plants; and the relative cover (percent total cover of all plants) of these same three plant categories. We also compared the floral composition of each natural pool with those of the created pools.

The results of this experiment strongly suggest that inoculation produces species richness and plant cover in created pools that are comparable, if not greater, than that found in existing vernal pools (Fig. 1 A1 and B1). The inoculated pools also excluded non-native wetland species as well as or better than source pools (Fig. 1 A2 and B2). However, this difference probably resulted from our ability to control the hydrology in the created pools, whereas some of the source pool samples were taken where shallow water may have given non-natives a competitive advantage. Some of the source pool, non-native species that did not grow in created pools were: bristly ox-tongue (*Picris echioides*), curly dock (*Rumex crispus*), prickleseed buttercup (*Ranunculus muricatus*), Italian ryegrass (*Lolium multiflorum*), and Mediterranean barley (*Hordeum marinum* ssp. *gussoneanum*). Inoculated pools also had low values for both the richness and cover of upland plants, a desirable result (Fig. 1, A3 and B3). We also discovered that the inoculated pools were able to retain the floras of their specific source pools, at least for the duration of our study.

We found few differences in species richness and cover among the three inoculation methods, although they were different in terms of cost and difficulty. Of the techniques we used, Sods was clearly the most time consuming and costly because it required marking and cutting small blocks of sod, transporting them by hand, and carefully putting them into the created pools. Soil and SV had the advantage of economy. Soil did, however, provide a small amount of nutrients to the new pools, which SV did not. Overall, these factors could be the major influences in deciding which method to use.

Acknowledgments

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References

Dodero, M. 1999. Vernal pool flora translocation techniques in southern California. Page 68 *in* Abstracts of the SER Eleventh Annual International Conference.

Holland, R.F. and S.K. Jain. 1997. Vernal pools. Pages 515-533 *in* M.G. Barbour and J. Major (eds.), Terrestrial Vegetation of California. New York: Wiley-Interscience.

Stromberg, L.P. 1997. Personal communication.

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Indian Mangrove Research Continues Toward Greater Community Use and Ecosystem Restoration. 1999. Balakrishna, P., M.S. Swaminathan Research Foundation, 3rd Cross St., Taramani Institutional Area, Chennai (Madras) 600-113, India. **Diversity** 15(2):15.

In response to the large-scale destruction of mangrove forests throughout India, the M.S. Swaminathan Research Foundation developed a program to propagate several species using both conventional and biotechnological techniques. To date, the Foundation has used tissue culture to successfully develop propagation protocols for several species, including blind-your-eye (*Exoecaria agallocha*) and holly (*Acanthus ilicifolius*) mangroves. In 1995, the Foundation staff transplanted 55,000 plants in degraded areas, where as many as 70 percent survived. Current projects include the Muthupet mangrove restoration in southeastern India, and research into the molecular mechanisms that enable mangroves to tolerate high levels of salt.

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Fire, Soil Heating, and the Formation of Vegetation Patterns in Chaparral. 2000. Odion, D.C., Dept. of Geography, University of California, Santa Barbara, CA 93106; and F.W. Davis. **Ecological Monographs** 70(1):149-169.

During a four- to five-year period, Odion and Davis monitored the effects of surface heating following fall burns on the community structure of two stands of a chaparral system dominated by the obligate post-fire seeder, chamise (*Adenostoma fasciculatum*). The authors' post-burn analysis showed that the amount and distribution of canopy fuel that smoldered on the ground during the fire caused spatial variations in total surface heating: seedlings and herbaceous resprouts of numerous species were abundant in areas where soil heating was low, especially in natural and created canopy gaps; however, areas where the canopy had been dense before the fire were barren, except for a few seedlings of species that had more deeply buried seed banks than chamise. These results indicate that the postfire distributions of local species in a chamise chaparral are linked to the physical and chemical properties of the prefire canopy.

