TITLE: Opportunities for Passive Restoration of the Salt River Riparian Corridor

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CONGRESSIONAL DISTRICT of PIs: 4th and 5th Congressional Districts of Arizona

SUMMARY. Portions of the urbanized Salt River have been dewatered and are now targeted for ecosystem restoration by measures such as tree planting. Little attention has been paid to the potential for natural redevelopment of plant communities along this river reach. We investigated the vegetation and soil seed banks of three reaches of the Salt River in and near Phoenix to determine 1) how the riparian plant community has been altered by diversion of stream flow and 2) how the pockets of riparian vegetation that have developed naturally at rewatered urban reaches compare to those in the upstream perennial reach. Our results indicate that long-term diversion of the Salt River has converted a species-rich hydromesic riparian forest/shrub community to a species-poor xeric shrub community. Yet, riparian species, such as cattail (*Typha domingensis*) and umbrella sedge (*Cyperus odoratus*) are present in the seed bank of these xeric shrublands. Species richness and functional group composition of the riparian patches in the rewatered urban reach (near urban storm drains) were very similar to values in the upstream rural perennial reach. These findings have implications for the way riparian restoration is approached. These small riparian storm drain communities provide anecdotal evidence for the resilience of this system, given adequate restoration of stream flows and sediments. The species composition of these sites provides an example of a plant community that can establish and maintain itself with limited intervention under these altered conditions. Also, these communities, if left intact during the planned restoration interventions, could function as source of propagules for the establishment of riparian species in adjacent reaches.

DESCRIPTION INFORMATION

A. Problem and Research Objectives

Riparian ecosystems of southwestern USA have changed extensively since European settlement. Rivers located in urban areas have undergone the greatest transformation, as exemplified by the Salt River in the Phoenix metropolitan area. Damming, water diversion, and stream channelization allowed for agricultural and urban development, but reduced the density of riparian vegetation and narrowed the riparian corridor. The cottonwood-willow forests, mesquite woodlands, shrublands, marshlands and riparian grasslands that were once common have become scarce in this reach of the river, as have patches of desert saltbush that occurred on terraces adjacent to the river (Graf 1982; Rea 1983; Hendrickson and Minckley 1984; Davis 2001). The changes in stream hydrology, geomorphology, and vegetation have reduced wildlife habitat and recreational opportunities and altered other functions including climate moderation and groundwater recharge (National Research Council 2002).

To restore some of the amenities once provided by the Salt River, several multi-million dollar riparian ecosystem restoration projects are planned or underway in the Phoenix metropolitan area. These include the Va Shly'ay Akimel project, Tempe Rio Salado Project, Phoenix Rio Salado Project, Rio Salado O'este, and the Tres Rios Project. These projects are partnerships between the U. S. Army Corps of Engineers and local municipalities. The projects have multiple goals, including increasing wildlife habitat quality and restoring historically-present plant communities while also providing recreational opportunities, maintaining flood water conveyance, and reducing the risk of mosquito-borne disease.

Explicitly, restoration refers to returning a site to a prior historical condition and thus to a pre-degradation state (Bradshaw 2002). The Salt River restoration projects are more accurately rehabilitations, as restoration to pre-dam conditions is not a realistic goal. Current restoration/rehabilitation plans for the Salt River seek to recreate the historical community-level structure of the river's biotic community largely by planting woody vegetation and installing and maintaining drip irrigation systems. Less emphasis is being placed on restoration of the historical physical processes, such as the flows of water and sediment, which are the primary determinants of riparian vegetation structure (Poff et al. 1997; Ward et al. 2001; Rood et al. 2002).

If physical processes such as water flows are restored, plants, animals, and microorganisms may colonize the site of their own accord if source populations are present. Many woody riparian plants, such as Fremont cottonwood (*Populus fremontii*) and Goodding willow (*Salix gooddingii*) trees, are highly fecund, fast growing, disturbance-adapted species that colonize floodplains; each year these trees produce large numbers of short-lived seeds. Many annual or short-lived perennial herbaceous riparian species are also disturbance adapted and often have viable seeds stored in the soil seed bank (Richter and Stromberg 2005); these seeds potentially serve as an *in situ* source for colonization, should water flows be restored to a site.

Some of the Salt River reaches targeted for restoration have been 'accidentally' rewatered in recent decades by storm drain runoff from the urban watershed. Pockets of riparian vegetation have developed at these storm drains, some of which have perennial stream flow and small flood pulses that reflect the climatic signal. These areas, although small, support a productive and diverse riparian flora indicating that riparian plant communities can reestablish where water flows are adequate. In addition, these sites may provide a source of propagules for natural revegetation of other river reaches. If seed sources are present in adequate densities in the seed bank or from standing vegetation, then passive restoration of a site can be a viable and inexpensive option (Briggs 1996).

