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Restoring a desert ecosystem using soil salvage, revegetation, and irrigation

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ABSTRACT

Effective restoration techniques are needed in many arid lands for reversing degradation and desertification. In the Mojave Desert of the American Southwest, we tested experimental techniques for enhancing survival of salvaged perennial plants and their establishment on severely disturbed sites. Rooting hormone, slurry, and soaking treatments were ineffective at enhancing plant survival of salvage. Survival of salvaged plants after one year of nursery care was 48% (1017 of 2105 plants). Of these survivors, 50% survived 27 mo after transplanting back to field restoration sites. On restoration sites, irrigation increased transplant survival by 50% (DRiWATER, a slow-release gel) and 79% (hand watering), compared to no irrigation (35% survival). Providing salvaged topsoil as a growth medium, without irrigation, doubled survival, nearly equivalent to irrigating plants. Survival varied by an order of magnitude across 23 species, and species amenable to salvage also generally survived transplanting to field sites ($r = 0.82$ between salvage and transplant survival). Selecting species amenable to restoration and identifying treatments effective at enhancing survival can reestablish native perennial plants, often considered a first step in restoring desert ecosystems.

1. Introduction

When desert ecosystems are severely disturbed, natural recovery may be slow or not provide functions for biodiversity conservation and ecosystem services (Allen, 1995; Bainbridge, 2007; Cortina et al., 2011). Active revegetation and restoration using effective, practical techniques can promote recovery and ecological functions (Aronson et al., 1993; Grantz et al., 1998; Burke, 2008). For example, revegetating desertified land in the Ulan Buh Desert reduced sand encroachment by 85% to Jilantai Salt Lake, among the most economically important salt sources in China (Gao et al., 2002). To achieve post-mining restoration in the Western Australia arid zone, soil treatments, combined with reintroducing plant propagules, created conditions suitable for plant establishment during times of high rainfall (Commander et al., 2013).

While these examples illustrate that revegetation is achievable, the same factors in deserts that limit natural recovery from disturbance complicate restoration (Allen, 1995; Burke, 2001; Brown and Al-Mazrooei, 2003). Intense granivory by invertebrates and mammals can remove large quantities of seed, and the amount remaining is subject to infrequent conditions suitable for germination (Suazo et al., 2013). An advantage of planting nursery-grown plants is that it bypasses necessity for field germination and seedling establishment (Bean et al., 2004). However, nursery-grown outplants face intense herbivory, often dry and nutrient-poor soil, and extreme climatic conditions (Commander et al., 2013). Selecting species most amenable to revegetation techniques and employing treatments to promote plant establishment can help increase restoration effectiveness (Abella and Newton, 2009). Protecting plants from herbivory (e.g., by enclosing plants in mesh cages), providing supplemental water, and promoting soil health are examples of treatments that can enhance plant survival (Bainbridge, 2007). Salvaging topsoil from areas to be disturbed for later re-application can promote soil health by retaining organic matter, soil microbes, and water-holding capacity, which may enhance plant establishment (Ghose, 2001). Reestablishing native perennial plants is often considered a first step in restoring desert ecosystems, because perennial plants form fertile islands. These fertile islands of nutrient-enriched soil and

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ameliorated microclimate regulate spatial patterning of biological activity and recruitment of annual plants (Padilla and Pugnaire, 2006; Cortina et al., 2011; Abella and Smith, 2013).

The objective of this study was to determine influences of species selection and experimental treatments on survival of salvaged perennial plants for restoration in a disturbed desert ecosystem. First, we anticipated that applying rooting hormone and soaking plants in water or water-retaining slurry upon salvage would increase species' ability to survive salvage (c.f. Fidelibus and Bainbridge, 1994). Second, we expected that transplant survival would be greater on field sites receiving salvaged topsoil compared to no topsoil (Burke, 2008). Third, we anticipated that DRiWATER (a slow-release irrigation gel) would increase survival similar to watering transplants by hand (Aref et al., 2006). Fourth, we expected ability to survive transplanting to vary among 23 species we evaluated (Bean et al., 2004). We conducted the experiment in a nationally designated protected area, where management goals include conserving biodiversity while allowing human recreation, also making esthetic restoration a priority.

