Multidisciplinary, Multisite Evaluation of Alternative Sagebrush Steppe Restoration Treatments: The SageSTEP Project

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Multi-disciplinary, multi-site evaluation of alternative sagebrush steppe restoration treatments: the SageSTEP project

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Key Words: soil nutrients, soil water, exotic annual grass, cheatgrass, woodland expansion, native perennial bunchgrass, sagebrush-obligate birds, sagebrush butterflies, resilience, resistance, thresholds, social acceptance, fuel reduction, prescribed fire, mowing, mastication, imazapic

INTRODUCTION

This special issue presents short-term ecological effects of restoration treatments imposed as part of the Sagebrush Steppe Treatment Evaluation Project (SageSTEP), and summarizes public attitude survey results related to restoration efforts. Funded by the U.S. Joint Fire Science Program (2005-2011), the Bureau of Land Management (2011 to present), the National Interagency Fire Center (2011 to present), and the U.S. Fish and Wildlife Service (2010), SageSTEP was designed and implemented to provide treatment-related information to managers concerned about the rapidly changing condition of sagebrush steppe ecosystems in the U.S. Interior West (McIver et al. 2010). Over the past 100 years, fire suppression, inappropriate livestock grazing, invasion of exotic plants such as cheatgrass (*Bromus tectorum*), and expansion of native conifers (*Juniperus occidentalis, J. osteosperma, Pinus monophylla, P. edulis*), have contributed most to the decline of sagebrush ecosystems in the Intermountain Region (Miller et al. 2008; Balch et al. 2012). At lower elevations, cheatgrass has 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 greatly increasing mean fire size (Whisenant 1990; Miller et al. 2011; Balch et al. 2012). At higher elevations, pinyon pine and juniper woodlands have encroached and displaced sagebrush and other shrubs, in some places shifting fire return intervals from 10-50 years to >>50 years, and significantly increasing mean fire severity (Miller and Heyerdahl 2008). Under current climate conditions, both cheatgrass and pinyon-juniper woodlands have the potential to dominate an even greater area (Wisdom et al. 2002) in the Great Basin and surrounding areas, 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 cheatgrass, and to restore more healthy native bunchgrass communities, by applying treatments such as prescribed fire, mowing, chaining, cutting, masticating, or herbicides. Although substantial site-specific information exists on the efficacy of such treatments, there is scant multi-disciplinary, long-term, comparative information available on treatment outcomes over the range of ecological conditions that support sagebrush steppe communities. Furthermore, since land managers nearly always deal with landscapes that show a wide range of degradation stages, they need information on recovery potential that is linked to these stages. In other words, while application of prescribed fire may work well in the initial stages of woodland encroachment into sagebrush steppe, this tool may actually produce undesirable outcomes in later stages of woodland development. SageSTEP has five key features that together provide this kind of information to land managers working in sagebrush steppe: 1) Experimental – allows for controlled manipulation of ecological factors considered to be drivers in sagebrush steppe; 2) Multi-site – evaluates responses across a considerable range of environmental conditions that characterize sagebrush steppe in the interior western U.S.; 3) Multivariate – measures a wide variety of both independent and dependent variables that characterize response to treatment, and that can potentially be identified as mechanisms that explain response; and 4) State and Transition Model-based – applies treatments across degradation gradients, which allows for direct testing of hypotheses on threshold conditions and ecological resilience.

EXPERIMENTAL DESIGN

SageSTEP consists of 20 widely distributed study sites, arranged in two similarly designed experiments, both conducted in ecosystems formerly dominated by sagebrush in the overstory, and herbaceous perennial vegetation in the understory. Although all study sites are classified as cool desert, and have similar vegetation and land use patterns, weather patterns differ markedly across this geographic range (Fig. 1). Sites in California, Oregon, Washington, and southwest Idaho have a Pacific Maritime climate, with nearly all precipitation originating in the Pacific Ocean, and falling between November and June. Sites in Nevada and Utah have a more Continental climate, with less precipitation falling from November to June, and relatively more summer rains originating from the Gulf of Mexico, usually in July and August.

