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Changes in riparian plant communities due to a canal barrier traversing ephemeral stream channels in the Sonoran Desert

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ABSTRACT

The Central Arizona Project (CAP) is a large canal system that traverses hundreds of ephemeral stream channels in the Sonoran Desert. This longitudinal barrier alters flow during runoff events, causing water to pond behind the canal's wall. We asked: How has riparian vegetation of the ephemeral streams changed over the course of 35 years in response to canal construction? We compared field data (vegetation volume, woody plant stem density and size, and herbaceous cover) collected in distinct zones located upstream and downstream of the canal to unaltered controls.

By ponding water and inducing sedimentation of fine particles, the canal has created areas that support dense vegetation. The wettest zone has the greatest vegetation volume and plant height, and supports densities of *Prosopis velutina* that are six times greater than in the control zone. *Larrea tridentata* and other desert shrubs are displaced to the border of the wettest zone, but have greater height and stem diameter than typically occur in the desert owing to increased frequency of soil wetting in the canal-associated anthropogenic-floodplain. This research aids in understanding the impacts of canal barriers on desert riparian vegetation, and can be used to predict future outcomes of proposed canals in desert environments.

1. Introduction

Barriers such as roads, fences, dams and canals affect landscape structure and species distributions. With respect to terrestrial barriers, many studies address changes to wildlife abundance, genetic diversity and migratory patterns (Epps et al., 2005; Holderegger and Di Giulio, 2010; Krausman et al., 1993). Much of the research on aquatic barriers has focused on dams, particularly as they effect fish migration and riparian vegetation dynamics (Bergkamp et al., 2000; Merritt and Cooper, 2000).

The spatial distribution of vegetation along perennial streams and rivers is controlled to a large degree by hydrogeomorphic processes associated with flooding (e.g., sedimentation and scour) (Hupp and Osterkamp, 1985). In dammed perennial rivers, changes to these processes haves major effects on below-dam vegetation by influencing plant regeneration and survivorship (Levine and Stromberg, 2001). Yet, for streams in arid to semi-arid regions, where flow often is ephemeral, water availability is the predominant factor regulating vegetation abundance and distribution (Hupp and Osterkamp, 1996; Stromberg et al., 1996). In dryland regions, supplemental water resources are crucial for sustaining high productivity (Fu and Burgher, 2015) and exert strong influence on species distribution in or along channels (Shaw and Cooper, 2008; Tooth and Nanson, 2000). Our current understanding of desert plant communities' responses and adjustments to human-constructed barriers along ephemeral streams is in its infancy.

One structure that has created a longitudinal barrier to ephemeral streams is the Central Arizona Project (CAP) canal (Johnson, 1977). Construction of the concrete-lined CAP canal was initiated in 1973 to meet the growing water demands of municipal and agricultural areas in Arizona's desert. This twenty-year long project was one of the most costly (approximately 4 billion US dollars) and largest (541 km) canals built in the United States. Currently, the CAP canal intersects hundreds of ephemeral stream channels (locally referred to as washes or arroyos). The ensuing changes to stream hydrology may affect riparian plant communities along longitudinal (upstream to downstream channel) and lateral (channel to upland) directions (Blanton and Marcus, 2009; Brierley et al., 2006). The larger streams remain connected to their

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downslope counterparts through overchutes or culverts. However, smaller streams are in most cases dammed causing stormwater runoff to pool upslope behind the canal wall/berm. Thus, the CAP canal can either completely disrupt upstream-downstream connectivity of ephemeral stream channels or can modify their flow regimes through culverts and overchutes. The CAP canal also may affect vertical conductivity (surface to groundwater) (Boon, 1998). Remotely sensed studies indicate that xeroriparian vegetation on the downslope end has become even drier, leading to desertification, while areas on the upslope end become seasonally ponded and more mesic (Hamdan, 2012). As global populations and urbanization increase, so will the need for water. This water, in many places on Earth, will be supplied through canal construction on large scales (Beyth, 2007; Bagla, 2014). An estimated 33 percent of the Earth's continents are characterized as drylands of which 15 percent is inhabited by people (Parsons and Abrahams, 2009). Riparian vegetation along ephemeral channels comprises a small portion of these drylands (Knopf et al., 1988). However small these areas seem, they support an abundance of desert wildlife and vegetation and have high ecological value (Steward et al., 2012).

In this study we ask: How have the abundance, composition and distribution of riparian vegetation along ephemeral streams changed over the course of 35 years in response to construction of the CAP canal? We document spatial shifts in plant distribution along longitudinal and lateral river dimensions, thereby providing a much needed understanding of plant community changes in response to anthropogenically altered ephemeral channels. Understanding the effects of the canal on riparian vegetation is critical for implementing sustainable practices in desert environments.