Our goal was to provide information that could be used to inform restoration planning of the Salt River riparian corridor. Specifically, our research goals were to: 1) determine how the Salt River riparian plant community has been altered by diversion of stream flow from Granite Reef diversion dam; 2) Determine how the pockets of riparian vegetation that have developed naturally at rewatered urban reaches compare to those in a perennial river reach, in terms of diversity and composition of plants in both the soil seed bank and extant vegetation.

B. Methodology

Study sites. Sites were selected within three reaches of the Salt River in and near the Phoenix metropolitan area (Figs. 1 and 2). The uppermost reach, referred to as the rural perennial reach, is located in Tonto National Forest and has perennial flow with suppression of most floods by Roosevelt Dam and other dams. The middle reach, referred to as the suburban diverted reach, is in the city of Mesa, below Granite Reef Dam, and due to water diversion by Salt River Project exhibits ephemeral flow. This reach is to be restored as part of the Va Shly'ay Akimel project. The lower reach flows through the large urban center of Phoenix. This reach, referred to as the urban rewatered reach, is watered in areas by outflows of treated wastewater, storm water, and irrigation runoff. Two sites were selected in this reach. This section encompasses portions of the Phoenix Rio Salado O'Este riparian restoration project area (in the planning stages) and the Phoenix Rio Salado riparian restoration project area (in the development stage).

The most prevalent patch types in each reach were selected for study. In the rural perennial reach, there were two patch types: a hydromesic forest patch type, vegetated by *Populus fremontii*, *Salix gooddingii*, and *Tamarix chinensis,* and a mesic woodland/shrubland vegetated by *Prosopis velutina* and *Baccharis sarothroides.* Within the suburban diverted reach there was one predominant patch type, a xeric shrubland vegetated mainly by *Bebbia juncea*. Within the urban rewatered reach there were three patch types: hydromesic forest vegetated by a mixture of tree species including *Salix gooddingii*, *Populus fremontii*, and *Tamarix chinensis*, mesic woodland-shrubland vegetated by *Prosopis velutina*, *Baccharis sarothroides* and grasses, and xeric shrubland vegetated by *Bebbia juncea*. Within this latter reach, the hydromesic forests were located along the Salt River channel, and also clustered in pockets at storm-drain outfalls.

Vegetation sampling: Six independent 100m² quadrats were randomly selected for vegetation and seed bank sampling within each patch type, per river reach, for a total of 36 quadrats. Herbaceous vegetation was sampled in March, June, and September of 2004, within five 1m² plots within each 100m² quadrat. March and September are periods of high seasonal rainfall while June is a seasonal dry period. Percent cover of herbaceous species was visually estimated using Daubenmire cover classes. Woody species were sampled within the 100m² plots for presence/absence. To characterize the overall vegetation structure in each reach, three line transects were established in 2005 within each of the four study reaches spanning the riparian zone. Vegetation patches along the transects were delimited in terms of dominant species and physiognomy, and the width of each patch was measured.

Seed banks: Within the quadrats three replicate soil cores were taken at three depths of 0-2.5 cm, 2.5-5 cm and 5-10 cm using a split-core sampler with a radius of 2.5 cm during February 2004. The three replicates of each depth were placed in baggies, labeled for site and depth, and then stored in a cooler for transport to the ASU greenhouse. A total 324 soil samples were taken (36 quadrats x 3 soil depths x 3 replicates). The seed banks were investigated using the seedling emergence method (Roberts 1981). The experiment was carried out in a greenhouse on the main campus of Arizona State University. Samples were spread over the potting soil with a maximum depth of 3 cm. The flats were placed in the greenhouse on three benches using a random block design. Temperatures were regulated to coincide with average temperature in the Phoenix area and were changed on a monthly basis for one year. The samples were bottom watered daily using irrigation. The seed bank was inventoried on two week to one month intervals. Seedlings were allowed to mature until they were able to be identified to species after which they were removed to eliminate competition.

Data reduction and analysis: The composition of the above and below ground vegetation community was characterized by classifying species as predominantly annual vs. predominantly perennial, as historically non-native vs. native to the United States (following designation in USDA 2002) and as riparian (species with a wetland indicator class as indicated in USDA 2002) vs. upland (species with no wetland indicator class). Mean plot-level species richness and vegetation abundance (cover for the extant vegetation and density for the soil seed bank) were calculated for each patch. Shannon-wiener diversity coefficients and patch-level species richness also were calculated.