2. Materials and methods

2.1. Study area and experimental sites

We conducted this experiment within the 563,513-ha Lake Mead National Recreation Area, managed by the National Park Service, in the eastern Mojave Desert of southwestern USA (Fig. 1). The Mojave is a hot desert receiving most of its precipitation in winter, with the remainder mainly monsoonal summer storms in July–August. A weather station near our experimental sites reported 1973–2012 averages of 16 cm/yr of precipitation (64% falling from November through April), 14 °C January daily high, and 41 °C July daily high (Valley of Fire State Park Weather Station, 610 m in elevation, Western Regional Climate Center, Reno, Nevada). Vegetation physiognomy is desert shrubland, with dominance by *Larrea tridentata*, *Ambrosia dumosa*, and *Atriplex hymenelytra*. Owing to numerous invertebrates, small mammals such as *Lepus californicus* (jackrabbit), and larger herbivores including *Ovis canadensis nelsoni* (bighorn sheep), granivory and herbivory is intense (Suazo et al.,

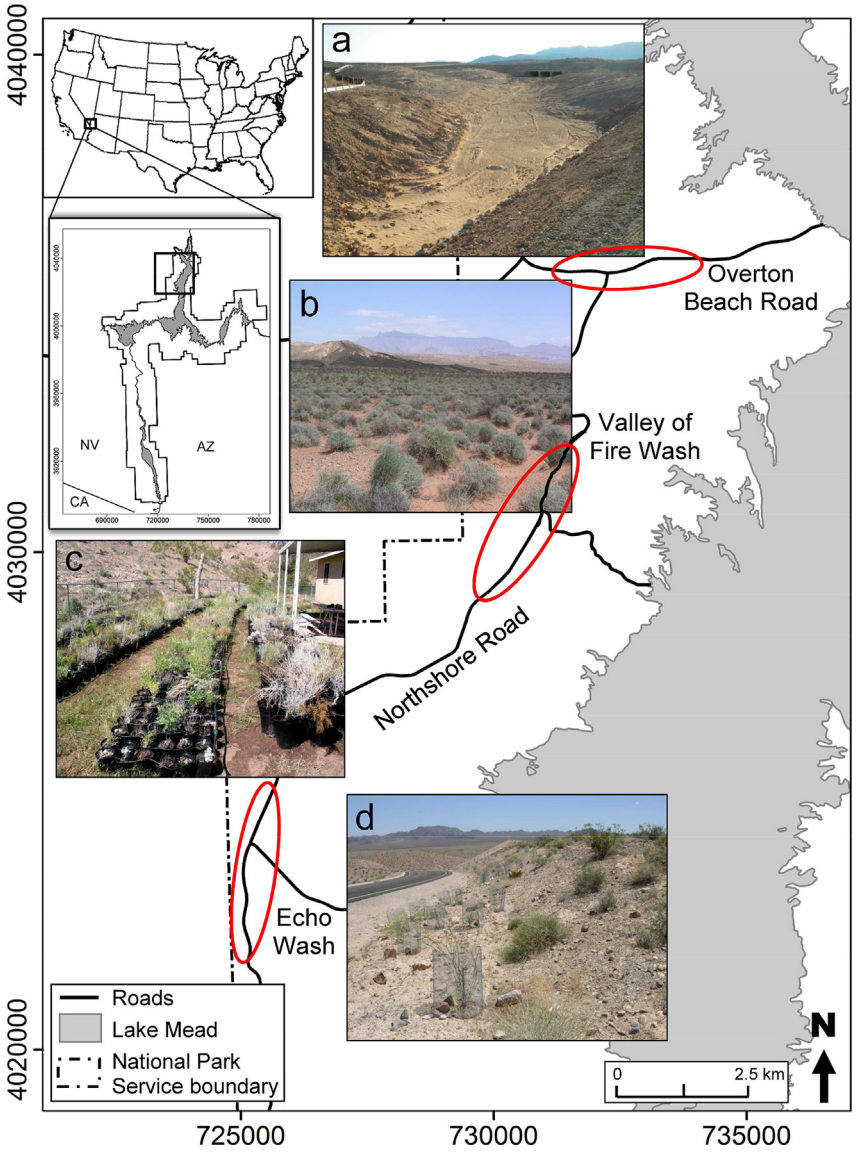

Fig. 1. Location of Lake Mead National Recreation Area in the Mojave Desert, USA, and study sites where we conducted a desert restoration experiment. Photos: a, severely disturbed site (after road removal) to be revegetated at Overton Beach; b, example of undisturbed desert at Valley of Fire Wash site; c, field nursery housing salvaged plants; and d, transplants back in the field at Echo Wash. Photo d by S.R. Abella; others by L.P. Chiquoine. Coordinates are UTM (m), North American Datum 1983.