tion manipulation, or the reintroduction of natural disturbances (e.g., fire)—is necessary. In this note, we describe three projects in the Pacific Northwest that are managed to maintain or restore biological diversity of rare and endangered ecosystems and their species.

The Oregon silverspot butterfly (*Speyeria zerene hippolyta*) is a federally listed threatened species. Its larvae feed on hook violet (*Viola adunca*), a plant of open habitats. However, fire suppression has allowed woody vegetation and bracken fern (*Pteridium aquilinum*) to invade the open, grassland habitats. This loss of habitat and habitat destruction by humans are the two main threats to the Oregon silverspot butterfly. On two hectares at Mt. Hebo, Tillamook County, Oregon, management by the Siuslaw National Forest to control bracken fern has dramatically increased butterfly numbers. Mowing in 1989 and 1990 cut back the taller bracken and depleted its food reserves. With the improved growing conditions, *Viola adunca* soon increased. About 12 Oregon silverspot butterflies existed on the site before management. In 1990, the site supported 60 butterflies; in 1991, 190 butterflies flourished.

*Lomatium bradshawii*, a federally listed endangered plant, is limited to native Willamette Valley wet prairies. In the last 150 years, woody plant invasion, agriculture, and urbanization have almost eliminated suitable habitats for *L. bradshawii*. *Lomatium bradshawii* is extremely resistant to fire. Recently, prescribed burning has reintroduced fire as an ecological process in three remnant populations. As a result, seed productivity increased five- to seven-fold following fires; seedling densities also became higher. Survival of *L. bradshawii* ranged from 89–100% in burn plots. Another rare plant species, the Willamette daisy (*Erigeron decumbens*), also increased dramatically after burning.

The Fender's blue butterfly (*Icaricia icarioides fenderi*), a candidate for federal protection through the Endangered Species Act, is restricted to native Willamette Valley grasslands. This butterfly depends on the rare Kincaid's lupine (*Lupinus sulphureus* ssp. *kincaidii*) as its larval food source. We are propagating Kincaid's lupine from local seed to supplement existing plants. Since butterfly abundance at the main population near Corvallis, Oregon, is directly proportional to lupine abundance, we hope these augmented lupine populations will boost butterfly numbers to viable levels. We also are testing how the control of woody plants will maintain these grassland communities.

In these studies, mowing, fire, and propagation have been important tools in restoring threatened ecosystems. Management, as well as habitat protection, is a vital method for preserving biodiversity.



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## Species' Interactions and Plant Diversity During Secondary Succession

Charles B. Halpern, College of Forest Resources (AR-10), University of Washington, Seattle, WA 98195; Joseph A. Antos, Department of Biology, University of Victoria, Victoria, British Columbia V8W 2Y2; Kermit Cromack, Jr., Department of Forest Science, Oregon State University, Corvallis, OR 97331-5705; and Annette M. Olson, School of Marine Affairs (HF-05), University of Washington, Seattle, WA 98195

Interactions among species, such as competition, have been posed as mechanisms that determine the rate and direction of the change of species composition after disturbance—succession (e.g., Connell and Slatyer 1977). Thus, as forests recover from disturbance, interactions among colonizing and/or surviving species may directly or indirectly influence levels of plant species diversity. Although changes in diversity with time are well documented for early successional (seral) Douglas-fir forests of the Pacific Northwest (e.g., Schoonmaker and McKee 1988; Halpern 1989), the biological processes regulating these changes are poorly understood.

As part of a broader study of early succession in these forests, we are examining how species' interactions, including the competitive effects of some of the dominant seral taxa, influence levels of diversity as forests recover from disturbance. We have designed a set of long-term field experiments in which prominent competing species are removed in various combinations from replicated plots in a recently logged and burned forest in western Oregon. The experimental taxa, *Senecio sylvaticus* (woodland groundsel), *Epilobium angustifolium* (fireweed), *Rubus ursinus* (wild blackberry), *Ceanothus* spp. (*C. sanguineus* [redstem] and *C. velutinus* [snowbrush]) were chosen to represent a range of growth forms that possess diverse regenerative strategies and that dominate early successional sites at different stages and for different durations.

The study site, Starrbright, lies on a gentle, east-facing slope at 730 m elevation in the Blue River Ranger District, Willamette National Forest, Oregon. Prior to harvest, it supported a 4-ha stand dominated by mature-to-old-growth Douglas-fir. During summer 1990, we established a series of 25 replicate understory plots (2.5 × 2.5 m in area) for each of eight experimental treatments and a control (a total of 225 plots). Plots were sampled for vegetation composition (based on cover, stem densities, and woody stem diameters) and for the physical characteristics and nutrient status of soils. The forest was logged during summer 1991 and slash was burned in fall (see Fig. 1). Species removal treatments (conducted three times annually) began in Summer 1992. Vegetation and soils will be sampled during

Fig. 1. One of the 25 experimental blocks before and after slash burning illustrates the nearly complete consumption of above-ground plant parts by fire. Steel reinforcing bars evident in the post-burning photo mark the corners of the nine experimental treatments. Photo by Charles Halpern.



early-, mid-, and late-summer for five or more growing seasons. We will compare changes in species composition and three components of species diversity—richness, heterogeneity, and evenness (based on percent canopy cover, stem density, and total above-ground biomass)—among treatment and control plots.

Silvicultural research in Douglas-fir forests has tended to focus on the growth responses of commercial tree species to competition from invasive or residual vegetation. In contrast, our study will be the first in these forests to examine how whole plant communities and related soil characteristics respond to altered competitive regimes. Knowledge of the factors that control changes in plant species diversity is essential to understanding the complex responses of natural and managed ecosystems to large-scale disturbance.

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### Changes in Plant Species Diversity after Harvest of Douglas-fir Forests

Charles B. Halpern and Jerry F. Franklin, College of Forest Resources (AR-10), University of Washington, Seattle, WA 98195; and Arthur McKee, Department of Forest Science, Oregon State University, Corvallis, OR 97331-5705

Clearcut logging and slash burning have been major agents of disturbance in forests of the Pacific Northwest since the early 1900s. Like their natural counterparts—windstorms and wildfires—these