

Distribution of Riparian Vegetation in Relation to Streamflow in Pima County, Arizona

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Abstract—We compared the distribution of riparian forest and woodlands relative to water resource availability for a 2.3 million-acre region for the Sonoran Desert Conservation Plan (SDCP). Most of Pima County's riparian vegetation occurs along stream reaches that classify as ephemeral. Ninety percent or more of the mesquite woodlands, riparian scrub, and riparian strand classifications of the Brown, Lowe and Pase system are associated with ephemeral stream reaches in Pima County. Over half of the Sonoran cottonwood-willow vegetation is associated with stream reaches that classified as ephemeral. Conservation planning has often focused on protecting perennial stream habitat. Our results support the importance of identifying and protecting ephemeral and intermittent streams, particularly those having shallow groundwater tables, in the Southwestern United States.

Introduction

This paper examines the significance and conservation status of riparian vegetation along ephemeral streams in Pima County, with special emphasis on deciduous riparian forests.

Despite the importance of riparian areas in the arid and semi-arid regions of the Western United States, the availability of water to riparian vegetation cannot be spatially evaluated over broad regions, in part because of inconsistent and incomplete information. U.S. Geological Survey (USGS) topographic maps differentiate perennial from non-perennial streams. Neither topographic maps nor National Wetland Inventory maps differentiate intermittent flow reaches from ephemeral stream reaches, a crucial distinction for many aquatic and riparian species of the Western United States. While discrete discharges of groundwater to the surface are sometimes mapped as springs on USGS maps, shallow groundwater systems that never discharge to the surface escape notice. Complicating the matter, effluent discharges today support riparian areas along streams that would otherwise be dry except during storm events (Fonseca and Regan 2001). The 2.3 million-acre area within Pima County that was studied for the Sonoran Desert Conservation Plan (SDCP) is one region where stream inventory allows for a comparison of the distribution of riparian vegetation relative to water resources, across a diverse terrain.

Resource Inventory and Analysis

The water resource inventory for the Conservation Plan was initially conducted by Pima Association of Governments (PAG 2000) for all of Pima County outside the Tohono O'odham Nation. Surface flows were classified according to the United States Geological Survey (USGS) (Langbein and Iseri 1960) definitions to differentiate perennial, intermittent, and ephemeral reaches of streams. Where long-term stream flow extent monitoring (also known as "wet-dry" mapping) was available, the extent of flow during the driest conditions was used to define the perennial reach.

Surface Flow Definitions

Perennial: one that flows continuously.

Intermittent: one that flows only at certain times of the year when it receives water from springs or from some surface source such as melting snow in mountainous areas.

Ephemeral: one that flows only in direct response to precipitation, and whose stream is at all times above the water table.

The topology of the ephemeral stream centerlines was based primarily on Pima County staff's delineation of stream centerlines from orthophotographs at a scale of 1:12,000. In remote areas of western Pima County the 1:24,000 USGS digital line graphs were used.

Shallow groundwater systems were identified based on evidence of a water table within 50 feet of the land surface. This definition was based on evidence that groundwater at this depth could sustain mesquite bosques (ADWR 1994). Many of the larger zones were mapped using a combination of aerial photographic and topographic interpretation, and review and mapping of groundwater level information from various state and local agencies. The inventory of shallow groundwater systems was, and still is, incomplete, consisting only of the larger and better documented sites (PAG 2000).

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The inventory identified 66 perennial stream reaches and 120 intermittent stream reaches on 57 different streams (PAG 2000). Pima County later augmented the inventory with additional spatial coordinates for streams, springs, and shallow groundwater systems. The data layers are maintained as part of Pima County's Geographic Information System and made available to the public at <http://gis.pima.gov/maps/sdcp/>.

To support conservation planning, Pima County used the Brown, Lowe, and Pase digital classification system (Brown et al. 1979) to classify the distribution and extent of vegetation along the region's watercourses. The vegetation study area consisted of the 2.3 million acres of land within Pima County and excluded Wilderness, Monument, National Park, Refuge or Military Reservation, and areas under tribal control.

Over 100 U.S. Geological Survey orthophotoquads at a scale of 1:24,000 were used to delineate polygons of increased vegetation size and density or geomorphological evidence of hydrological patterns (Harris 2001). Biologists then assigned a vegetation classification to each polygon based upon field experience and existing data.