To compare the riparian plant communities above and below Granite Reef diversion dam, two sample t-tests (n=6) were used to test for differences in richness and abundance (of seed bank and extant vegetation) between the xeric patch type in the diverted reach and the upstream hydro-mesic patch, and between the xeric patch types and the upstream mesic patch type. To make comparisons between the rural perennial and urban rewatered reaches, two sample t-tests (n=6) were used to test for differences between the two hydro-mesic riparian forest patch types and between the two mesic woodland/shrubland patch types. To scale up the results from the patch level to the entire riparian zone, patch values were weighted by the proportion of the floodplain the patch occupied. All two sample tests were done in SAS (version 9.1, SAS institute Inc, Cary NC). Assumptions of normality and equal variance for parametric tests were analyzed by normal probability plots and F-tests for equal variance respectively. Shannon-wiener diversity indices were calculated using estimateS (Colwell 2005).

C. Principal Findings and Significance

Effects of river diversion on the riparian plant community. Below Granite Reef diversion dam, both the above and below ground vegetation communities differed substantially from the above dam reach floodplain (Table 1). Species richness in the soil seed bank was 47% lower and annual extant vegetation richness was 23% lower below the diversion dam (Fig. 3). A 21% reduction in ground cover was recorded and canopy cover above 1 m was nonexistent in the diverted reach. The number of individuals in the soil seed bank was 43% lower below the dam as well. Shifts in composition were also observed in the diverted reach, most evidently in the extant vegetation, which were dominated by upland rather than by riparian species. The soil seeds banks of the dewatered reach also had a smaller proportion of riparian species compared to the above dam reach (Fig. 4).

Significance. These results indicate that the long-term diversion of the Salt River stream flow has converted the remaining undeveloped floodplain from a species-rich hydromesic riparian forest/shrub community to a species-poor xeric shrub community. This community reassembly, although to an altered condition, demonstrates the resilience of the ecosystem to respond to a disturbance (i.e., dewatering). Yet, riparian species, such as cattail (*Typha domingensis*) and umbrella sedge (*Cyperus odoratus*), are present in the seed bank of these xeric shrublands. This may facilitate redevelopment of the former riparian state following a new perturbation, i.e., the planned rewatering of the river as part of restoration actions. Support for this hypothesis was observed when a small riparian herbaceous patch developed in the diverted reach following the 2005 flooding of the lower Salt River after a release from the upstream diversion dam. The seed source for the post-flood recruitment of riparian species may have been the soil seed bank or the annual seed rain.

Effects of rewatering on the urban riparian plant community. Species richness (Table 2) and diversity (data not shown) of the riparian patches were similar in the urban rewatered and rural perennial reaches for both seed bank and extant vegetation. For the hydromesic patch type, 30 seed bank species were in the urban rewatered reach (per 1062 cm^2) compared to 33 in the rural perennial reach (Fig. 5). Respective values for the mesic patch type were 22 (rural perennial) and 30 (urban rewatered) (figure not shown). No significant differences were observed in the mean number of seed bank species per plot between the rural perennial and urban rewatered reaches for the hydromesic patches, but there was a trend for significantly more species in the urban rewatered reach for the mesic patches. Similarly, species richness of the extant vegetation was comparable between the rural perennial and urban rewatered reaches for the hydromesic patches but was greater in the urban rewatered reaches for the mesic patches. In both reaches most species were classified as riparian, both for the soil seed banks and extant vegetation (Fig. 6). Both reaches had a high percentage of exotic species. There was high overlap in the composition of riparian species observed the soil seed bank in the rural perennial and urban rewatered reaches (Table 3).

Significance. These findings of similarities in species richness and composition between riparian patch types of the above-dam perennial and below-dam rewatered reaches have implications for the way riparian restoration is approached. Presently, the riparian restoration efforts that are ongoing and planned for the Salt River entail a large component of tree planting and seeding. Our results indicate that this highly altered urban river has high resilience in the sense of having high capacity to redevelop species-rich riparian plant communities without intervention, given that adequate flows of water and sediment are restored.

The composition of the plant community in the urban reach differs from the historical condition, but this change is inevitable given that the flow of water, seeds, and sediment from upstream sources are restricted, and the physical processes that maintained the historical plant community cannot be restored in an urban setting. In addition, the urbanization of the surrounding watershed is reflected in the riparian plant community. The storm drains appear to be functioning as urban tributaries, providing not only water, sediments and flood disturbance, but also seeds from the urban watershed. It is noteworthy, however, that the proportion of exotic species in both the soil seed bank and the extant vegetation of the urban rewatered reach were similar to the proportion observed in the upstream perennial reach.