The 'Sage-Cheat' experiment examined cheatgrass invasion at seven drier, lower elevation sites located in five states (Fig. 1). Each site was a statistical block, at which we established one 20-80 ha 'core' plot as un-manipulated control, and applied prescribed fire, a mowing treatment, and an herbicide treatment across the remaining three plots. Plot-level prescriptions were intended to reduce the sagebrush overstory in an effort to alter the competitive balance between perennial bunchgrasses and cheatgrass in the understory. Within each plot, we established between 18 and 24 sub-plots, 30 x 33m in size (0.1 ha), within which we measured most response variables. The sub-plots were chosen to span a 'condition' gradient defined by the balance of native perennial bunchgrass and cheatgrass within each sub-plot. Prescribed fire was applied first, from May to October 2006, 2007, or 2008, and was intended to blacken 100% of each plot area (Tab. 1). Due to variation in weather and fuel moisture conditions, prescribed fires burned between 40 and 79% of each plot area for six of the seven sites; the Roberts site was excluded from the experimental analysis because the Jefferson Fire burned two of the four plots there in the summer of 2010 (two years after treatment). Once fire was implemented for each site, both mowing and herbicide treatments were applied to the two other treated plots within the following eight months. For the mowing treatment, rotary mowers were set at a pre-determined height to remove and distribute roughly 50% of sagebrush biomass. For the herbicide treatment, tebuthiuron was applied over the entire plot at a rate dictated by prior testing to remove 50% of the overstory. Finally, the pre-emergent herbicide imazapic was applied after plot-level treatments to one-half of the sub-plots within each plot; at low rates, imazapic selectively acts on annual plants.

The ‘woodland’ experiment examined pinyon and juniper encroachment at 12 higher elevation sites located in five states (Fig. 1). The woodland experiment is divided into three regions: Western Juniper (four sites in Oregon and N. California), Pinyon-Juniper (four sites in Nevada), and Juniper-Pinyon (four sites in Utah). Each site was a statistical block, at which we established one 10-25 ha ‘core’ plot as un-manipulated control, and applied prescribed fire and a ‘cut and leave’ treatment across the other two plots. At the four Utah woodland sites, we applied a mastication treatment in an additional plot. Plot-level prescriptions were intended to remove trees, in an effort to release the shrub and herbaceous understory. Within each plot, we established 15 measurement sub-plots (0.1 ha), spanning a condition gradient defined by the relative dominance of trees within each sub-plot. An effort was made to establish a roughly equal number of sub-plots within each of three woodland encroachment ‘phases’: phase 1, in which trees have encroached, but the shrub and herbaceous still dominates; phase 2, in which trees and the understory are about equally dominant; and phase 3, in which trees dominate. Prescribed fire was applied first, between August and November of 2006, 2007, or 2008 (Table 1). The goal was to kill all trees within each treatment plot. Due to variation in weather and fuel moisture conditions, prescribed fires burned between 38 and 95 percent of each plot area; unburned sub-plots were later burned by hand in order to kill all trees within each measurement sub-plot. Clearcut and mastication treatments were implemented within six months of fire treatments. For the clearcut treatment, all trees >2 m tall were cut down and left on the ground across the contour. For the mastication treatment, all trees >2 m tall were shredded with the rotary mower and residue left where initially deposited. The Stansbury Mt. woodland site experienced a severe wildfire (Big Pole Fire) on August 6, 2009, which severely burned all four plots (Tab. 1). Since treatments were applied at Stansbury Mt. in 2007, we will thus present only two years post-treatment data for this site (2008, 2009).

VARIABLES AND DISCIPLINES STUDIED

SageSTEP measured treatment response in nearly 100 key variables within several components of the ecosystem, and evaluated both socio-political and economics factors. Vegetation variables were measured at the sub-plot level, and included cover and density of trees, shrubs, forbs, and grasses, biological crusts, bare ground, and gap size and number (distance between perennial plants). To evaluate the extent of fuel and fire risk reduction, we measured the fuel bed within all sub-plots, including standing dead woody, surface woody, litter, duff and live fuels. Since vegetation and fuels were measured at the sub-plot level, we could evaluate the response of these variables within the context of the established condition gradients. We measured nitrogen availability, carbon, cations, and anions at three to six locations within each plot, also chosen to span the condition gradient across each plot. Birds abundance and richness were studied only at woodland sites, by conducting point counts within each woodland ‘core’ plot, and by conducting intensive demographic work in a set of four 400 ha plots. Butterfly abundance and richness were estimated at the plot level, by cruising 1000m belt transects between one and three times per year prior to treatment (2006), and up to six years after treatment (2012); butterfly host plants and nectar sources were noted if observed within or near a plot, or along a transect. Concerns about runoff and erosion were addressed by studying water relations within adjacent plots at three woodland sites: the western juniper site at Castlehead, the pinyon-juniper site at Marking Corral, and the juniper-pinyon site at Onaqui

