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A Synopsis of Short-Term Response to Alternative Restoration Treatments in Sagebrush-Steppe: The SageSTEP Project

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Abstract

The Sagebrush Steppe Treatment Evaluation Project (SageSTEP) is an integrated long-term study that evaluates ecological effects of alternative treatments designed to reduce woody fuels and to stimulate the herbaceous understory of sagebrush steppe communities of the Intermountain West. This synopsis summarizes results through 3 yr posttreatment. Woody vegetation reduction by prescribed fire, mechanical treatments, or herbicides initiated a cascade of effects, beginning with increased availability of nitrogen and soil water, followed by increased growth of herbaceous vegetation. Response of butterflies and magnitudes of runoff and erosion closely followed herbaceous vegetation recovery. Effects on shrubs, biological soil crust, tree cover, surface woody fuel loads, and sagebrush-obligate bird communities will take longer to be fully expressed. In the short term, cool wet sites were more resilient than warm dry sites, and resistance was mostly dependent on pretreatment herbaceous cover. At least 10 yr of posttreatment time will likely be necessary to determine outcomes for most sites. Mechanical treatments did not serve as surrogates for prescribed fire in how each influenced the fuel bed, the soil, erosion, and sage-obligate bird communities. Woody vegetation reduction by any means resulted in increased availability of soil water, higher herbaceous cover, and greater butterfly numbers. We identified several trade-offs (desirable outcomes for some variables, undesirable for others), involving most components of the study system. Trade-offs are inevitable when managing complex natural systems, and they underline the importance of asking questions about the *whole system* when developing management objectives. Substantial spatial and temporal heterogeneity in sagebrush steppe ecosystems emphasizes the point that there will rarely be a "recipe" for choosing management actions on any specific area. Use of a consistent evaluation process linked to monitoring may be the best chance managers have for arresting woodland expansion and cheatgrass invasion that may accelerate in a future warming climate.

Key Words: cheatgrass invasion, ecological resilience, ecosystem management, environmental gradients, sagebrush restoration, woodland expansion

INTRODUCTION

This synopsis highlights the initial ecological effects of sagebrush steppe restoration treatments implemented as part of the Sagebrush Steppe Treatment Evaluation Project (SageSTEP), and summarizes socio-economic results related to restoration efforts. SageSTEP was designed to provide treatment-related information on how to address the rapidly changing condition of sagebrush (*Artemisia tridentata* spp.) steppe ecosystems in the US Intermountain region (McIver et al. 2010). Over the past 100 yr, fire suppression, inappropriate livestock grazing, invasion of exotic plants such as cheatgrass (*Bromus tectorum*), and expansion of native conifers (western juniper [*Juniperus occidentalis*], Utah juniper [*Juniperus osteosperma*], single-leaf piñon pine [*Pinus monophylla*], Colorado piñon pine [*Pinus edulis*]), have contributed most to the declining condition of sagebrush ecosystems within the region (Pellant 1994; Miller et al. 2008; Balch et al. 2012). At sagebrush steppe sites that do not support trees, cheatgrass and other exotic species have become more dominant at the expense of native perennial bunchgrasses, in some locations shifting fire return intervals from >50–100 years to <20 years, and vastly increasing the number of fires and total area burned (Whisenant 1990; Miller et al. 2011; Balch et al. 2012). At sagebrush steppe sites into which piñon and juniper woodlands have expanded and displaced sagebrush, other shrubs, and herbaceous vegetation, fire return intervals have shifted from 10–50

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years to >50 years, and significantly increased mean fire severity (Miller and Heyerdahl 2008). Under current climate conditions, both cheatgrass and piñon and juniper trees have the potential to dominate an even larger area in the Great Basin and surrounding lands (Wisdom et al. 2002), and global warming is likely to exacerbate this trend (Neilson et al. 2005; Miller et al. 2011).

Federal, state, and private land managers and owners have for many years attempted to arrest the conversion of sagebrush steppe communities into woodland and annual grassland and to restore native herbaceous communities by applying treatments such as prescribed fire, mowing, chaining, cutting, mastication, or herbicides. Restoration practices have the potential to alter fuel beds and decrease future fire suppression costs (Taylor et al. 2013), lower competitive suppression of perennial bunchgrass species, and decrease longer-term risk of cheatgrass dominance (Chambers et al. 2014a). Substantial published information exists on the efficacy of such treatments in sagebrush steppe, but most studies are site-specific, short-term (Miller et al. 2013), and focused on few variables. Recognizing this, the Bureau of Land Management, in collaboration with the Joint Fire Science Program (JFSP), solicited sagebrush steppe scientists and managers to design a broader study that would provide multisite, multidisciplinary, long-term information on outcomes of alternative treatments over a range of ecological conditions, and that would also provide insight on cost and public acceptance of management practices. A planning grant was provided by JFSP in 2003 to design SageSTEP, and the study was ultimately funded by JFSP in 2005.