Not only do these small riparian storm drain communities provide anecdotal evidence for the resilience of this system, but they are also useful tools for restoration of the Salt River riparian corridor. The species composition of these sites provides an example of a riparian community that can establish and maintain itself with limited intervention under these altered conditions. Also, these communities, if left intact during restoration interventions, could function as source of propagules for the establishment of riparian species in adjacent reaches.

Table 1: Change in vegetation community within the floodplain above and below Granite Reef Diversion Dam

	Above Dam	Below Dam	Percent Change
Floodplain patch type composition			
Hydro-mesic	44%	0	--
Mesic	56%	0	--
Xeric		100%	
Soil seed bank			
Species richness (1062 cm^2)	28.3	15.0	47
Abundance (1062 cm^2)	373.7	212.0	43.3

Mean species richness (177 cm^2)	9.1	4.8	46.8
Mean abundance (177 cm^2)	66.2	34.0	48.7
Extant vegetation			
Species richness (30 m^2)	23.4	17.0	23.1
Mean species richness (5 m^2)	7.6	7.7	1.3
Mean percent ground cover	11.1	8.7	21.2
Percent canopy cover	29.2	0	--

Table 2: Change in vegetation community within the floodplain in the rural perennial and urban rewatered reaches

	Rural Perennial	Urban Rewatered	Percent Change
Floodplain composition			
Hydro-mesic	44%	63%	
Mesic	56%	37%	
Soil seed bank			
Species richness (1062 cm^2)	28.3	30.0	6.1
Abundance (1062 cm^2)	373.7	755.4	102.1
Mean species richness (177 cm^2)	9.1	10.1	11
Mean abundance (177 cm^2)	66.2	127.3	92.3
Extant vegetation			
Species richness (30 m^2)	23.4	35.93	53.5
Mean species richness (5 m^2)	7.6	10.393	37.3
Mean percent ground cover	11	26	132.6
Percent canopy cover	29	16	-44.9

Table 3: Riparian species observed in the soil seed bank of the riparian patch types in the urban rewatered and rural perennial reaches

					Urban Rewatered		Rural Perennial	
Species	Family	Habit*	Lifespan*	Origin*	Hydro-mesic	Mesic	Hydro-mesic	Mesic
Amaranthus albus	Amaranthaceae	F	A	N		X		
Aster subulatus	Asteraceae	F	A	N	X	X	X	
Calibrachoa parviflora	Solanaceae	F	A	N	X	X	X	X
Chenopodium sp	Chenopodiaceae	F	P			X		
Conyza Canadensis	Asteraceae	F	A	N		X	X	
Cynodon dactylon	Poaceae	G	P	I	X			
Cyperus difformis	Cyperaceae	G	A	I		X		
Cyperus involucratus	Cyperaceae	G	P	I	X	X		
Cyperus odoratus	Cyperaceae	G	P	N	X	X	X	
Echinochloa colona	Poaceae	G	A	I	X	X		
Eclipta prostrate	Asteraceae	F	A	N	X	X		
Eleocharis montevidensis	Cyperaceae	G	P	N	X	X	X	X
Leptochloa fusca ssp uninervia	Poaceae	G	A	N	X	X	X	X
Melilotus indicus	Fabaceae	F	A	I	X	X	X	X
Pluchea odorata	Asteraceae	SS/S	A/P	N	X		X	
Polypogon monospeliensis	Poaceae	G	A	I	X	X	X	X
Portulaca oleracea	Crassulaceae	F	A	N	X	X	X	X
Prosopis sp	Fabaceae	T	P	N	X			
Rumex crispus	Polygonaceae	F	P	I	X		X	X
Schenoplectus americanus	Cyperaceae	G	P	N	X			X
Sonchus asper	Asteraceae	F	A	I	X	X	X	X
Typha domingensis	Typhaceae	F	P	N	X	X	X	X
Veronica anagallis aquatica	Scrophulariaceae	F	P	N	X	X	X	X

*Forb, Graminoid, Subshrub; Annual, Perennial; Native, Introduced

Figure 1. Location of study sites (stars) along the Salt River.