2. Materials and methods

2.1. Study area

We addressed our questions by collecting and comparing field data between altered sections of stream channels and unchanged controls areas upstream from the CAP. Our study area is located at 33°44′53.09″ N, 112°28′27.93″ W near Wittmann, AZ, within the Basin and Range physiographic province. This area is a low-latitude warm desert (Sonoran Desert) with average annual precipitation of 22 cm. We randomly selected three ephemeral stream channels, all located on the same alluvial fan, on the lower piedmont surface of the Hieroglyphic Mountains (Fig. 1a). The alluvial fan deposits are late Tertiary and early to middle Quaternary (Huckleberry, 1994). The lower piedmont surfaces are characterized by sand, sandy loam sediment, gravel and cobbles. The ephemeral channels have anabranching characteristics and have widths that vary from approximately 1 m to 6 m. The main channels are characterized by a sandy to gravely surface substrate, but as the channels approach the canal barrier particle size becomes much smaller as fines are deposited by the impounded water during runoff events. Stream #3 has the smallest basin area.

The three study streams are not completely impounded by the canal; rather, they have connectivity via overchutes. However, even with the longitudinal connectivity through overchutes, stormwater no longer follows the same path as it did along the pre-canal stream channel. The stream channels are confined to drain through a pipe of a fixed diameter (183 cm), which ultimately causes water to flow laterally onto the desert floor (Hamdan, 2012). During periods of intense and prolonged precipitation, stormwater backfills and creates green-up zones that contain the main channel and a newly-created anthropogenic floodplain zones. This green-up zone (i.e., anthropogenic floodplain) increases in width as it approaches the canal's boundary. The main channel periodically overflows its banks to distances of approximately 200 m upstream from the CAP canal (Hamdan and Myint, 2015).

The main woody plant species at the study sites are a mix of Sonoran Desert upland shrubs (*Ambrosia deltoidea*, *Larrea tridentata*), xeroriparian shrubs (*Ambrosia ambrosioides*, *Baccharis sarothroides*), mesoriparian shrubs (*Baccharis salicifolia*), and desert

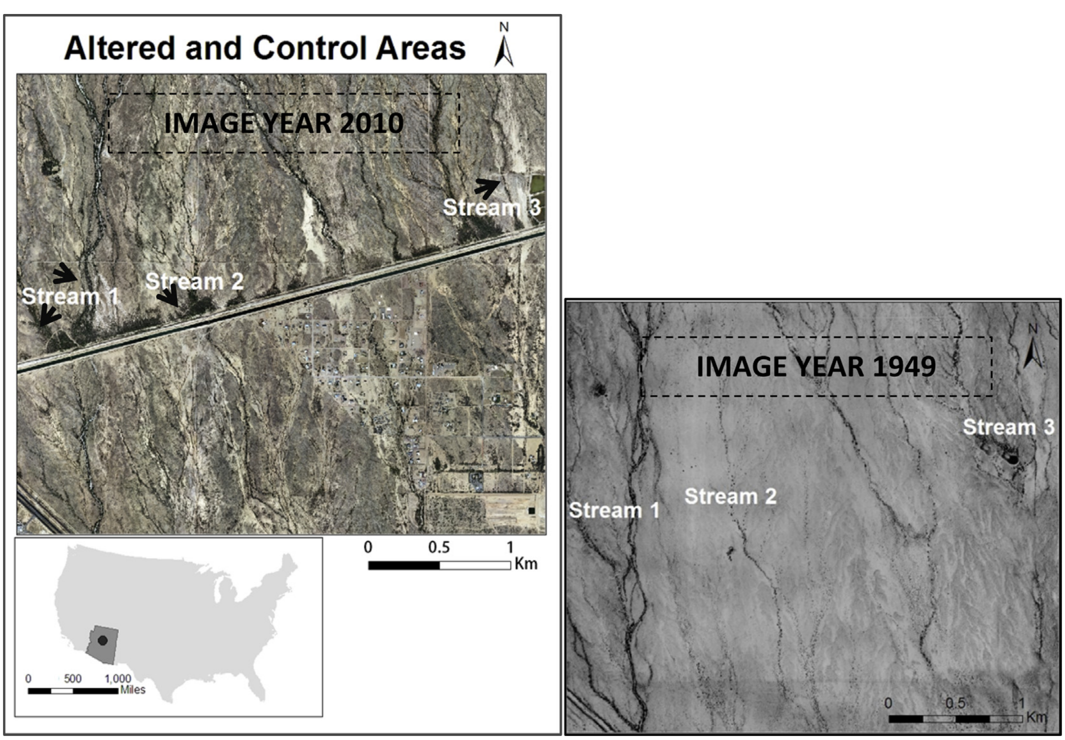

Fig. 1. Images of the study area after the construction of the CAP canal, in 2010 (1a, left) and before the construction of the CAP canal, in 1949 (1b, right) (Sonoran Desert, Arizona, USA).