Vegetation polygons were classified to the "biome" level, with the exception of the Sonoran Riparian Deciduous Forest and Woodlands biome (BLP code 224.5), which was further subdivided to distinguish mesquite from cottonwood-willow forest (Harris 2000). In this paper, "riparian" vegetation refers to 200-series BLP biomes or associations.

The distribution of riparian vegetation along the watercourses was analyzed by intersecting watercourse centerlines with riparian vegetation polygons using ArcGIS 10. The miles of stream length was summed for the three types of flow and for the five categories of riparian vegetation.

Watercourse centerlines came from three files. "Wash" centerlines were based on delineations by County staff circa 1990, regardless of water resource availability. 'Istreams' and 'pstreams' were independently delineated by PAG in 2000 to identify intermittent and perennial stream reaches, respectively. To deal with overlapping centerlines in our analysis, we buffered 'istreams' and 'pstreams' and used the buffer zones to erase any adjoining centerlines from the 'wash' file. In areas where the thalweg of the channel had moved substantially over time, or where the topologies diverged, the two centerlines were retained as independent flow paths. This occurred along a few miles of the effluent-dependent Santa Cruz River.

Results

Over 320,000 acres of streamside vegetation was defined in 13 naturally occurring biomes. The vast majority (86%) of vegetation along streams in Pima County is classified as upland vegetation (table 1). The remaining 14% consisted of four distinct riparian vegetation communities, with the Sonoran Riparian Deciduous Forest and Woodland biome being the most common, at over 25,000 acres.

About 88% of this biome was mesquite "bosque" or woodland association. The remainder, some 3100 acres, was cottonwood-willow association (defined herein as 224.53 or 224.523).

The distribution of riparian vegetation communities is biased towards eastern Pima County (fig. 1). Interior Southwest riparian deciduous forest (223.2) is found primarily above 3000 feet, whereas mesquite bosques (224.52) are most common below 3000 feet. The majority of Sonoran cottonwood-willow forest (224.53) and riparian scrub (234.7) is found between 3000 and 5000 feet.

Most of Pima County's riparian vegetation (200-series Brown, Lowe and Pase classification) occurs along stream reaches that classify as ephemeral (table 2; fig. 2). Ninety percent or more of the mesquite woodlands, riparian scrub, and riparian strand plant communities are associated with ephemeral stream reaches in Pima County.

The Sonoran cottonwood-willow association of the Sonoran deciduous riparian forest and woodland biome is the type of plant community that is most closely, in the literature, tied to perennial or intermittent flow (e.g. Lite and Stromberg 2005). In Pima County, this association is more closely affiliated with perennial and intermittent flow than the other four riparian associations (table 2; fig 2). Still, over half of the Sonoran cottonwood-willow vegetation in our study area is associated with ephemeral stream reaches. Three-fourths of the cottonwood-willow vegetation was along a non-perennial reach.

Of the approximately 45 miles of Sonoran cottonwood-willow association found along ephemeral reaches, shallow groundwater conditions are known to occur along over 8 miles (18 percent). About 76 of the 410 miles of ephemeral streams having Sonoran mesquite woodlands are mapped as intersecting a shallow groundwater polygon (19%).

Discussion and Conclusions

Over 870 miles of ephemeral stream in Pima County possess some type of riparian vegetation. The majority of each of the five riparian vegetation associations was found along ephemeral, not perennial streams. Our results point to the importance of evaluating and protecting ephemeral streams for the significant habitat values they may provide to a wide array of wildlife. The degree of protection offered to ephemeral streams under the Clean Water Act is under debate (Levick and others 2008). Our results bolster evidence presented by Levick and others regarding the ecological functions of ephemeral streams.

Shallow groundwater conditions, including perched aquifers along streams, could explain the persistence of some riparian vegetation found along ephemeral streams. Past groundwater pumping has contributed to a loss of year-round flowing streams and riparian forests in Pima County, mainly at lower elevations (Scalero and Fonseca 2000). Even after the water table no longer discharges to the surface,

Table 1—Acres of vegetation in Brown, Lowe and Pase biome classification.