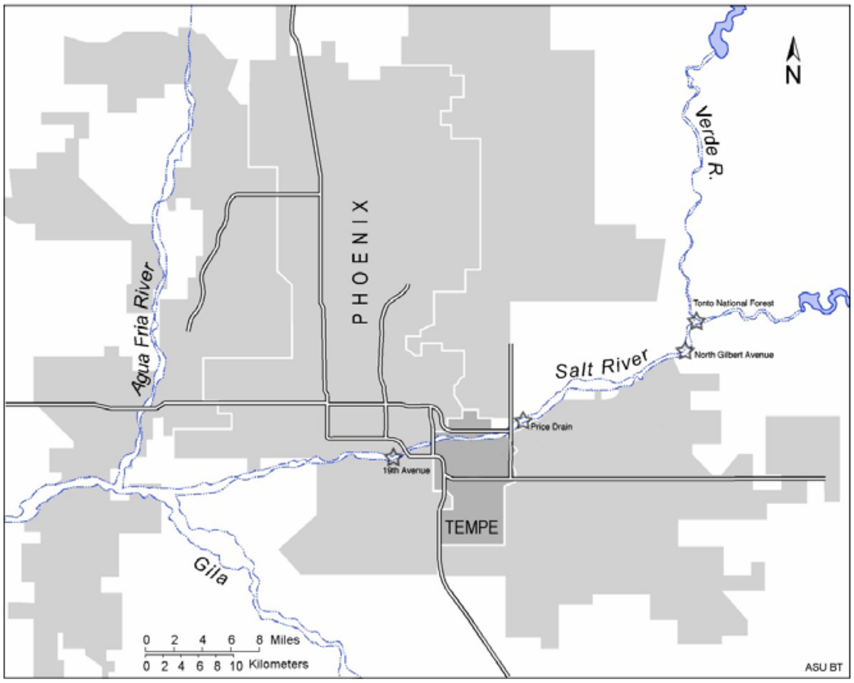

Fig. 2. (following page) Photographs of the Salt River in a reach upstream of Granite Reef Diversion dam (top), a reach downstream of the dam (middle), and a reach receiving storm drain inflow (bottom).

