Restoring native grasslands via carbon addition and grazer exclusion: initial results of a multi-year study

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Abstract. Our previous research suggested that invasion of grasslands by introduced plants can be partly reversed by adding sugar to the soil and excluding mammalian herbivores. Our current, three-year project is testing the hypotheses that sawdust can have the same effect as sugar and that treatments are similarly effective at other sites in the coastal grasslands of northern California. One experiment is crossing 2 grazing treatments (control, exclusion of large mammals) with 3 soil treatments (control, addition of sugar, addition of sawdust) at 3 sites. Percent cover of each plant species was measured 3 months after treatments began at the University of California Bodega Marine Reserve and 2 months after they began in Sonoma Coast State Park. At the Reserve, cover of introduced species was lower and cover of natives was higher in plots with added sugar or added sawdust than in control plots, but the effect of soil treatment was significant ($P < 0.05$) only for the difference in cover of introduced plants between controls and sawdust plots. In the Park, cover of introduced species was highest in controls and lowest in sugared plots (P [effect of soil treatment] = 0.008), while cover of natives was lower in plots with sawdust than in other plots ($P = 0.03$). Neither site showed significant grazing effects on the total cover of introduced or of native species (all $P > 0.4$). These results generally suggest that carbon addition may be a viable way to reverse invasion of coastal grassland, but that it may require several years of treatment to see significant effects.

Introduction

Introduced grasses have largely replaced native plants in most grasslands of California. Our previous study showed that defertilization of soil with sugar and prevention of herbivory by mammals could partly reverse this invasion. To translate these results into practical methods for control of invasive species, we are now testing if (1) sawdust, available free, has the same effects as sugar and (2) treatments are effective at multiple sites.

Methods

We crossed 2 grazing treatments (grazed [no treatment] or ungrazed [fenced to exclude large mammals]) with 3 soil treatments (none, sugar [1 kg m^{-2} y^{-1}; photo below], or sawdust [2 kg m^{-2} y^{-1}]) in 10 randomized blocks of 4 x 4 m plots at 3 sites along the central coast of California (photos above right). We estimated percent cover of each plant species in each plot at the first 2 sites in May-June 2007.

Treatments began in Feb 2007 at the Bodega Marine Reserve of the University of California at Davis, in March 2007 at Peaked Hill in Sonoma Coast State Park, and in 2008 at Palomarin in Point Reyes National Seashore, and will continue through 2009. Cover was estimated visually by intervals of 5%. Initial results were analyzed for groups of species (introduced or native, annual or perennial, and forb or graminoid), using separate ANOVAs with grazing treatment and soil treatment as fixed effects, followed by Bonferroni tests to compare individual means.

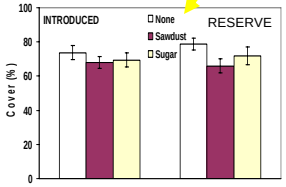
adding sugar to a grazed plot

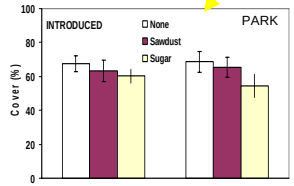
Acknowledgements. We thank the California State Parks, Point Reyes National Seashore, and UC Bodega Marine Lab for collaboration; Todd Karalius for assistance with measurements of plant cover; Michelle Cooper, Chase Campbell, and Mailea Miller Rhoads for assistance with treatments; and the U.S. Department of Agriculture for research support through the UCIPM Program.

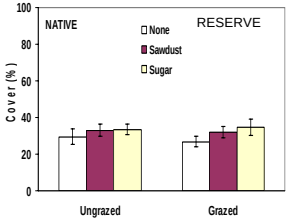
UC Bodega Marine Reserve

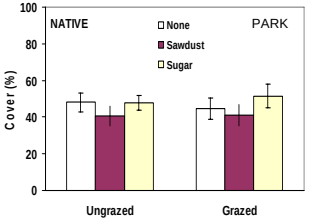
Sonoma Coast State Park

Point Reyes National Seashore









Results

Cover of introduced plants was lower in plots with sawdust or sugar than in plots with none (above graphs; P [effect of soil] = 0.05 [Reserve], 0.008 [Park]). Introduced cover was as low in plots with sawdust as with sugar at the Reserve but marginally lower with sugar than with sawdust at the Park (P [Bonferroni] = 0.08).

Cover of native species did not differ between soil treatments at the Reserve ($P = 0.20$), and was lower in plots with sawdust than in other plots at the Park (P [effect of soil] = 0.03).

Grazing did not affect cover of introduced or native species at either site (each P [effect of grazing] > 0.4).

In the Park (table below; values are mean [SE]), soil treatments affected graminoids rather than forbs. Cover of introduced graminoids (all annual grasses) was lower in plots with sawdust or sugar than with none (P [Bonferroni] = 0.03 [sawdust v. none], 0.006 [sugar v. none]), and did not differ between plots with sawdust or sugar ($P > 0.9$). Cover of native graminoids (all perennials) was lowest in plots treated with sawdust, (P [Bonferroni] = 0.045 [sawdust v. none], 0.005 [sugar v. sawdust], > 0.9 [sugar v. none].

At the Reserve (data not shown), neither soil nor grazing treatment significantly affected cover of any subgroup of introduced or native species (each $P > 0.08$).

	Ungrazed			Grazed			P (ANOVA)		
	none	sawdust	sugar	none	sawdust	sugar	grazing	soil	grazing * soil
Introduced									
annual forb	12.7 (1.9)	13.0 (2.6)	10.4 (2.9)	12.1 (2.8)	12.3 (2.8)	11.2 (2.5)	0.91	0.31	0.67
perennial forb	34.0 (3.8)	34.8 (4.6)	33.2 (2.8)	35.4 (3.3)	37.2 (4.9)	31.1 (4.4)	0.84	0.44	0.63
annual graminoid	20.9 (3.2)	15.5 (2.4)	16.7 (2.1)	21.2 (3.1)	16.1 (3.3)	12.2 (1.9)	0.37	**0.004**	0.31
Native									
annual forb	15.7 (3.3)	13.7 (3.2)	16.4 (3.3)	13.5 (3.6)	16.5 (4.5)	15.3 (3.8)	0.76	0.88	0.67
perennial forb	8.3 (1.8)	9.1 (2.2)	6.7 (2.1)	7.8 (3.4)	8.1 (2.5)	10.6 (2.9)	0.86	0.95	0.24
perennial graminoid	20.9 (2.4)	16.0 (3.0)	23.0 (3.3)	19.6 (3.4)	12.9 (0.8)	22.5 (3.9)	0.47	**0.004**	0.88

Discussion

Initial results at the Reserve were consistent with the hypothesis that sawdust is as effective as sugar at controlling introduced plants, but results at the Park suggested that sawdust might be less effective.

Results were partly consistent with the hypothesis that treatments would control invasion at multiple sites. Adding sugar was effective at both sites, but excluding grazing had no effect at either site.

We conclude from these early results that addition of carbon to soil may prove effective in the restoration of native grasslands in California, but that at least 2 years of treatment will be needed to show useful effects. Compared to other methods for controlling invasions, manipulation of soil nutrients with sawdust bears low risk and low cost. If effective, it could lead to large-scale restoration of natives.