Effects of River Modification on the Soil Seed Bank of the Salt River, Arizona

A case study of an arid region river

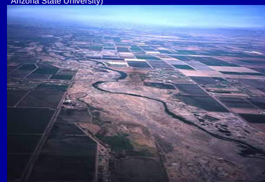
Jacqueline White and Juliet Stromberg
School of Life Sciences, Arizona State University, P.O. Box 874601, Tempe AZ 85287-4601

Abstract

Riparian ecosystems have been degraded in the southwestern US over the past century as demand for water has increased and driven the construction of dams and water diversion projects. The Salt River in Arizona is no exception. This once large perennial river has been reduced to a small ephemeral channel in places. Other reaches within the large urban center of Phoenix flow intermittently because storm drains provide runoff from a variety of urban sources. The flow regime of a river is an important ecological mechanism driving riparian plant community structure. Currently, there are several restoration projects of various scales being planned and implemented on the Salt River. No preliminary research has been conducted to determine the effects of flow regime alteration and watershed urbanization on the riparian plant community much less on the soil seed bank, which could provide a valuable yet inexpensive resource for revegetation. Studies on other rivers in the Sonoran Desert show that a large percentage of the riparian flora are seed-banking species, and that remnant floras may persist in the seed banks of below-dam reaches. I am conducting a case study of the riparian soil seed bank along the highly modified arid region river, the Salt River, Arizona. I address several questions. How is the riparian soil seed bank affected by long-term river damming and diversion and by the return of flow and small flood pulses from constructed urban tributaries? How does the soil seed bank compare to the extant vegetation? What are the implications for restoration projects? To address these questions, I am analyzing the soil seed bank using the seedling emergence method and sampling the extant vegetation three times per year. I am contrasting results between reaches that differ in stream flow permanence, as well as in inundation frequency, substrate size, and water quality

INTRODUCTION

Salt River, Arizona (Photo by Sharon Reynolds, Arizona State University)



The Salt River located in the southwestern United States exemplifies the strong influence that anthropogenic activities can have on rivers and their floodplains in semi-arid regions. Dams and water diversion projects constructed at the beginning of the 20th century have decreased stream flow rates and inhibited the upstream-downstream connectivity of the Salt River. Reaches above the Granite Reef diversion dam flow perennially but their flow regimes are altered by dams further upstream. Other reaches of the river near the large urban center of Phoenix flow only as a result of inputs from storm runoff, irrigation, or treated wastewater. The result of urbanization of the Salt River watershed is a flow regime that diverges dramatically from the flow regime of a wild river.

Two theoretical concepts are useful for describing the relationship between the river and its floodplain: the river continuum concept, which emphasizes the longitudinal continuity of the river, and the flood pulse concept, which emphasizes the lateral connection between the river and its floodplain (Naiman and Bilby, 1998). Longitudinal and lateral connectivity both broadly control the high biological and structural diversity associated with riparian habitats. Riparian plant community development also is influenced by the flow regime of a river, which encompasses the magnitude, frequency, timing, duration, and rate of change of high and low stream flows (Poff et al. 1997). River continuity allows for the transport of nutrients, sediments, and propagules. During high flow events water exceeds the banks reconnecting the river to its floodplain. Depending on the magnitude of the flood pulse, sediments and vegetation may be scoured away leaving substrates open for colonization, or sediments, nutrients and propagules may be deposited onto the floodplain. High levels of species diversity can be attributed to the variety of microsites and successional phases created by the scouring of vegetation and deposition of sediments and nutrients by floodwaters (Nilsson and Svedmark, 2002).

Storage of seeds in soil seed banks is one mechanism by which frequently disturbed riparian plant communities maintain high species diversity (Boudell and Stromberg, unpublished data, Combroux et al. 2002). Soil seed banks contain a variety of species with different life cycles (Brock and Rogers, 1998), but most seed banking species are ruderals (Wetzel et al. 2001; Rossell and Wells, 1999, Barbour et al, 1999; Goodson et al.2001). This life history strategy is characterized by high fecundity, short life cycles, and a rapid response to resource availability. Plant species in this functional group are often the initial colonizers after flood events, and therefore they play a vital role in riparian plant community development. Disruption of river continuity and river-floodplain connectivity associated with a modified flow regime and modified channel geomorphology can have a profound impact on the riparian plant community and its associated seed bank.

