density of about 1000 seeds/m$^2$, which we found produces the highest seed germination, bed expansion, and greatest rate of lateral shoot production (Granger and others 2002, Granger and others 2000 a, b).

Since fall 1999, we have conducted small-scale (less than 0.25-acre) tests with the seeder. In fall 2003, we plan to conduct a large-scale seeding in Narragansett Bay.

We currently have a patent pending on the seeder, and a local machine shop that has worked with us to design the machine can replicate it for sale to interested parties. In addition, we will soon publish a pamphlet that provides details about this seeding method and how to get started.

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**Restoring Southern California's Kelp Forests.** 2002-2003. Collier, C.E., California Coastkeeper Alliance, Los Angeles, CA. **Wild Earth** 12(4):29-33.

In partnership with the National Oceanic and Atmospheric Administration Fisheries' Community-Based Restoration Program, the California Coastkeeper Alliance has begun the Southern California Regional Kelp Restoration Project to restore the area's kelp (*Macrocystis pyrifera*) "forests." The project has a significant level of community involvement and relies on laboratory-grown kelp as a primary restoration tool. Many science classrooms have portable aquaria, known as "eco-Karts," which allow students to study and grow some of the kelp used in restoration efforts. Divers plant, maintain, and monitor kelp forests, tagging kelp transplants for survivorship, growth, and canopy development. Preliminary results show a 14-percent survival rate, higher that the projected 10 percent. For more information, visit www.cacoastkeeper.org.

## OTHER COMMUNITIES

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**A Prescription for Restoring Native Vegetation on Former Agricultural Land (Arizona)**


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During the 1900s, large tracts of native vegetation in the low-elevation deserts of Arizona were cleared for irrigated crop production. As the region's economy changed, much of this land was retired from agriculture and now occupies roughly 850 mi$^2$ (2,200 km$^2$) (Jackson and others 1991, Bean 2002). Unfortunately, these lands often exhibit little vegetative recovery, especially in areas with clay soils (Karpiscak 1980).

Any successful effort to restore native plant communities on these lands must address the realities of low and variable precipitation, extreme temperatures and evapotranspiration, few available propagules, and the relatively static population dynamics of native desert plant communities. We have developed a prescription for restoring native desert plants to large areas (more than 2,500 acres {1,000 ha}) of former agricultural land in south-central Arizona that uses drip-irrigated transplants to simultaneously address the problems of limited water availability and invariant population dynamics of native perennial species. Many of these transplants begin producing seed in the first year, which creates a seed rain and addresses the issue of limited propagule availability.

Our study site is located on adjacent properties with functioning wells that are about 40 miles (70 km) southwest of Phoenix, and owned by Arlington Valley Energy and Mesquite Power. Soils are loams and clay loams. In March 2001, we experimented with two different methods of irrigation (drip and furrow) and propagule types (seed and two transplant sizes). We were most successful in achieving one-year survival of native species in the desired densities and proportions, while minimizing establishment of invasive exotics, when using drip-irrigated, one-gallon (3.8-l) container-sized transplants. We now plant a mixture of 15 native species (Table 1) at densities of 100 plants/acre (250 plants/ha).

Our plants, which are all derived from seed, are ordered from a nursery up to one year in advance of planting, since we require large quantities and unusual species. Provenance of the seed used to grow the transplants is unknown, although local ecotypes—if they exist—may not have any adaptive advantage over nonlocal ecotypes given that our site conditions no longer resemble those that existed before cultivation. We use a low-cost drip irrigation system that is similar to ones used in vegetable

Table 1. Native desert species planted at the Arlington Valley Energy Project and Mesquite Power properties.