Brown, Lowe and Pase vegetation (biome) in acres	Upland biomes (sum of all 100-series)	Interior Southwest riparian deciduous woodland (223.2)	Sonoran riparian deciduous forest and woodland (224.5)	Sonoran deciduous riparian scrub (234.7)	Sonoran interior strand (254.7)
	269,281	5,833	25,437	7,752	5,337

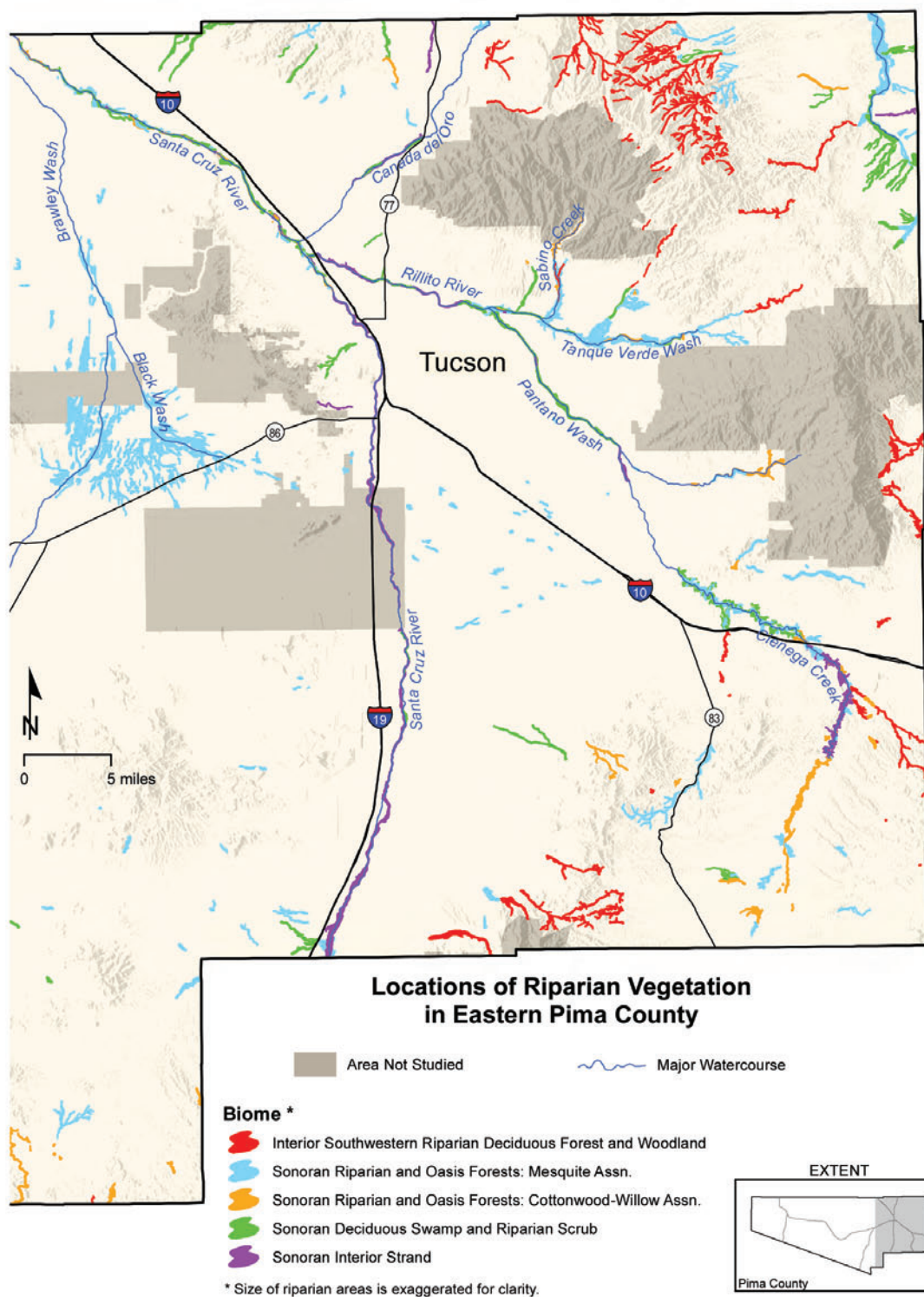
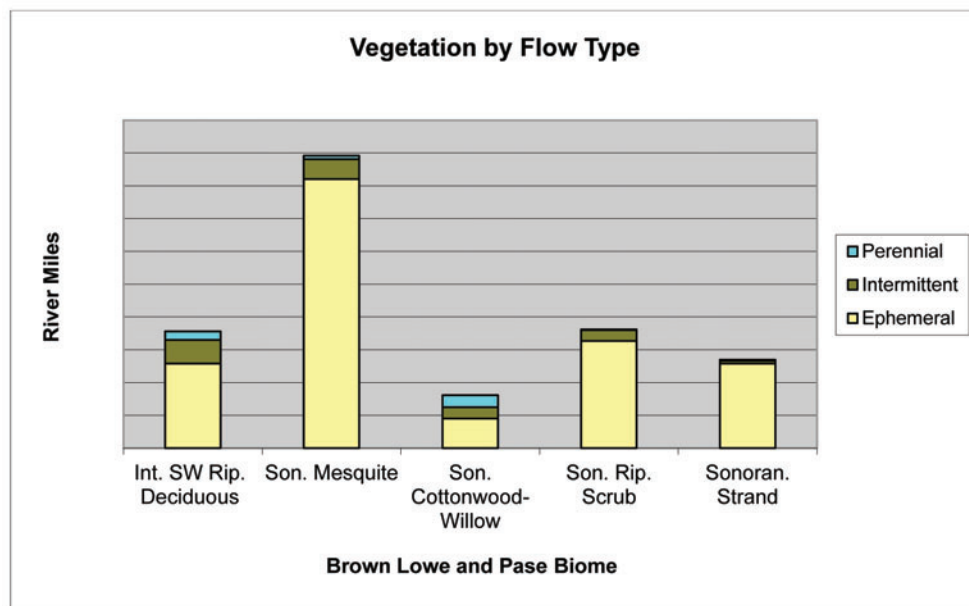


