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Bidirectional recovery patterns of Mojave Desert vegetation in an aqueduct pipeline corridor after 36 years: II. Annual plants

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ABSTRACT

We studied recovery of winter annual plants in a 97-m wide disturbed aqueduct corridor in the Mojave Desert 36 years after construction. We established plots at 0, 20, and 40 m from the road verge at the corridor center and at 100 m in undisturbed vegetation. We recorded 47 annual species, of which 41 were native and six were exotic. Exotic species composed from 64 to 91% of total biomass. We describe a bilateral process of recovery: from the road verge to the outward edge of the corridor and from undisturbed habitat into the corridor. Native annual plants significantly increased in richness from road verge to undisturbed vegetation, but not in density, biomass, or cover. In contrast, exotic annual plants increased in density, biomass, cover and richness with increasing distance from the road verge. The species of colonizing shrubs and type of canopy cover affected density, biomass, and richness of annuals. Species composition of native annuals differed significantly by distance, suggesting secondary succession. In general, native annuals were closer to achieving recovery on the 40-m plots than at the road verge. Recovery estimates were in centuries and dependent on location, canopy type, and whether considering all annuals or natives only.

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1. Introduction

Disturbances in deserts and to desert vegetation worldwide occur as a result of natural events such as flooding, wind erosion, or herbivory from rabbits, rodents, and other animals or as a consequence of anthropogenic activities (MacMahon, 1999). While the literature on disturbances, succession, and recovery of desert perennial plants has grown, a similar literature on annual plants has lagged (e.g., MacMahon, 1999; Abella, 2010), probably because annual plants are dependent on rainfall and less available for study. Frequency and abundance of annuals are affected by many factors, e.g., timing and level of precipitation (Brooks and Berry, 2006), microhabitats (Brown and Porembski, 2000), interference or competition from non-native or exotic species (El-Ghareeb, 1991; Brooks and Berry, 2006), and herbivory (Brooks et al., 2006; Sassi et al., 2009). The type, severity, and history of disturbances also are important and range from settlements and towns (Knapp, 1992; Webb et al., 2009), agriculture (El-Ghareeb, 1991), livestock grazing (Webb and Stielstra, 1979; Brown and Al-Mazrooei, 2003; Sassi et al., 2009), roads (Johnson et al., 1975), fires (Abella, 2010), military vehicles (Prose and Wilshire, 2000), and contamination (Brown and Porembski, 2000). Annual plants historically were described as early pioneers and colonizers of disturbed areas, based on research conducted in non-desert areas (e.g., Frenkel, 1970; Whittaker, 1975). Results of studies on successional stages of annuals have varied considerably and appear to be dependent on the aforementioned variables as well as length of time since disturbance, status of the seed bank, soil type and surficial geology, vegetation type, and presence of exotic plants.

We studied recovery of winter annual plants in a disturbance

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corridor created by construction of a buried aqueduct in the Mojave Desert. Transportation and utility corridors are common throughout North American deserts and elsewhere in the world, fragment landscapes, and may leave enduring impacts on vegetation. Impacts are especially noticeable in deserts where rainfall is low and variable, and regrowth of vegetation does not quickly erase signs of disturbance. Such corridors provide important opportunities to document natural recovery processes and to experiment with restoration techniques. In the Mojave and Sonoran deserts, botanists and ecologists have previously reported on responses of vegetation to disturbances along roads and from construction of roads, pipelines, transmission lines and aqueducts (Johnson et al., 1975; Vasek et al., 1975a, 1975b; Kay, 1979, 1988; Lathrop and Archbold, 1980; Brown and Porembski, 2000; Hessing and Johnson, 1982; Abella et al., 2007; Abella, 2010). The primary focus of these earlier papers was recovery of perennial shrubs and other perennial vegetation.

Germination and production of annuals may be affected by microhabitat, including the location (intershrub space or under a shrub canopy); the species, size, structure, and canopy type of the shrub; and whether the shrub is living or dead (Went, 1942; Muller, 1953; Muller and Muller, 1956; Halvorson and Patten, 1975; DeSoyza et al., 1997). Therefore, in disturbed areas, the species of colonizing perennial shrubs may in turn affect recovery of annual species. Ecologists and botanists have identified perennial plant species that colonize disturbed areas in the Mojave Desert. Most of these plants are shrubs. Shrubs can be categorized as short- or long-lived, and the short-lived species tend to be the colonizing or pioneer species (Vasek et al., 1975a, 1975b; Abella, 2010). Common short-lived species include *Ambrosia salsola*, *Eriogonum fasciculatum*, and *E. inflatum*. Two common long-lived species are *Larrea tridentata* and *Ambrosia dumosa* (Vasek et al., 1975a), both of which have also demonstrated pioneering capacities. Vasek (1983) presented evidence that succession occurs in perennial vegetation in the Mojave Desert and pointed out that pioneer species such as *A. salsola* invade, become established in disturbed areas, and represent early stages in succession (Vasek et al., 1975b). The question then arises whether recovery of annual plants parallels that of associated perennial shrubs or is on a separate trajectory.