PROPAGATION & INTRODUCTION

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Restoration of Smoke-Dependent Species

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Restoration of disturbance-prone ecosystems is often complicated by the fact that many species produce deeply dormant seeds that require precise triggers to induce germination. This is particularly true of many species in fire-type shrublands, such as California chaparral and coastal sage scrub, South African fynbos and Western Australian heathlands. Ecologists have known for some time that literally hundreds of species in each of these ecosystems accumulate dormant soil-seed banks that are triggered to germinate by fire. Recent studies have determined that while heat-shock induces germination in some species, the majority are stimulated by chemicals formed in the combustion of organic matter (Keeley and Fotheringham, 1998).

Charred wood- or smoke-stimulated germination is found in a wide diversity of plant families, although it is largely lacking in the families noted for heat-stimulated germination, such as the

Fabaceae, Rhamnaceae, Cistaceae, and Convolvulaceae. In California, smoke-dependent species are commonly found in the Hydrophyllaceae, Papaveraceae, Polemoniaceae, and Scropulariaceae, and are known to exist in other families such as the Asteraceae, Boraginaceae, Brassicaceae, Caryophyllaceae, Lamiaceae, Loasaceae, Onagraceae and Solanaceae. In the Southern Hemisphere, smoke-induced germination is common in the Dilleniaceae, Epacridaceae, Ericaceae, Goodeniaceae, Haemodoraceae, Myrtaceae, Poaceae, Proteaceae, Restionaceae, Rutaceae, and Thymelaceae. Within these families, smoke- or charred-wood stimulated germination is not randomly distributed across growth forms, but is common in annuals and shrubby perennials, uncommon in trees, and rare in herbaceous perennials.

Both smoke and charred wood ground to a fine powder are effective in triggering germination in a wide range of species. Under natural conditions, combustion products that trigger germination are transferred to seeds as vapor or liquid, which may occur directly from smoke or indirectly from soil particles after a fire (Keeley and Fotheringham, 1997). Species do, however, differ both in the level of smoke products needed to stimulate germination and in the level that is lethal to seeds (Keeley and Fotheringham, 1998). These two factors make it critical that experiments be undertaken to determine the dosage-response curve for the species in question.

A variety of techniques have been employed to apply smoke to seeds. Researchers in Australia and South Africa have treated local species by burning organic matter in a large steel drum and then using a bellows to pump the smoke into a tent that covers a 1- or 2-m^2 plot of soil containing the dormant seeds. Typically this technique requires an exposure of an hour or longer. In California, Keeley and Fotheringham (1997, 1998) have scaled down this apparatus to a small pan heated by a hot plate and covered with an inverted glass funnel. A short hose from the glass funnel feeds smoke into a 10-gallon glass aquarium with an airtight lid and two ports—one for feeding smoke in and the other for a vacuum line that draws the smoke through the chamber. With such an apparatus most species are sufficiently treated within one to two minutes.

Researchers have also found that growing media, such as sand or filter paper, that has been impregnated with smoke are sufficient to stimulate the germination of smoke-dependent species. The active components of smoke bind to these substrates and are later released in water or air. Often these substrates bind very high, potentially lethal, levels of smoke products, which means that the appropriate application time for these products is much shorter than for the direct application of smoke to seeds. Bubbling smoke through water and then applying the water to seeds is another effective technique. For all of these substrates, the smoke components will remain active for periods of weeks or months, although this varies with application and storage techniques.

Keeley and Fotheringham (1997, 1998) have demonstrated that nitrogen oxides, at levels as low as 500 ppm, are the active component in smoke for some species. For these, but not all smoke-dependent species, one can artificially recreate the smoke response with an application of dilute nitric acid, sulfuric acid, or oxidizing agents, such as hydrogen peroxide. In the case of some very hard-to-germinate species, it has been determined that germination requires a long (about one year) period of storage in soil followed by a smoke treatment (Keeley and Fotheringham, 1998).