To counter the decline in riparian habitat quality associated with urbanization and modification of the flow regime of the Salt River, local and federal agencies have initiated several restoration projects. For example, a habitat restoration effort, the Phoenix Rio Salado project, is in the works along a five mile section of the Salt River in central Phoenix, AZ (theriosaladoproject.org). A demonstration constructed wetland,, the Tres Rios project, is present farther downstream west of Phoenix. Other restoration projects along the river are still in the planning phases. Many of these restoration projects are being planned and implemented without detailed inventories of the riparian biota, their functions, or the processes that drive community

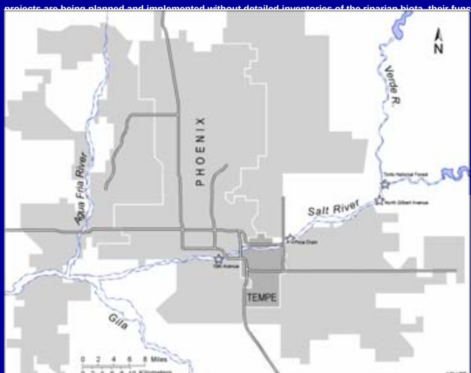


Figure 1: Map of Salt River study area. Markers were added to indicate study sites. Map courtesy of Wendy Bigler. CAP-LTER, 2001

OBJECTIVES

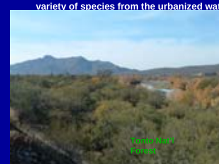
- Determine how the riparian soil seed bank is affected by long-term river damming and diversion and by the return of flow and small flood pulses from constructed urban tributaries
- Determine how the soil seed bank compares to the extant vegetation
- Characterize abiotic conditions that may influence the composition of the soil seed bank such as substrate size, inundation frequency, and water quality
- Provide restoration managers with baseline data

SIGNIFICANCE

Riparian seed pools can increase the resilience of an ecosystem, and influence its ability to respond to environmental change. Effects of urbanization on riparian seed pools have been little studied, however, and this study will fill information gaps. Knowledge of the potential role of the seed bank in allowing for natural revegetation in these Salt River restoration projects will be useful for planners and managers. Information will be obtained on species or types of species that are available to revegetate if appropriate site conditions are restored (Rossell and Wells, 1999; Wetzel et al. 2001). Comparisons between the soil seed bank and the extant vegetation will allow us to make inferences on the processes influencing the present and potential future plant assemblages.

EXPECTED RESULTS

We expect composition and diversity of the soil seed bank to differ between reaches with different flow regimes, and we expect the degree of similarity between the extant vegetation and the soil seed bank to differ as well. The soil seed bank in the perennial reach that experiences high river-floodplain connectivity is expected to be the most diverse and the most similar to the extant vegetation, given that this reach is more frequently inundated by flood waters. Inundation allows for an input of propagules through hydrochory, but also promotes germination from the soil seed bank, which provides a mechanism to maintain soil seed bank composition. In contrast, the reach with the lowest level of river-floodplain connectivity is expected to have lower diversity and less similarity with the extant vegetation and the soil seed bank, because the mechanisms that would have maintained the riparian soil seed bank have been significantly reduced if not eliminated. The soil seed bank of intermittent reach may be similar to that of the perennial reach in terms of diversity and similarity with the extant vegetation, but the composition is likely altered due to the loss of upstream downstream continuity and to inputs of a wide variety of species from the urbanized watershed.



METHODS

The study sites for this investigation are located along a 10 mile stretch of the Salt River between the Salt-Verde and Salt-Gila River confluences. This region can be divided into three areas for the purpose of this study. The uppermost region is located in Tonto National Forest and experiences perennial flow with suppression of most floods by Roosevelt Dam and other small dams. The middle region is in the city of Mesa located below Granite Reef dam, and due to water diversion by the Salt River Project (SRP) exhibits ephemeral flow. The lower region is in Phoenix and flows intermittently due to the presence of storm drains which provide water from urban runoff. Sites were classified into four vegetation/water availability patch types that represent the dominant conditions present. Not all patch types are present in all reaches. Three of the most prevalent patch types were selected for study (Table 1).

