



Bidirectional recovery patterns of Mojave Desert vegetation in an aqueduct pipeline corridor after 36 years: I. Perennial shrubs and grasses

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ARTICLE INFO

Article history:

Received 15 September 2013

Received in revised form

15 January 2015

Accepted 4 March 2015

Available online 13 March 2015

Keywords:

Linear disturbance

Succession

Larrea tridentata

Ambrosia dumosa

Ericameria nauseosa

Ambrosia salsola

ABSTRACT

We studied recovery of 21 perennial plant species along a severely disturbed aqueduct corridor in a *Larrea tridentata*-*Ambrosia dumosa* plant alliance in the Mojave Desert 36 years after construction. The 97-m wide corridor contained a central dirt road and buried aqueduct pipeline. We established transects at 0 m (road verge), 20 m and 40 m into the disturbance corridor, and at 100 m in undisturbed habitat (the control). Although total numbers of shrubs per transect did not vary significantly with distance from the verge, canopy cover of shrubs, species richness, and species diversity were higher in the control than at the verge and other distances. Canopy cover of common shrubs (*Ericameria nauseosa*, *Ambrosia salsola*, *A. dumosa*, *L. tridentata*, *Grayia spinosa*) and perennial grasses (*Elymus elymoides*, *Poa secunda*) also varied significantly by location. Discriminant analysis clearly separated the four distances based on plant composition. Patterns of recovery were bidirectional: secondary succession from the control into the disturbance corridor and inhibition from the verge in the direction of the control. Time estimated for species composition to resemble the control is dependent on location within the disturbance corridor and could be centuries at the road verge. Our findings have applications to other deserts.

Published by Elsevier Ltd.

1. Introduction

The Mojave, Sonoran, and Chihuahuan deserts of North America and the Monte Desert of South America have many similarities, including several genera of trees, shrubs, and perennial grasses (Turner et al., 1995; Roig et al., 2009; Baldwin et al., 2014). One genus of shrubs (*Larrea*, family Zygophyllaceae) is represented by four species, one in North America (creosote bush, *Larrea tridentata*) and three in South America (*Larrea divaricata*, *Larrea cuneifolia*, *Larrea nitida*) (Laport et al., 2012). *L. tridentata* is the predominant and widespread shrub of North American deserts (Turner et al., 1995) and *Larrea* spp. characterize the Monte Desert in South America (Roig et al., 2009). *Larrea* spp. are part of many simple and complex vegetation associations and communities (e.g.,

McAuliffe, 1988; Turner et al., 1995; Guevara et al., 2009). The deserts of North and South America also share some commonalities in historic and current land uses and disturbance regimes: settlements and urbanization, occupation of riparian areas, development of agriculture, livestock grazing, extraction of wood, and fire (e.g., Gibbens et al., 2005; Lovich and Bainbridge, 1999; Guevara et al., 2009; Villagra et al., 2009). Degradation and desertification from the accumulation of anthropogenic land uses are widespread in these New World deserts.

The recovery of disturbed lands has been an important topic in ecology for the last century (Walker, 2012). Desert ecologists have focused on identifying and describing anthropogenic disturbances, succession and recovery of vegetation and soils, time required for recovery, and whether recovery could be enhanced by remediation (e.g., Lovich and Bainbridge, 1999; Weigand and Rodgers, 2009; Guevara et al., 2009). In North America, vegetation alliances with *L. tridentata* have received considerable attention. Severe disturbances result after vegetation and surface layers of soil are scraped away, trenches are dug for pipelines, town sites are abandoned, or fires have consumed vegetation. Several authors have described

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early stages of succession and noted that the Mojave Desert is slow to recover after disturbance (Vasek, 1979/1980; Lathrop and Archbold, 1980a, 1980b; Webb et al., 2009; Abella, 2010). Estimates for perennial plant species to re-occupy disturbed areas range from decades to centuries, depending on severity and extent of disturbance, precipitation patterns, soil types, landforms, surficial geology, and other factors. Further, estimated times for recovery depend on whether the objective is to attain a desired perennial plant density, biomass, canopy cover, or floristic composition similar to adjacent, undisturbed lands. The longest times projected for recovery are for floristic composition (Vasek et al., 1975a, 1979/1980; Lathrop and Archbold, 1980b; Bolling and Walker, 2002; Webb et al., 2009; Abella, 2010). Most studies of recovery have involved examples of secondary succession; however, Vasek and Lund (1980) described an example of primary succession at the edges of a dry lake bed in the Mojave Desert.

Linear corridors of disturbance, specifically utility rights-of-way for pipelines, aqueducts, and transmission lines, are special cases. These rights-of-way, often hundreds of kilometers in length and widespread throughout North American deserts, are narrow in width and often have associated unpaved access roads. Ecologists and botanists have documented plant succession and partial recovery from linear disturbances in the Mojave Desert (Vasek et al., 1975a, 1975b; Kay, 1979, 1988; Lathrop and Archbold, 1980a, 1980b; Abella et al., 2007).