(Figure 1). SageSTEP hydrological research used artificial rainfall experiments to evaluate how tree removal treatments influenced runoff and erosion, and to identify which conditions might exacerbate those effects. The socio-political component addresses the social and political feasibility of alternative treatments, to identify factors in the treatments, or in the conditions those treatments produce, that constrain implementation of practices. The goal of the economics research was to provide a comprehensive understanding of the tradeoffs and incentives that face decision-makers as they consider whether and how to treat sagebrush steppe lands.

CONTRIBUTIONS

The SageSTEP 'Special Issue' includes 11 papers, spanning most of the major disciplines studied. Most papers focus on ecological effects of fuel reduction and restoration treatments, up to six years post-treatment. We studied the vegetation (Chambers, Pyke, Miller, Roundy), water relations and soil chemistry (Roundy, Pierson, Rau), and the fauna (Knick, McIver). Two additional contributions expand the research to remote sensing (Hulet), and socio-political (Gordon) work. The Special Issue concludes with a synopsis of short-term effects, which focuses on findings from the 11 preceding papers, but also includes information from other published SageSTEP work.

The issue begins with a contribution from Chambers et al., which evaluates how ecological site type influenced both resistance to invasion and resilience after treatment. This work extends recent findings that show that warmer and drier sagebrush steppe sites tend to be less resistant to annual grass invasion, and less resilient after disturbances such as fire.

Working at six Wyoming big sagebrush sites, Pyke et al. show that fire, mowing, and imazapic treatments were effective in reducing fuels for up to three years, but that each had distinct undesirable consequences for plant communities. Fire in particular increased the proportion of large gaps between perennial plants, thus lowering resistance to cheatgrass invasion.

Miller et al. show that deep-rooted perennial grasses, litter, and bare ground initially declined after burning, but rebounded to pre-existing levels by the third year post-treatment. A key finding is that response to treatment depends on pre-treatment vegetation composition and structure.

Roundy et al. extend these results to an examination of how different levels of tree infilling influence vegetation response. They show that as long as encroached sites have at least 8-10% residual perennial herbaceous cover, removal of trees is unlikely to push the site across a biological threshold, even in advanced stages of in-filling.

Vegetation recovery after treatment will depend in part on how surviving plants compete to capture the water and nutrient resources made available by the disturbance. Roundy et al. show that tree removal treatments can increase the time of available water in spring by as much as 26 days for highly encroached woodlands. Rau et al. show that soil texture and water holding capacity play a key role in the distribution of plant species, and demonstrate that woody fuel reduction treatments increase available nitrogen and soil water, which in turn provide resources for the plant community.

Hydrological work by Pierson et al. demonstrates that alternative fuel reduction treatments in woodland encroached sagebrush steppe have radically different short-term effects, with erosion increasing 3-10-fold after prescribed fire, but decreasing by 4-5-fold after mastication. They then discuss how these short-term findings would be expected to change in the long run, as herbaceous vegetation responds to the removal of woody vegetation.

For the fauna, McIver and Macke demonstrate that short-term butterfly response to treatment was generally positive, and followed the response of the native perennial herbaceous vegetation. The response of the bird community however, was more complicated, with sagebrush-obligate species responding positively to treatment in only two masticated plots, where the influence of trees had been completely removed. Findings on the fauna illustrate how focus on different components of the ecosystem can lead to different conclusions on the efficacy of restoration treatments.

While intensive, field-based studies like SageSTEP are necessary to provide reliable information on ecological response to restoration treatments, managers need less expensive assessment tools to determine when and where to apply treatments. Hulet et al. describe how remote sensing can be used to evaluate longevity of fuel treatments, and to determine the spatial distribution of horizontal fuel structure across large landscapes.

Finally, Gordon et al. show that public acceptance of restoration treatments was best predicted by trust of the agencies' ability to implement treatments, rather than information on how treatments influence landscapes. This information implies that efforts by management agencies to build trust in stakeholders is likely to pay off more than just providing information on treatment effects.

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FIGURE CAPTION

Figure 1. Location of SageSTEP study sites in Great Basin and surrounding sagebrush steppe lands, within major land resource areas (NRCS).