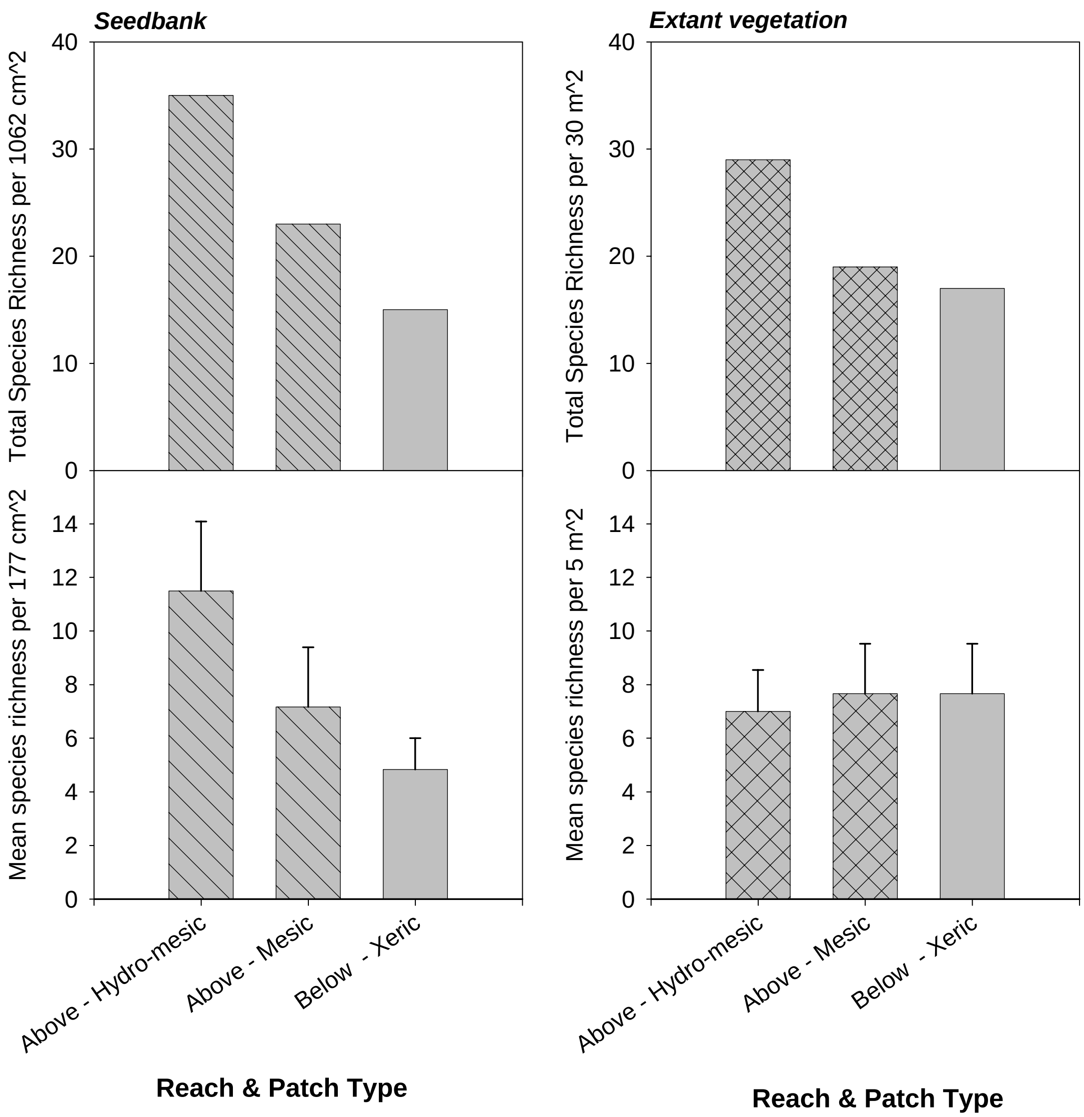

Figure 3: Species richness in the soil seed bank and extant vegetation above and below Granite Reef Diversion Dam. Patterned bars represent above dam patch types and solid bars represent below dam patch types. Top panel displays overall richness across all plots. Lower panel displays mean richness per plot ± one standard deviation.