Several people have found that commercially-available, smoked-water solutions are effective for restoration work (Baldwin et al., 1994; Jäger et al., 1996) These solutions typically include concentrates of hickory smoke and are sold in supermarkets as an additive to barbecue sauce. However, since no set formulas are available for using these solutions, the proper rates of application have to be determined empirically for each species using a response curve of serial dilutions.(We use Wrights Concentrated All Hickory Seasoning Liquid Smoke, diluted 1000-fold [dilutions of 500-fold or less are toxic].)

These various germination-enhancing techniques have tremendous potential and applicability to large-scale land reclamation and restoration projects (Roche and others, 1997). In fact, without their use the restoration of Mediterranean ecosystems, such as coastal sage and chaparral, will always remain incomplete in terms of species composition. Theoretically, it is a simple matter to introduce the essential chemicals by soaking seeds in a smoke solution prior to sowing. Alternatively, one could incorporate a smoke solution or ground charred wood into a hydroseed slurry along with untreated seed, thus ensuring the continued contact with the combustion-derived chemicals throughout the seeding and germination process.

To date, however, there has been limited documentation of field applications where smoke or charred wood have been used to increase the success of a planting. This makes it difficult to quantify the effectiveness of these methods as well as the species-specific operating dosages. Nonetheless, the progress made in Kirstenbosch Garden, South Africa, and in Australia (http://www.tecnica.com.au/smokemaster.html) provides hope that further research and documentation in this area will contribute to the field of land restoration and recovery.

References

Baldwin, I.T., L. Staszak-Kozinski, and R. Davidson. 1994. Up in smoke. 1. Smoke-derived germination cues for postfire annual, *Nicotiana attenuata* Torr ex Watson. *Journal of Chemical Ecology* 20: 2345-2372.

Jäger, A.K., T. Rabe, and J. van Staden. 1996. Food-flavouring smoke extracts promote seed germination. *South African Journal of Botany* 62:282-284.

Keeley, J.E. and C.J. Fotheringham. 1997. Trace gas emissions in smoke-induced seed germination. *Science* 276:1248-1250.

_____. 1998. Smoke-induced seed germination in California chaparral. *Ecology* 79:2320-2336.

Roche, S., J.M. Koch, and K.W. Dixon. 1997. Smoke enhanced seed germination for mine rehabilitation in the southwest of Western Australia. *Restoration Ecology* 5:191-203.

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FROM: Abstracts from the 1999 Annual Meeting of the Society of Wetland Scientists.

94.1

A Pre-Vegetated Mat Technique for Restoration of Submersed Aquatic Vegetation. Boustany, R., United States Geological Survey National Wetlands Research Center, Lafayette, LA.

Boustany attempted to overcome the destruction that wave and current action causes to newly planted, submersed aquatic vegetation by first establishing tapegrass (*Vallisneria americana*) in durable, biodegradable fibrous mattings. The author pinned six prevegetated mats in rows of two at three sites that were 30 feet from the bank of a coastal wetland in the Cameron Prairie, Louisiana, in order to compare growth inside and outside the mats. Preliminary measurements showed coverage inside and outside the mats was 10.8 percent and 17.5 percent, respectively, at a site that currently had a heavy growth of aquatic vegetation; 28.3 percent and 19.7 percent, respectively, at a site with sparse growth; and 24.2 percent and zero percent, respectively, at site with no record of previous growth. At all sites, the percent coverage inside the mats increased with distance from the shoreline, while the reverse was true for growth outside the mats.

94.2

Successful Establishment of Eelgrass (*Zostera marina*) Beds in North Bend, Oregon. Ulm, I.M., CH2M Hill, Portland, OR 97232-2146; and M. Girts.

Ulm and Girts describe the steps they took to restore 2.3 acres of eelgrass that had been lost during construction of an airport runway. The project began with four, 0.25-acre test plots consisting of transplants that were extracted by hand at low tide from two donor beds. The authors used a split-plot design to evaluate several factors affecting plant survival, including the numbers of plants in a bundle, spacing, elevation, water depth, salinity, air and water temperature, specific conductivity, and light transmission. When completed, the site consisted of 4.5 acres of transplanted eelgrass and an additional 5 acres of volunteer beds. The authors have documented use of the restored site by a variety of marine organisms, such as dungeness crabs (*Cander magister*) and starry flounder (*Platichthys stellatus*).