Table 1: Vegetation patch types located within four sections of the Salt River, AZ

		Hydro-Mesic forest	Mesic Woodland/ Shrubland	Marshland	Xeric Shrubland
Perennial flow-Tonto Nat'l Forest		6 plots	6 plots		
Dry Channel- Mesa					6 plots
Re-watered	Intermittent Flow – Large Drain Tempe	3 plots	3 plots		3 plots
Re-watered	Intermittent Flow – Small Drain Phoenix	3 plots	3 plots	none	3 plots

Field work

Six independent 100m² quadrats were randomly selected within each patch type, per river reach, for a total of 36 quadrats. Within the quadrats three replicate soil cores were taken to a depth of 10 cm in January 2004. Substrate surfaces will be characterized by Wolman's pebble count (Leopold et al. 1964), as substrate size may have a significant influence on the soil seed bank. Percent cover of herbaceous vegetation was sampled three times in March, June, and September. In addition, woody vegetation was sampled for species presence/absence within each plot.

Soil Seed Bank

Soil seed bank samples are being analyzed in the ASU greenhouse using the seedling emergence method (Roberts, 1981). Samples were spread over sterilized potting soil to a maximum depth of 3 cm . The trays were placed in the greenhouse in a randomized block design. Temperatures were regulated to coincide with average temperature in the Phoenix area. All trays are bottom watered daily using drip irrigation. Periodically, inventories of the emerging seedlings are conducted. As individuals reach reproductive maturity they are removed for identification. The greenhouse experiment will be continued through March 2005. Total experiment duration is 1.5 years.

DATA ANALYSIS

Species richness and vegetation abundance (cover for extant vegetation, density for the seed bank data) of patch types will be analyzed by nested ANOVA with post-hoc means separation tests. These tests will indicate whether vegetation traits within a patch type differ between river reaches. Sample size will be 18 for each soil seed bank per patch type per reach and 30 plots for extant vegetation per patch type per reach.

Seed banks will be compared to above ground vegetation by determining Sorensen's coefficient of similarity (Barbour et al. 1999). Species composition will be compared between patch types by performing an ordination analysis (Barbour et al. 1999) in order to determine the relatedness of the nine different patch types. Ordination will be conducted separately using the extant and seed bank data sets. A histogram will be used to describe the relative abundance of patch types within the four different sections of the river. This will allow the results of the seed bank study to be scaled up from the patch level to the level of the entire riparian zone.

References

Barbour, MG, JH Burk, WD Pitts, FS Gilliam, and MW Schwartz. 1999. Terrestrial Plant Ecology 3rd ed. Addison Wesley Longman. California.

Brock, M and KH Rogers. 1998. The regeneration potential of the seed bank of an ephemeral floodplain in South Africa. Aquatic Botany 61:123-135

Combroux, IC, G Bornette, and C Amoros. 2002.Plant regenerative strategies after a major disturbance: The case of a riverine wetland restoration. Wetlands 22:234-246

Goodson, JM, AM Gurnell, PG Angold, IP Morrissey. 2001. Riparian seed banks: structure, process and implications for riparian management. Progress in Physical Geography 25:301-325

Leopold, LB, MG Wolman, and JP Miller. 1964. Fluvial Processes in Geomorphology. W.H. Freeman, San Francisco, California

Naiman, RJ. and RE. Bilby. 1998. River Ecology and Management: lessons form the pacific coastal ecoregion. Spinger. New York.

Nilsson, C and M Svedmark. 2002. Basic principles and ecological consequences of changing water regimes: riparian plant communities. Environmental Management 30:468-480

Poff NL, JD Allan, MB Bain, JR Karr, KL Prestegaard, BD Richter, RE Sparks, JC Stromberg. 1997. The natural flow regime. A paradigm for river conservation and restoration. BioScience 47: 769-784.

Rio Salado project website. www.riosaladoproject.com . Online. January, 2004

Roberts, HA. 1981. Seed banks in soils: Reserves of viable seeds present in the soil and on its surface. Advances in Applied Biology 6:1-55.

Rossell, IM and CL Wells. 1999. The seed banks of a southern Appalachian fen and adjacent degraded wetland. Wetlands 19:365-371

Wetzel, P R, AG van der Valk, and LA Toth. 2001. Restoration of wetland vegetation on the Kissimmee River floodplain: potential role of the seed banks. Wetlands 21:189-198