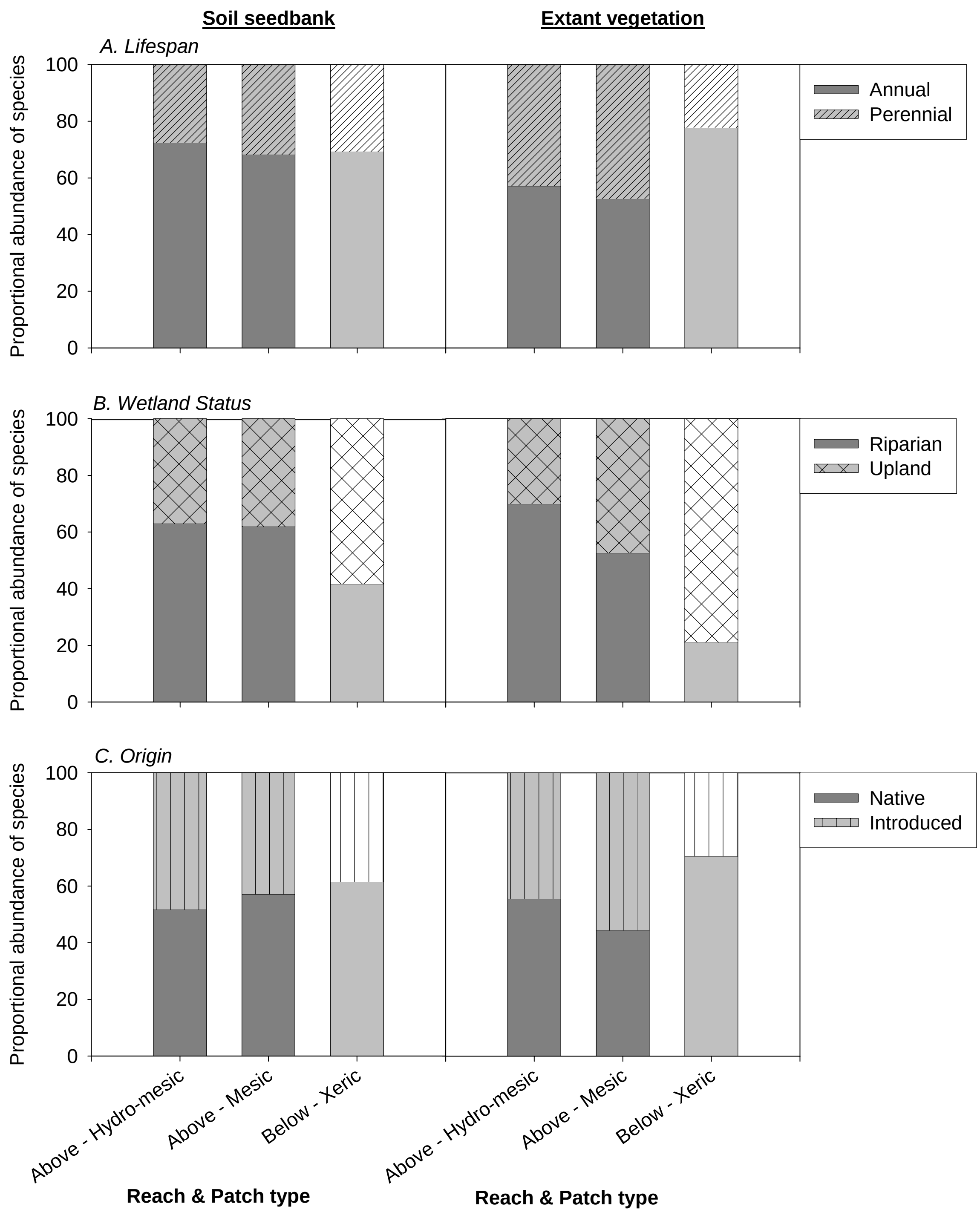

Figure 4: Composition of species in the soil seed bank and extant vegetation of patch types located above and below Granite Reef Diversion Dam. Darker shaded bars indicate patch types above the dam and lighter colored bars indicate patch types below the dam.

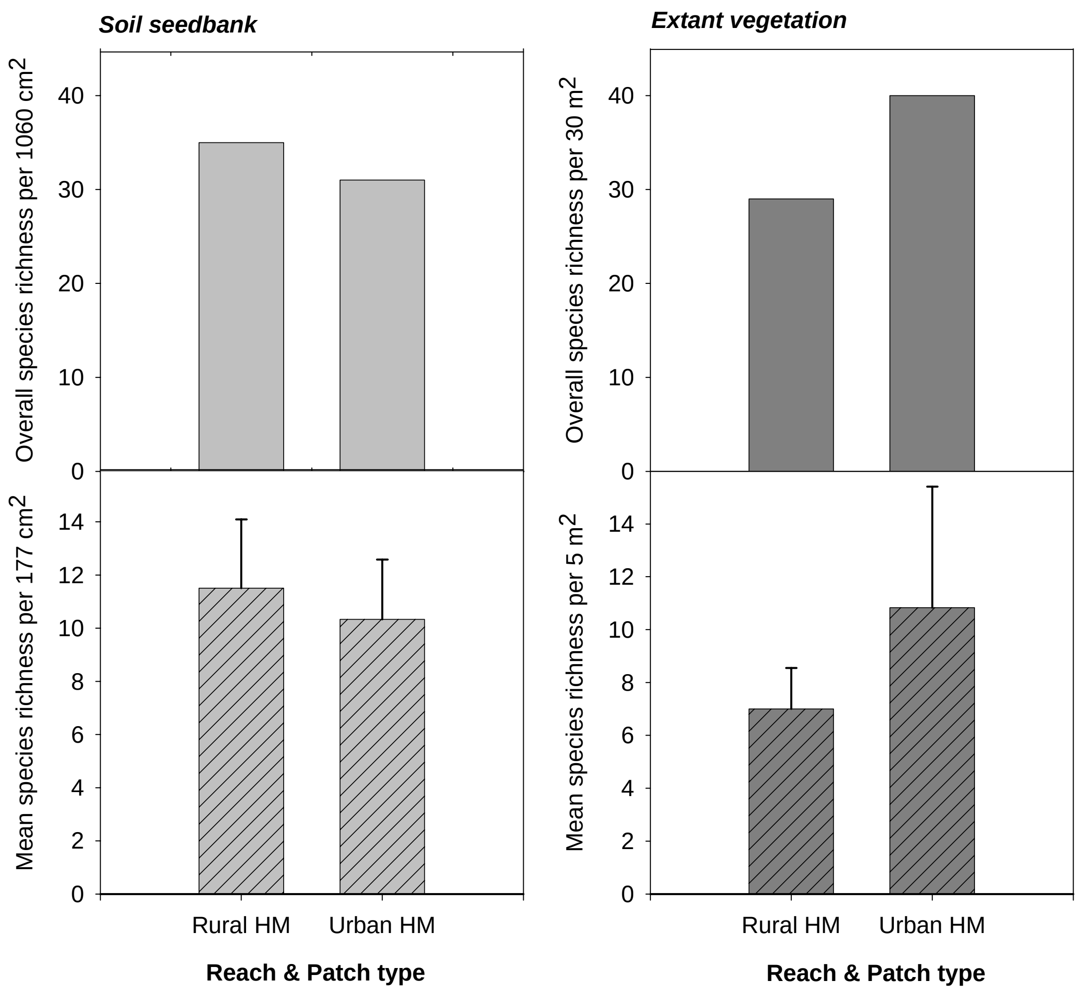

Figure 5: Species richness in the hydro-mesic (HM) patch type soil seed bank and extant vegetation of two reach types. Top panel displays overall richness across all plots. Lower panel displays mean richness + one standard deviation.

