available water on these sites might not be affected by the presence of the stream.

Another interpretation of the results is that the availability of water determines species composition. This hypothesis implies that the main similarity between sites and relative elevation is the availability of water, which is supported by the natural histories of the species comprising the three communities. For example, a shrub-dominated *Mimosa biuncifera* community is comprised of species that are adapted to xeric conditions (Whittaker and Niering 1964), while the riparian community is comprised largely of phreatophytic species that require the presence of elevated watertables (Whittaker and Niering 1964, Stromberg et al. 1991).

An alternative hypothesis is that differences in the soils helps to explain the observed differences in plant community structure. Soils in the floodplains are coarse-grained alluvial soils, while hillslope soils are finer-textured, higher in clay content, and rockier. It is possible, therefore, that textural differences alone could explain patterns of species distribution and abundance. It is also important to consider the interactive effects of soils and hydrology on the availability of water to plants. However, the most plausible explanation for the results obtained is that water availability as moderated by soil texture controls species composition and distribution. Other researchers have proposed that succession, stability, and site productivity within riparian ecosystems respond mostly to the positioning of the water table and soil structure (Petts 1980, Kovalchik and Chitwood 1990).

Herbaceous Plants

That herbaceous plants exhibited little community pattern is likely also related to the availability of water. Herbaceous plants might be unaffected by a losing stream, because most of the species sampled in this study use moisture that is available only in the top half meter of the soil profile and, as a consequence, are generally incapable of accessing deeper water. A myriad of other factors could also have influenced the composition and distribution of herbaceous plants, for example, nutrient gradients or biotic mechanisms that alter the micro-environment (Barbour et al. 1987).

CONCLUSIONS

We determined that relative elevation was more important in determining differences in the composition and distribution of woody plants than distance to the main stream channel. Three woody plant communities were associated with changes in relative elevation. However, the composition and distribution of herbaceous plants did not exhibit a community pattern, indicating that herbaceous plants at Paige Creek were largely unaffected by the riparian ecosystem. Overall differences in the composition and distribution of plants that were observed within the study area were primarily a function of woody plants for this semi-arid system.

The results from this study should be helpful in managing the composition and distribution of plants in multispecies riparian buffer strips. These vegetated bands along stream channels are often more effective than buffer strips, comprised of only a few tree or shrub species, in reducing the delivery of sediments to stream channels, maintaining streambanks stability, and filtering excess nutrients that occur in runoff water (Brooks et al. 1997). These multispecies buffer strips also provide shade, shelter, and food for terrestrial wildlife and aquatic biota while creating a visually diversified landscape. Knowing the composition and distribution of the plant species in the buffer strips facilitates planning and management actions that sustains their respective growth and survival requirements.

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