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Riparian vegetation of ephemeral streams

Juliet C. Stromberg [a,*], Danika L. Setaro [a], Erika L. Gallo [b], Kathleen A. Lohse [c], Thomas Meixner [b]

[a] Arizona State University, Tempe, AZ 85287-4501, USA
[b] University of Arizona, Tucson, USA
[c] Idaho State University, Pocatello, USA

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ABSTRACT

Ephemeral streams are abundant in drylands, yet we know little about how their vegetation differs from surrounding terrestrial zones and about their projected response to regional warming and drying. We assessed plant communities at seven ephemeral streams (and terrestrial zones) distributed among three climatic settings in Arizona. Compared to terrestrial zones, riparian zones had similar herbaceous cover but greater woody vegetation volume. They supported more plant species, with several woody taxa restricted to the ephemeral zone (consistent with the idea that herbaceous plants are rain-dependent while riparian trees rely on runoff stored in stream sediments). Their herbaceous communities had high compositional overlap with terrestrial zones and may sustain regional diversity as droughts intensify. Presumably owing to periodic flood disturbance, riparian plant communities had greater evenness than terrestrial zones, many of which were dominated by *Eragrostis lehmanniana*. Patterns along the climatic gradient suggest that increasing aridity will reduce the number of herbaceous (and total) plant species within riparian zones (110 species per stream in semihumid settings, 88 in semiarid, 48 in arid) and drive compositional shifts from perennials grasses and forbs to annuals. Hotter and drier conditions will drive sharp declines in herbaceous cover, converting riparian savanna to xeroriparian scrubland.

1. Introduction

In hot dryland regions, the groundwater-dependent riparian ecosystems that border perennial to intermittent rivers and streams have substantially more biomass and greater productivity than the surrounding terrestrial vegetation (Scott et al., 2014). They are vegetated by distinct suites of fast-growing and flood-adapted wetland plant species (obligate riparian taxa), while also providing habitat for many plant species that are typical of more xeric habitats (facultative riparian taxa). They maintain levels of plant species diversity that are greater or lesser than in adjacent desert habitat, depending on context, and increase regional diversity (Sabo et al., 2005).

Ephemeral streams are the predominant stream type in desert regions but are understudied relative to their wetter counterparts. By definition, ephemeral streams are decoupled from regional groundwater and flow only in response to major storm runoff events (Meinzer, 1923). Their plant communities-drought-adapted taxa including small-leaved shrubs and short-canopies trees-have been referred to as xeroriparian (Warren and Anderson, 1985; Johnson et al., 1984). The trees grow in narrow linear bands, sustained by water supplied by periodic floods (run-on events) that recharge the often-sandy stream sediments and/or create shallow perched water tables (Atchley et al., 1999; de Soyza et al., 2004; Rassam et al., 2006). Soils often are deeper than on alluvial fans. The extent to which the plant communities of these ephemeral streams differ in biomass, species composition, and species diversity from the terrestrial vegetation remains little studied.

While many parts of the world are becoming warmer and wetter, many arid and semiarid regions are becoming hotter and drier (Dominguez et al., 2010; Vicente-Serrano et al., 2012). Analyses of long-term data sets in the American Southwest have documented recent drought-related declines of desert shrubs and upward elevational range shifts of various taxa (Bowers, 2005; McAuliffe and Hamerlynck, 2010; Brusca et al., 2013). Vegetation

* Corresponding author.
E-mail address: jstrom@asu.edu (J.C. Stromberg).

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patterns along spatial aridity gradients reveal yet other changes that may occur through time as climate changes, including decreases in above and below ground biomass, shifts in plant growth form, and declines in species richness (Schulze et al., 1996; Munson et al., 2013; Ulrich et al., 2014).

Plant communities in riparian ecosystems are changing in response to direct effects of temperature and precipitation and to indirect effects of climate change on watershed processes that regulate flows of surface water and groundwater (Perry et al., 2012; Davis et al., 2013; Garssen et al., 2014; Kløve et al., 2014). For groundwater-dependent-ecosystems (GDEs) in dryland regions, declining groundwater inflows will induce shifts from perennial flow to intermittent flow in susceptible river reaches (Seager et al., 2013). This will cause riparian vegetation to transition from tall, broad-leaf riparian forests to more deeply-rooted and smaller-leaved shrublands (Stromberg et al., 2010), and drive initial increases in species richness followed by declines to lowest levels as flow becomes highly infrequent (Katz et al., 2012). The effect of increasing aridity on ephemeral stream vegetation remains little studied. Particularly for streams draining small watersheds, effects may mimic those in the adjacent terrestrial vegetation.

There has been a recent surge of interest in understanding and conserving ephemeral streams in desert landscapes (Acuña et al., 2014; Datry et al., 2014). Our goals were to increase understanding of the ways in which vegetation along ephemeral streams differs from the desert matrix and how vegetation will change under a climate scenario of increasing aridity. Focusing on the American Southwest, we asked, (1) to what extent do biomass, diversity, and composition differ between ephemeral streams and adjacent terrestrial zones, and (2) how do plant community attributes vary along an aridity gradient?