| Scientific name | Common name |
|---|---|
| *Acacia greggii* | catclaw acacia |
| *Ambrosia dumosa* | burrobush |
| *Aristida purpurea* | purple threeawn |
| *Atriplex canescens* | fourwing saltbush |
| *Atriplex lentiformis* | quailbush |
| *Atriplex polycarpa* | cattle saltbush |
| *Baileya multiradiata* | desert marigold |
| *Larrea tridentata* | creosotebush |
| *Lycium exsertum* | Arizona desertthorn |
| *Muhlenbergia porteri* | bush muhly |
| *Parkinsonia microphylla* | yellow paloverde |
| *Pleuraphis rigida* | big galleta |
| *Prosopis velutina* | velvet mesquite |
| *Senna covesii* | Cove's cassia |
| *Sphaeralcea ambigua* | desert globemallow |

production in the lower Colorado River Valley. The emitters have flow rates of 0.56 gallons (2.1 l) per hour at 10 psi. We custom designed the rest of the system to accommodate variations in well specifications, size of the sites, and field topography. We apply a preemergent herbicide (Pendulum®) according to label specifications at the same time that the drip lines are buried in the field. Irrigation systems are installed and tested one to two months before planting so that we can address any problems with water delivery prior to plant delivery. We plant in early November or late March, placing the transplants into wetted soil that has not been amended or fertilized since the area was last planted with crops.

Although some species do no require all elements of the planting protocol to perform optimally, the large-scale nature of this effort does require a uniform protocol. Most species have flowered and produced seed within one year. Species that have most successfully spread to interspaces include velvet mesquite (*Prosopis velutina*), desert marigold (*Baileya multiradiata*), and desert globemallow (*Sphaeralcea ambigua*). Fourwing saltbush (*Atriplex canescens*) and quailbush (*A. lentiformis*) perform well when transplanted from smaller containers (rose pots) and have also shown high establishment when seeded with irrigation. We have also observed that creosotebush (*Larrea tridentata*) is particularly sensitive to overwatering.

Our total cost is about $1,800/acre ($4,600/ha). This includes the cost of the irrigation system and its installation, maintenance, and repair; plants and their transplanting; irrigation water; hand-weeding to remove exotics; a management fee; and plant replacement. The plantings will receive supplemental irrigation during the first year, and after that, only if necessary. In 2001 and 2002, we planted about 360 acres (150 ha) using this prescription. We planted another 900 acres (360 ha) starting in March 2003, and plan to plant some 3,000 additional acres (1,200 ha) in future years.


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## Soil Microorganisms Affect Survival and Growth of Shrubs Grown in Competition with Cheatgrass (New Mexico)


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When cheatgrass (*Bromus tectorum*) and other invasive annual grasses infest rangelands, they create changes in soil moisture regimes, soil microorganism communities, fire frequency, and severely limit shrub establishment. Reversing these changes and reestablishing a functional native plant community is a difficult and often unsuccessful process.

Research by Harper and Pendleton (1993) suggests that mycorrhizal fungi may play an important role in plant uptake of atmospheric nitrogen that is fixed by soil crusts as well as more immobile elements, such as phosphorus. Here, we report on a greenhouse experiment in which we examined the effects of soil microorganisms on growth and survival of five native western shrub species planted with and without cheatgrass.

In 1997, we tested the effects of various fertility and inoculum treatments on Mormon tea (*Ephedra viridis*), blackbrush (*Coleogyne ramosissima*), sand sagebrush (*Artemisia filifolia*), black sagebrush (*A. nova*), and rubber rabbitbrush (*Chrysothamnus nauseosus ssp. hololeucus*). We placed germinated seed of the five species into 1-liter pots filled with steam-sterilized, low-fertility bank sand amended to one of two fertilizer levels (0 and 5 oz. per cubic foot Osmocote 17-7-12). We used four inoculation treatments: 1) algal crust inoculum consisting of dried and ground pelletized algal slurry of the genus *Schizothrix* (Buttars and others 1998) applied at a rate of 100 g/m$^2$; 2) arbuscular mycorrhizal inoculum consisting of 50-100 spores extracted from soil collected where sand sagebrush, Mormon tea, and blackbrush were