We designed a study to determine the status of recovery of perennial vegetation in a *L. tridentata* alliance along the second Los Angeles aqueduct 36 years after construction. Construction of the second Los Angeles aqueduct created a severe linear disturbance traversing 219 km of Great Basin and Mojave deserts and the San Gabriel Mountains (Kay, 1979, 1988; Baldwin et al., 2014). The disturbance involved removing soil and vegetation sufficient to bury the aqueduct pipe, construction of a dirt service road, breaking up compaction after construction, and continuously maintaining the road through the middle of the 97-m wide corridor (Kay, 1979, 1988). Few studies are available describing natural recovery of vegetation for similar linear disturbances for the Mojave Desert (Johnson et al., 1975; Lathrop and Archbold, 1980a; Abella et al., 2007; Webb et al., 2009). Most studies (summarized in Webb et al., 2009; Abella, 2010) on natural recovery of vegetation have dealt with large and irregularly-shaped disturbances (towns, fires, military maneuvers) or roads and are not necessarily applicable to the unique characteristics of an aqueduct right-of-way corridor with a maintained dirt road at the center.

Our objectives were to address topics that would provide basic information on succession and the recovery process of perennial plants in the *L. tridentata*-*Ambrosia dumosa* vegetation alliance (Sawyer et al., 2009) under these types of disturbance scenarios and to provide information for abbreviating the recovery process. Our focus was not only on the two more common and well-known species of shrubs but also on the other perennial species and their potential inter- and intra-specific associations. Our questions were: 1) Do perennial plants differ in total numbers, canopy cover, or canopy types (live, dead, or a combination of live and dead) within the disturbed right-of-way of the aqueduct corridor and between the corridor and adjacent undisturbed vegetation? 2) Do species composition, richness, and diversity vary with distance from the disturbance at the road verge of the right-of-way? 3) Do patterns of contagion within and between species exist? 4) Which species serve as nurse shrubs for other perennials? and 5) How much time might be required for perennial vegetation in the disturbed right-of-way corridor to recover to conditions similar in adjacent undisturbed habitat? These questions are important to address because hundreds of square kilometers of Mojave, Sonoran, and Great Basin deserts require restoration of degraded habitat

from solar and wind development and other activities (e.g., California Energy Commission, 2014). Similarly, habitats of rare and threatened plant and animal species require restoration if the species are to thrive, e.g., the Mohave ground squirrel (*Xeromorphophilus mohavensis*), a species endemic to the western Mojave Desert, and Agassiz's desert tortoise (*Gopherus agassizii*) (California Department of Fish and Wildlife (2015a), 2015b). Both species require cover of shrubs to protect them from temperature extremes and predators.

2. Methods

2.1. Site description

The site is a 1.17-km stretch of the second Los Angeles aqueduct right-of-way in Kern County between 35° 33' 32" N, 117° 58' 22" W, 1048 m (Fig. 1A). The topography is uniform and typical of large stretches of aqueduct corridor and *L. tridentata* vegetation in the Mojave Desert, is devoid of desert washes, and is on a broad alluvial fan. 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, gravelly coarse sandy loam (depending on depth), and sand (U.S. Department of Agriculture, Natural Resources Conservation Service [USDA NRCS], 2008). *L. tridentata* is a canopy-emergent shrub in a *L. tridentata*-*A. dumosa* alliance with 19 other species of perennial shrubs, grasses and cactus (Table 1). The arid climate has an average annual precipitation of ~150 mm with most precipitation occurring in fall and winter months (USDA NRCS, 2008). We selected the site because Kay (1979, 1988) documented and photographed site treatment and recovery of perennial shrubs twice after construction, once in 1979 (Fig. 2A) and again in 1988 (Fig. 2B), and because the site is typical of about 70% of the aqueduct corridor.

In 1968, the Department of Water and Power for the City of Los Angeles (LADWP) bulldozed the right-of-way for the aqueduct and removed all vegetation from the 97-m wide corridor. When completed, the right-of-way corridor contained the aqueduct and dirt service road in the center with adjacent disturbed land. In 1971–1972, after completion of the aqueduct, much of the construction zone adjacent to the service road was ripped to a depth of 25 cm on 61-cm centers to reduce soil compaction and to facilitate seedling growth of naturally colonizing shrubs (Kay, 1979, 1988, Fig. 2A). Although a few parts of the aqueduct corridor were seeded with *A. dumosa*, *Ambrosia salsola*, *Atriplex canescens*, *Atriplex polycarpa*, *Ephedra nevadensis*, *L. tridentata*, and *Lepidospartum squamatum*, the study site we selected had not been seeded. The LADWP maintains the service road by grading, and a low berm is often present at the road verge.

The study site and much of the aqueduct corridor in the Mojave Desert are on public land administered by the U.S. Department of the Interior, Bureau of Land Management (BLM). Livestock have grazed the area since the 1870s (Wentworth, 1948; U.S. BLM, 1980). Other nearby anthropogenic uses include the first Los Angeles aqueduct, constructed between 1905 and 1913 (Nadeau, 1997).

2.2. Sample design for vegetation

The disturbance corridor at the sampling site was approximately 90 m wide with a 7-m wide graded dirt service road in the center. We established fourteen 20-m × 1-m randomly selected transects at each of four distances (0, 20, 40, and 100 m) parallel to the north verge of the service road into undisturbed habitat for a total of 56 transects (Fig. 1B). The 0-m transects were next to the road berm but not on it, were the closest to the buried aqueduct, and were designated as “verge” sites. Transects at 20-m and 40-m distances

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