In this synopsis, we will briefly describe the SageSTEP study, and then present short-term results in the context of five key themes that the study was designed to address: 1) resilience and resistance, which are key concepts in state-and-transition models; 2) effectiveness of fire vs. fire surrogates, which differ in suitability depending on the situation; 3) trade-offs among key response variables, which are important for decision-making by managers; 4) temporal scale of response in different variables; and 5) heterogeneity in time and space, which is the source of much of the variation found in the literature. Finally, we also briefly discuss the SageSTEP Project as a model of a multisite, multivariate, and long-term study intended to provide information more useful to managers than traditional single-site, single-variable, short-term studies.

EXPERIMENTAL DESIGN

SageSTEP consists of 21 widely distributed sites, arranged in two parallel experiments, both conducted in ecosystems formerly dominated by sagebrush in the overstory and by herbaceous perennial vegetation in the understory. The experiments emphasize the major restoration challenges in the region: invasion of cheatgrass into drier Wyoming big sagebrush communities, and expansion of piñon and juniper into higher-elevation sites.

The "sage–cheat" experiment examined cheatgrass invasion at seven dry, lower-elevation sites located in five states (Fig. 1). Each site was a statistical block, comprising one 20–80-ha plot as unmanipulated control, and prescribed fire, mowing, and herbicide applied across the other three plots. Plot-level treatments were intended to reduce the sagebrush overstory in an effort to alter the competitive balance between perennial bunchgrasses and cheatgrass in the understory. Although treatments that reduce sagebrush may seem to contradict the management goal of preserving sagebrush steppe ecosystems, they may in some cases lead to more desirable vegetation states in the long run, if they stimulate native perennial herbaceous plants relative to exotic annual plants. Within each plot, between 18 and 24 subplots (0.1 ha) were established, within which were measured most response variables. Prescribed fire was applied first, from May to October 2006, 2007, or 2008; fire blackened about half of each plot (Table 1). Once fire was implemented at each site, mowing and herbicide treatments were applied to the other plots within 8 mo. For the mowing treatment, rotary mowers were set at a height that removed and distributed approximately 50% of sagebrush cover. For the herbicide treatment, tebuthiuron was applied over the entire plot at a rate intended to remove 50% of the overstory. Finally, the pre-emergent herbicide imazapic was applied after plot-level treatments to one-half of the subplots within each plot; at low rates, imazapic is intended to target annual plants.

The "woodland" experiment examined piñon and juniper expansion at 14 higher-elevation sites located in five states (Fig. 1). The woodland experiment was divided into three regions: sites dominated by western juniper (six sites in Oregon, southwestern Idaho, and northern California), sites with a roughly equal balance of both piñon and juniper (four sites in Nevada), and sites dominated by Utah juniper (four sites in Utah). Each site was a statistical block; one 10–25-ha "core" plot served as a control, and prescribed fire and clear-felling were applied across the other two plots; at the four Utah woodland sites, mastication was applied in an additional plot. Plot-level prescriptions were intended to remove trees in an effort to stimulate the shrub and herbaceous understory. Within each plot, we established 15 measurement subplots (0.1 ha), spanning a condition gradient defined by the relative dominance of trees within each subplot. Prescribed fire was applied first, between August and November of 2006, 2007, or 2008 (Table 1), with clear-fell and mastication (Utah sites only) treatments implemented within 6 mo.

VARIABLES AND DISCIPLINES

SageSTEP measured treatment response in a wide variety of ecological variables, and also evaluated socio-political and economic variables related to sagebrush steppe restoration. Vegetation variables were measured at the subplot level, and included cover and density of trees, shrubs, forbs, grasses, biological soil crusts, and bare ground, and gap size (distance between perennial plants). Fuel mass and fire risk reduction were evaluated by measuring the fuel bed within all subplots, including standing dead wood, surface wood, litter, duff, and live fuels. We measured soil water and temperature, nitrogen availability, carbon, cations, and anions at three to six locations within each plot, also chosen to span the condition gradient across each plot. Bird communities were studied at woodland sites by conducting point counts within each of the 14 woodland plots, and by conducting intensive demographic work at five pairs of >400-ha plots (prescribed burned and control), at the