Recovery of annual communities after disturbance and the potential for succession are other important topics. Abella (2010), in a review of the limited literature on recovery of annuals in Mojave and Sonoran deserts after disturbance, reported that annual communities “seem to reestablish fairly rapidly, and in moister years little difference may exist in cover and species composition between disturbed and undisturbed areas after disturbances.” In a five-year study of revegetation of a powerline corridor in the Sonoran Desert, Hessing and Johnson (1982) reported that the herb community probably represented a seral stage. Vasek (1979/1980, 1983) suggested that the topic deserves in-depth exploration and noted that rich, dense annual vegetation was correlated with large old clones of *L. tridentata* in the southern Mojave Desert, a stable community persisting for several thousand years. He suggested that “some constellations of annual species may be members of stable old communities and therefore probably have evolved intricate highly integrated adaptations for long persistence in stable desert conditions” (Vasek, 1983).

We report here on our research on colonization and recovery of winter annual plants at a site along a severely disturbed aqueduct corridor in the Mojave Desert of California. Construction of the 219-km, second Los Angeles aqueduct was initiated in 1968 and completed in 1970 (Kay, 1979, 1988). The buried pipe of the aqueduct extends from the Great Basin Desert south through the western Mojave Desert to the Los Angeles Reservoir complex in southern California. Our general objectives were to characterize recovery of annual plants in the aqueduct corridor 36 years after disturbance. We addressed the following topics and questions:

1) Distance effects—How similar are composition, density, biomass, cover and richness of native and exotic annuals at different distances from the service road in the disturbed right-of-way of the aqueduct corridor to adjacent undisturbed desert? For example, does recovery of annuals follow a gradient from the center of the right-of-way (service road) to undisturbed habitat?
2) Effects of perennial shrub canopies and intershrub spaces—What effects do live and dead perennial plant species, specifically shrubs, have on annual plant composition, density, biomass, cover, and richness? Are the characteristics of annual plants similar under perennial shrub canopies compared to intershrub spaces for different species of perennial shrubs, and for different perennial canopy classes?
3) Evidence for succession in recovery of annual plants—Is there evidence for secondary succession in the recovery process within the aqueduct corridor? and
4) Recovery time—How many years might be required to achieve a composition of annual plants similar to adjacent undisturbed desert?

2. Methods

2.1. Study site

We selected a 1.17-km stretch of the Los Angeles aqueduct right-of-way in Kern County between UTM points 411260E, 3935144N and 412358E, 3935560 N (NAD 83, Zone 11N) at an elevation of 1048 m (Fig. 1A). The right-of-way for construction was 97-m wide with a dirt service road through the center. In 1970–1971, the City of Los Angeles, Department of Water and Power (LADWP), ripped the compacted soil (25 cm deep on 61 cm furrows) in much of the aqueduct corridor and then planted seeds of seven species of perennial shrubs at six experimental sites. We chose this site because Kay (1979, 1988) documented and photographed the aqueduct 9 and 12 years (in 1979 and 1988) after construction was completed, and he recorded the process of recovery of annual and perennial plants. He further identified the site as unseeded.

The site has uniform topography typical of large stretches of the aqueduct corridor in the Mojave Desert, is devoid of stream channels, and is on the broad alluvial fan of the Scodie Mountains in Indian Wells Valley. Soils are from the Dovecanyon–Koehn association on 2–8% slopes and are characterized as alluvium derived from granite with loamy sand, coarse sandy loam and gravelly coarse sandy loam (depending on depth) and sand (U.S. Department of Agriculture, Natural Resources Conservation Service [NRCS] 2008). Vegetation is a *L. tridentata–A. dumosa* plant alliance (Sawyer et al., 2009), in a community dominated by *A. dumosa*. Average annual precipitation is 150 mm, most of which occurs in fall and winter months (U.S. Department of Agriculture, NRCS, 2008). Prior to and during the study, rainfall for the winter of 2005–2006 was 72% of the long-term average at the Inyokern weather station, 17 km northwest of the site and at a lower elevation, 743 m (National Oceanic Atmospheric Administration, 2005–2006, Inyokern weather station). However, at the study site in spring 2006, annual plants were common and below average winter precipitation (as recorded at the Inyokern weather station) did not appear to affect plant numbers.