Figure 1—Location of riparian vegetation in eastern Pima County.

Table 2—Distribution of vegetation associations (Brown and others 1979) by stream flow type.

Flow type (reach miles) (%)	Interior Southwest riparian deciduous (223.2)	Sonoran mesquite woodland (bosque) (224.52)	Sonoran cottonwood- willow (224.53)	Sonoran deciduous riparian scrub (234.7)	Sonoran interior strand (254.7)	Total flow length in miles
Ephemeral	129 (73%)	410 (92%)	45 (56%)	163 (90%)	129 (96%)	877
Intermittent	36 (20%)	30 (7%)	17 (21%)	16 (9%)	4 (3%)	104
Perennial	13 (7%)	5 (1%)	19 (23%)	1 (1%)	1 (1%)	39
Total miles intersecting vegetation biome or association	178	446	81	181	134	1020

**Figure 2**—Vegetation by flow type.

shallow groundwater tables or moisture in the unsaturated zone below streambeds may remain accessible to streamside plants.

This study did not analyze vegetation condition across the spectrum of flow intermittency. Along the San Pedro River in adjoining Cochise County, dense, multi-aged cottonwood-willow forests appear to be restricted to perennial or intermittent rivers where depth to the water table is less than 4 meters (Lite and Stromberg 2005).

When analyzed for the Sonoran Desert Conservation Plan, only 63% of the Sonoran cottonwood-willow forest type was located within an existing reserve, a lower degree of protection that was available to many other, more common vegetation communities in Pima County (Fonseca and Regan 2001). About 75% of the higher elevation Interior Southwestern forests were protected, although much of that was within National Forests subject to mining and other competing interests.

Pima County and Pima County Regional Flood Control District have adopted a number of provisions to conserve riparian areas, including floodplain management regulations that pertain to riparian habitats found along the County's predominantly ephemeral streams.

A 2004 general obligation bond for implementing the SDCP resulted in Pima County acquiring cottonwood-willow forests and mesquite bosques formerly subject to private land development, and managing state grazing leases that include additional riparian areas. Pima County holds and manages water rights associated with the land acquisitions. However, Arizona law provides little protection for groundwater-dependent ecosystems and no direct protection for the water needs of riparian vegetation (Losi 2012). These "sub-irrigated" ephemeral and intermittent streams are critical wildlife resources in arid and semi-arid areas like Pima County, Arizona.

Some 25 river miles of riparian vegetation along the Santa Cruz River is supported in part by effluent flows, supporting over 300 acres of riparian forest and woodland as well as riparian (Fonseca and Regan 2001). Continued discharge of effluent to the river depends largely on the actions of City of Tucson, which owns the majority of the effluent, and the Secretary of the Interior, who holds in trust 28,300 acre-feet of effluent for the benefit of the Tohono O'odham Nation.

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The content of this paper reflects the views of the authors, who are responsible for the facts and accuracy of the information presented herein.