2. Materials and methods

We selected seven ephemeral streams (colloquially, washes or arroyos) in central and southern Arizona, spanning three aridity zones (Table 1; Appendix 1, electronic version only). The aridity gradient is created by elevational change, and encompasses changes in mean annual precipitation and mean annual temperature. All sites have a summer wet season (July–September) and winter wet season (December through March), although the westerly sites receive a higher percentage of rainfall in winter (56%) relative to summer (44%) compared to other sites (42% and 48% respectively). Study streams were functionally Type I (Shaw and Cooper, 2008) in that they drain small watersheds and are regulated more by the local climate than by that of distant mountains.

We determined the percentage of time that surface water was present in study streams by instrumenting one 200-m stream length per site with three electrical resistance sensors with exposed leads (ER, Tidbit v2 UTBI-001 data logger, Onset Corporation, Bourne, MA) (Blasch et al., 2002). (The 200-m stream length also served as the base area for vegetation sampling). The sensors logged a resistance signal every 10 min over a two-year period. For one stream, Sauceda Wash, surface flow data were obtained from USGS stream gaging station 09519760. Collectively, these data indicated that study streams had surface flow for only a few days per year (Table 1; Fig. 1).

We calculated aridity using the de Martonne Aridity Index (mean annual precipitation in mm divided by the sum of mean annual temperature in °C plus a constant of 10) (Quan et al., 2013). A value of <5 is arid, 5–10 is semiarid, 10–20 is semihumid, 20–30 is humid, and >30 is perhumid. Black Gap Wash and Sauceda Wash, within the Barry M. Goldwater Air Force Range near Gila Bend, Arizona, were arid, with Aridity Index of 3. Both are in the Lower Gila River Basin, on semi-consolidated alluvial basin fans. Their matrix vegetation is Sonoran Desertscrub (Lower Colorado Valley subdivision) (Brown, 1994). Two unnamed streams in the Santa Rita Experimental Range (currently administered by the University of Arizona College of Agriculture), Santa Cruz River Basin, had a semiarid climate with Aridity Index of 8. Both are center-of-basin braided unconsolidated sandy channels. Their matrix vegetation is degraded semidesert grassland (a mix of cacti, grasses, and woody plants). The three ephemeral streams with the greatest precipitation and lowest temperature (semihumid climate, Aridity Index from 11 to 15) drained the foothills of the Huachuca Mountains near Sierra Vista, Arizona, within the San Pedro River Basin. These piedmont streams have semi-consolidated alluvial channels. Two of the three were on land managed by the Department of Defense (Fort Huachuca) and the third was on the Coronado National Forest. For convenience, we named these three streams based on the name of the closest canyon. Their matrix vegetation is semidesert grassland.

We delineated the riparian zones from the terrestrial zones based on vegetation cues including changes in size of facultative riparian shrubs (i.e., those that also grow in the dryland). We determined the boundary between the channel and riparian zone using hydrological cues (recent evidence of flow) and vegetation cues (differences in cover). The combined riparian/channel zone width ranged among sites from 15 to 58 m. We established a terrestrial zone of comparable length and width at each site, with a buffer of at least 15 m between the riparian and terrestrial zones.

Given the importance of edaphic factors to vegetation, we collected soils or sediments in the channel, riparian, and dryland zones from the 0–5 cm depth using a core sampler (n = 5 replicates

Table 1
Attributes of ephemeral streams. Precipitation and temperature values are 30-year means (US Climate Data; http://www.ncdc.noaa.gov/). A = arid, SA = semiarid, SH = semihumid. DoD = Dept. of Defense; USFS = U.S. Forest Service.

Site name	Lat. and long. in decimal degrees	Mean annual temp.(°C)	Mean annual precip.(mm)	Winter precip. as percent of total	Coefficient of variation in precip.	Aridity Index	Aridity zone	Elev-ation(m)	Surface flow (% of time)	Catchmentarea (km^2)
Goldwater sites										
Black Gap Wash	32.711123, 112.831066	22.3	97	56%	0.48	3.0	A	324	0.6	10
Sauceda Wash	32.878405, 112.752874	21.6	97	56%	0.48	3.1	A	258	1.1	326
Santa Rita sites										
Small Santa Rita	31.885414, 110.88042	19.0	227	42%	0.23	7.8	SA	947	1.1	2
Large Santa Rita	31.880545, 110.883672	18.1	227	42%	0.23	8.1	SA	952	2.0	18
Huachuca sites										
Nr. Huachuca (DoD	31.540278, 110.334113	16.7	293	42%	0.34	11.0	SH	1453	1.9	1.3
Nr. Garden (DoD)	31.506705, 110.316744	16.6	335	42%	0.34	12.6	SH	1494	2.0	0.5
Nr. Ramsey (USFS)	31.468538, 110.294548	16.3	397	42%	0.34	15.1	SH	1533	1.3	0.3