Strategies to Reduce Invasive Plant Outbreaks after Prescribed Fire in Black Hills Pine Forest

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Background and Question

Prescribed fire is an important tool for restoring and maintaining forest structure and health in Black Hills ponderosa pine. In forests with a long history of fire suppression, burn prescriptions may target higher-than-usual intensity in order to reduce canopy density. However, this practice may increase the risk of post-fire invasive plant outbreaks, as it releases nutrients in litter, duff, and understory vegetation and provides new light to the forest floor when it opens up the canopy. Natural resource managers in Black Hills NPS units sought quantitative information on invasive plants and prescribed fires to better weigh the pros and cons of using more intense prescribed fires in dense forests and to derive efficient strategies to find invasive plant outbreaks following prescribed fire if they were to occur. Thus, we designed a study to answer the question,

- **What practical strategies can be used to prevent and, if necessary, quickly find invasive plant outbreaks following prescribed fire in Black Hills ponderosa pine forest?**

Methods

We measured environmental characteristics and the abundance of 20 target invasive plant species in the growing season before and two growing seasons after two prescribed fires in plots distributed in a stratified random design. We also calculated four indices of fire severity. Principal components analysis (PCA) reduced the numerous, highly correlated environmental variables to three components for use in models. We used an information-theoretic model selection approach to determine which combination of environmental and fire severity variables best explained individual invasive species and total invasive species cover. "Supplemental" plots, established in high invasive-cover areas in the second year post-treatment, provided some anecdotal insight missed by the random plots.

Target Invasives

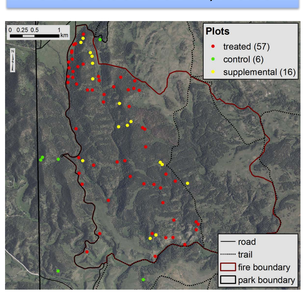
Species	Common Name	Growth Form
Acroptilon repens	Russian knapweed	perennial forb
Bromus japonicus & B. tectorum (BROMUS)	Japanese brome & cheatgrass	annual grass
Carduus nutans	musk thistle	biennial forb
Centaurea stoebe	spotted knapweed	bi- or perennial forb
Cirsium arvense (CIRARV)	Canada thistle	perennial forb
Cirsium vulgare	bull thistle	biennial forb
Cynoglossum officinale (CYNOFF)	houndstongue	biennial forb
Euphorbia esula	leafy spurge	perennial forb
Hyoscyamus niger	black henbane	biennial forb
Hypericum perforatum	common St. Johnswort	perennial forb
Leucanthemum vulgare	oxeye daisy	perennial forb
Linaria dalmatica	Dalmatian toadflax	perennial forb
Linaria vulgaris	yellow toadflax	perennial forb
Melilotus officinalis	sweetclover	biennial forb
Marrubium vulgare	white horehound	perennial forb
Onopordum acanthium	Scotch thistle	biennial forb
Potentilla recta	sulfur cinquefoil	perennial forb
Salsola collina & S. tragus	Russian thistle	annual forb
Tanacetum vulgare	common tansy	perennial forb
Verbascum thapsus (VERTHA)	common mullein	biennial forb

Explanatory Variables

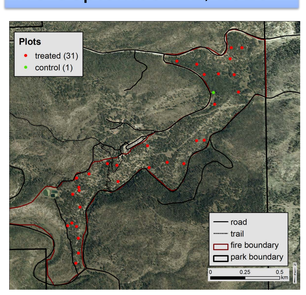
Variable	Description	In PCA?
Elevation	elevation above sea level	yes
Grade	slope grade	yes
AspectNS	north-south component of slope aspect	yes
AspectEW	east-west component of slope aspect	yes
TreeDens2010	tree (DBH > 15 cm) density	yes
PoleDens2010	pole (2.5 cm ≤ DBH ≤ 15 cm) density	yes
SeedDens2010	seedling (DBH < 2.5 cm) density	yes
BA2010	basal area	yes
Canopy2010	tree canopy cover	yes
DuffDepth2010	duff depth	yes
LittDepth2010	litter depth	yes
Bare2010	bare ground cover	yes
Forb2010	forb cover	yes
Gram2010	graminoid cover	yes
Shrub2010	shrub cover	yes
(S1 + S2)	two categorical variables to classify slope position	no
Dist	distance from nearest road	no
CBIcalc	composite burn index from satellite data (+)[a]	no
ΔBA	relative change in basal area, pre- to post-fire (+)[a]	no
ΔFuel	change in total fuel load, pre- to post-fire (+)[a]	no
SeverityCode	surface fire severity measured Nov 2010 (–)[a]	no

[a] Sign in parentheses indicates whether the measure of fire severity increases (+) or decreases (-) with increasing fire severity.