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Department of Defense Evaluates Genetic Diversity on Military Lands and Breeds New Plants for Army Training Grounds. 1998. Palazzo, A.J., United States Army Cold Regions Research and Engineering Laboratory, 72 Lyme Road, Hanover, NH 03755-1290; D. Huff and K.H. Asay. **Diversity** 14(3 & 4):28-30.

The heavy equipment used for military training missions causes extensive damage to the plants and soil on military lands, resulting in the destruction of native vegetation and the spread of invasive weeds. The authors describe a program by the Army Corps of Engineers, in partnership with Pennsylvania State University and the United States Department of Agriculture, to revegetate training lands with hardy cultivars that closely match, or in some cases enlarge, the gene pool of plants currently growing in these areas. Using a combination of traditional breeding methods and genetic marking techniques to evaluate both native and introduced species, researchers are attempting to develop species that have improved germination characteristics, more rapid tiller or rhizome development, resistance to drought and other environmental stresses, high seed yield, and persistence.

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Cactus Seed Germination: A Review. 2000. Rojas-Aréchiga, M., Instituto de Ecología, UNAM, Apartado Postal 70-275, 04510, México, D.F., México; and Carlos Vázquez-Yanes. **Journal of Arid Environments** 44(1):85-104.

This article provides a general overview of information about germination of seeds of species of cactus (*Cactaceae* spp.). Topics include seed features such as color, form, and size; a discussion about dormancy, dispersal, predation, and soil seed bank formation; and techniques for propagating cacti. The authors also note areas where information is scarce and there is a need for further research.

CONTROL OF PEST SPECIES

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FROM: Abstracts of the 1999 Annual Meeting of the Society of Conservation Biology

97.1

Synecology of Feral Horses: Effects of Grazing, Socio-Political Conflicts, and Management Considerations. Beever, E., Program in Ecology, Evolution, and Conservation Biology, University of Nevada-Reno, Reno, NV 89557-0015, ebeever@scs.unr.edu; and P.F. Brussard.

Beever and Brussard analyzed vegetation, ant mounds, small mammals, and soil compaction at sites in nine mountain ranges in Nevada to determine the scope of disturbance created by feral horses (*Equus* spp.) and to formulate monitoring strategies. In comparison with horse-excluded sites, the authors found that sites with horses had a lower diversity of plant and mammal species; reduced cover of grasses, shrubs, and overall vegetation; fewer aboveground ant mounds; greater soil-surface compaction; more deer mice (*Peromyscus maniculatus*); and greater abundances of exotic plant species.

97.2

Effect of Deer Exclosure on the Herb Layer and the Invasive *Alliaria petiolata*. Brown, L., Dept. of Biology, the College of New Jersey, Ewing, NJ 98628, brownl@tcnj.edu; and J. Morrison.

During this two-year experiment, Brown and Morrison examined a theory that suggests that the invasive garlic mustard proliferates because it is unpalatable to deer. After measuring the percent cover of total ground flora and the height of caged and uncaged garlic mustard located in three forests, however, they found that garlic mustard was more abundant in the forests with no deer populations. They also observed that, while the ground cover of garlic mustard was significantly greater inside the caged plots in forests with deer, the ground cover of other plant species did not vary. Their results suggest that deer herbivory significantly affects garlic mustard, and that the animals are not avoiding this species in favor of native species.

97.3

Causes and Consequences of Lag Times in the Population Explosions of Invasive Alien Species. Crooks, J.A., Smithsonian Environmental Research Center, Edgewater, MD 21037, crooks@serc.si.edu; and M.E. Soulé.

Crooks and Soulé discuss the effects of genetic "lags," or fitness deficits, that have been found to occur in some exotic species during the early stages of introduction. The likelihood of overcoming a lag period is directly proportional to the size of the species' population. Since lag