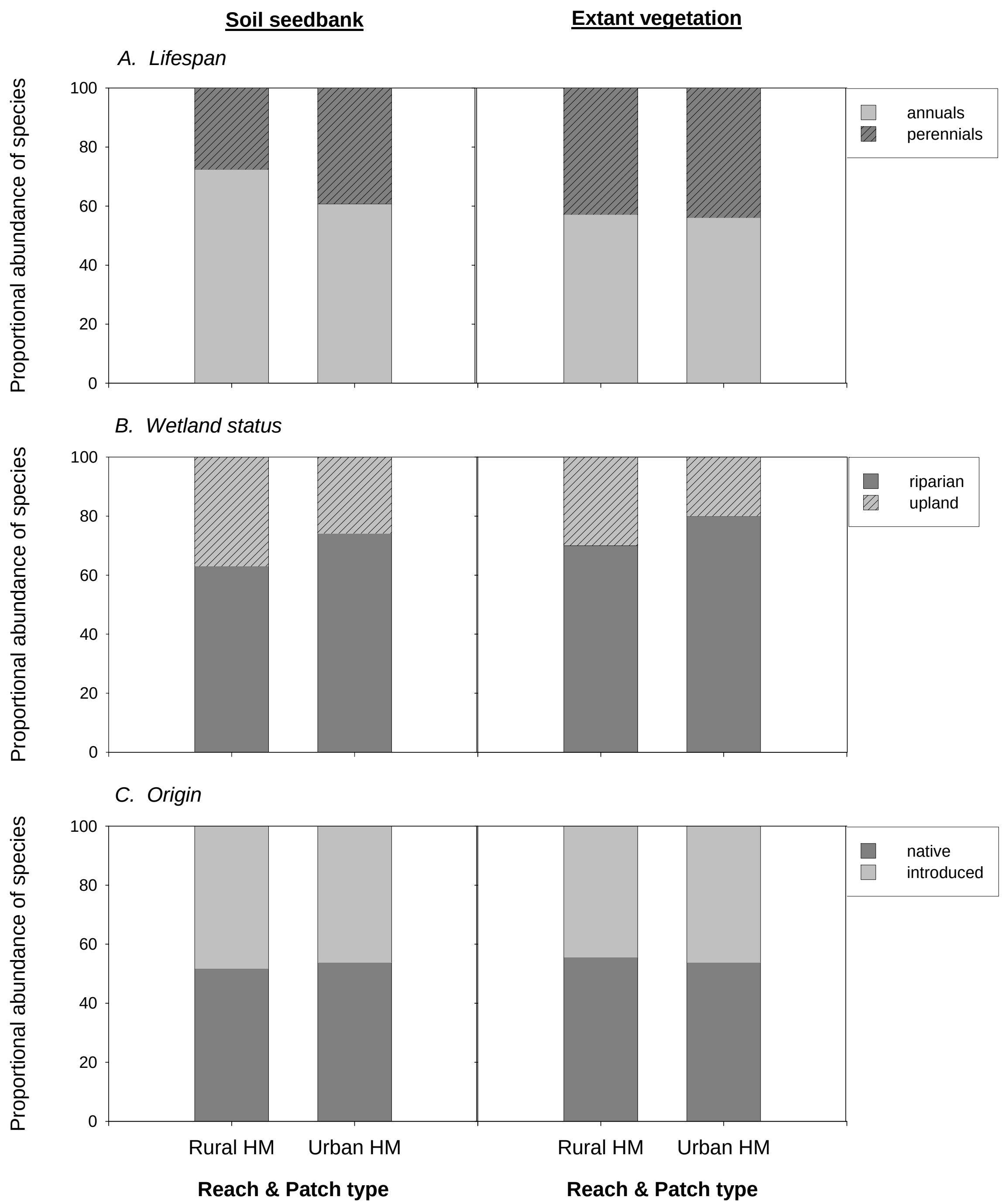

Figure 6: Composition of species in the soil seed bank and extant vegetation of the hydro-mesic (HM) forest patch type for rural and urban reaches.

D. References

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PUBLICATIONS

No reports were published during the reporting period. A Master's Thesis (by Jacqueline White) will be forthcoming in summer of 2006.

The following presentations were made:

White J, JC Stromberg. August 7-12, 2005. Effects of urbanization and river modification on the soil seed bank of an arid region river: a case study of the Salt River, AZ. Ecological Society of America-Intecol Joint Meeting. Montreal, Canada. (poster)

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Undergraduate __________

Masters_1_______________
Ph.D.___1_______________
Post-Doc._______________
Total__2_________________