Wind Cave Nat. Park
fire October 20-22, 2010

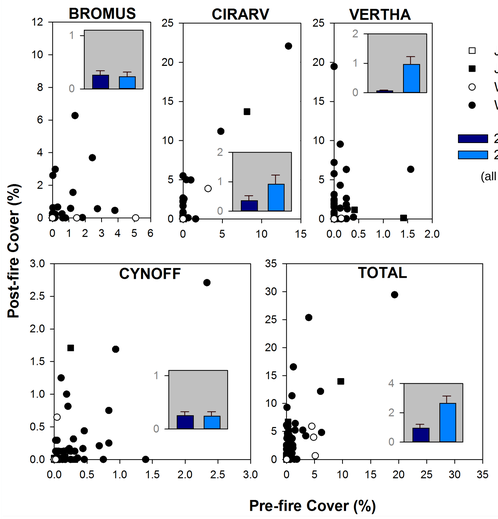


Jewel Cave Nat. Mon.
fire September 21, 2010



Results

Invasive cover did increase after fire, but it was generally low.



Pre- to post-fire increase in cover did not differ significantly between treated and control plots, but our power to detect such a difference was low.

Pre- and post-fire cover were highly correlated for some species.

Species	r	p
BROMUS	0.39	<0.001
CIRARV	0.84	<0.001
CYNOFF	0.83	<0.001
VERTHA	0.25	0.015
All Invasives	0.67	<0.001

PC1 represents closed-canopy, thick-floored forest.

Correlations between principal components (PC) and pre-fire environmental variables. Only variables with |r| > 0.50 are shown.

PC1	PC2	PC3
0.88 Canopy2010	-0.69 Elevation	-0.65 Gram2010
0.87 BA2010	0.68 SeedDens2010	0.50 Grade
0.75 TreeDens2010	0.60 Shrub2010	
0.69 LittDepth2010		
0.68 DuffDepth2010		
-0.55 Bare2010		

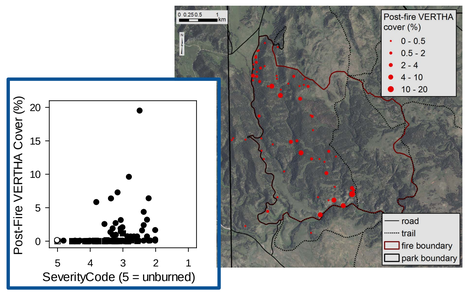
Post-fire invasive plant cover was related to pre-fire forest structure, fire severity, and distance to nearest road.

We considered only those models with ΔAICC ≤ 2.0 and adjusted r^2 > 0.20 to be ecologically meaningful. Few species had ecologically meaningful models.

Species	Ecologically Meaningful Model(s)	Adjusted r^2
CIRARV	- PC1 + Dist - SeverityCode	0.29
	- PC1 + Dist - SeverityCode + ΔFuel	0.30
VERTHA	+ Dist - SeverityCode	0.25
	+ Dist + ΔFuel	0.24
	+ Dist	0.23
All invasives	- PC1 + PC2 + Dist – SeverityCode	0.34

Canada thistle (CIRARV) cover was higher in areas that experienced more severe surface fire, were further from roads, and had less dense pre-fire overstory structure (PC1).

Common mullein (VERTHA) cover was higher in areas further from roads and that experienced more severe surface fire.

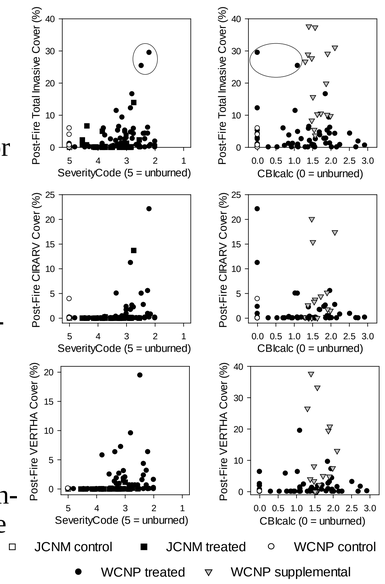


Total invasive cover was higher in areas that experienced more severe surface fire, were further from roads, had lower pre-fire overstory, and had lower pre-fire understory density and/or were at lower elevations.

Implications

Keeping fire severity low should reduce invasive plant outbreaks, but not all high-severity areas will necessarily have high invasive cover.

Plots with low surface fire severity (litter only partially consumed, duff only partially blackened, foliage and smaller twigs of shrub layer scorched or partially consumed; left-hand graphs) had no CIRARV or VERTHA cover and generally low total invasive cover. Very high invasive cover was generally limited to plots that experienced the highest fire severity (right-hand graphs), especially when plots with high pre-fire invasive cover (circled plots in top graphs) are excluded. However, there were many high-severity plots with low invasive cover two years after the fire.



If possible, control Canada thistle before the fire.

The high correlation between pre- and post-fire CIRARV cover suggests strong control of this species before a prescribed burn may reduce post-fire outbreaks. Unfortunately, pre-fire forest conditions explain only a moderate amount (<20%) of the variance in this species' pre-fire cover, which was quite low in our study.

Concentrate post-fire invasive plant search efforts in more severely burned areas.

Keeping fire severity low may not achieve even standard prescribed burn objectives of killing a high percentage of pine seedlings, reducing litter and duff depths, and low overstory mortality, let alone reducing overstory density. Furthermore, some target invasives become readily apparent only after a fire (e.g., common mullein). Therefore, post-fire control of invasives will likely be necessary. Higher surface fire severity was the characteristic most consistent among species for post-fire invasive cover in our study. We cannot explain why invasive cover was positively related to distance from roads and are therefore hesitant to draw any conclusions regarding this characteristic.

Acknowledgements

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