Short Communication

Burn Severity and Non-Native Species in Yosemite National Park, California, USA

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ABSTRACT

We examined non-native species density three years after the Tuolumne Fire, which burned 1540 ha in upper montane forest in California, USA. We sampled 60 plots, stratified by burn severity (low, moderate, or high severity) and landscape position (lowland or upland). We detected non-native species in 8 of 11 (73%) of high severity lowland sites and in 5 of 10 (50%) of moderate severity lowland sites but, overall, richness and abundance was low. We detected only five non-native species, of which bull thistle (*Cirsium vulgare* [Savi] Ten.) was the most common. Although non-native abundance is currently low, we recommend continued low intensity monitoring, especially on high severity burned lowland sites.

Keywords: *Abies concolor, Abies magnifica,* bull thistle, burn severity, *Cirsium vulgare*, non-native plants, Yosemite National Park

Citation: Kaczynski, K.M., S.W. Beatty, J.W. van Wagtendonk, K.N. Marshall. 2011. Burn severity and non-native species in Yosemite National Park, California, USA. Fire ecology 7(2): 145-149. doi: 10.4996/fireecology.0702145

INTRODUCTION

Throughout many western forest ecosystems, fire is an historical and influential ecological process, and many native plants have adapted characteristics to allow them to persist with repeated burning (Agee 1996). However, after more than a century of fire suppression and exclusion, resulting in an excess of fuels, fires are often more intense and burn with higher severity in some forested ecosystems. Post fire, this can lead to an increased likelihood of colonization by some non-native species (Keeley *et al*. 2003, Fornwalt *et al*. 2010). High severity fires decrease canopy cover, increase light levels and nutrients, and are more

likely to expose mineral soil (Keeley *et al*. 2003). However, in a study that covered all elevations of Yosemite National Park, California, USA, Klinger *et al*. (2006) found no difference in non-native plant species richness or cover between burned and unburned plots. They concluded that environmental gradients including elevation overrode the response to fire and that non-native species that did occur in burned areas decreased with time.

Lowland areas are often hotspots for non-native species establishment, and can act as corridors for the spread of some non-natives (Stohlgren *et al*. 1998). Lowland sites include seasonal and perennial riparian corridors and wet meadows. Although much work has been done on non-natives in lowland systems, few studies have looked at the interaction of fire and non-natives in these lowland areas.

In this study, we assess non-native species colonization on burned mid-elevation mixed conifer forest in Yosemite National Park across varying burn severity on lowland and upland landscape positions. These forests are predicted to have lower abundance of non-native species (Klinger *et al*. 2006) and have historically been studied less than lower elevation forests and shrublands, such as ponderosa pine (*Pinus ponderosa* C. Laws.) forest and chaparral. We examined the relationship between three classes of burn severity (low, moderate, and high) and density of non-native plants by species in upland and lowland sites.

METHODS

Located in the central Sierra Nevada, Yosemite National Park totals 302 768 ha and has an elevation range from 524 m to 3998 m. Yosemite contains over 1400 species of vascular plants including 155 non-native species (Botti 2001), 63 of which are ranked as priority species for management (Gerlach *et al.* 2003).

We chose the Tuolumne Fire of 2003 because of its large size and range of fire severity and landscape positions. This fire burned 1540 ha in upper montane conifer forest, ranging in elevation from 1890 m to 2560 m. The forest and woodland communities were predominantly mixtures of red fir (*Abies magnifica* A. Murray) and white fir (*A. concolor* [Gord. & Glend.] Lindl. ex Hildebr.), with Jeffrey pine (*Pinus jeffreyi* Balf.), lodgepole pine (*P. contorta* Douglas ex Louden var. *murrayana* [Balf.] Engelm.), western white pine (*P. monticola* Douglas ex D. Don), and sugar pine (*P. lambertiana* Douglas). Based on surveys throughout the park, Underwood *et al*. (2004) predicted that few non-natives would occur within the burn. Burn severity, as determined by the relative differenced normalized burn ratio (RdNBR) (Miller and Thode 2007), was heterogeneous throughout the burn, with approximately 44% of the site described as a moderate burn, 30% as a low severity burn, 17% as a high severity burn, and 9% of the area was unburned. The burned area contains perennial and seasonal drainages.

We sampled 60 plots between June and August 2006 (Table 1) using a stratified random sample based on burn severity level and physiographic location. We sampled 9 to 11 plots in each of the high, moderate, and low severities in both upland and lowland sites. We defined lowland sites as locations within 25 m of either side of a river, creek, stream, seasonal drainage, or wetland. We sampled one 0.1 ha (20 m × 50 m) plot at each upland point and one 0.05 ha (20 m × 25 m) plot at each lowland point. Upland plots were established with the 50 m side parallel to the slope. Lowland plots were established with the 25 m side parallel to the wet area. At each plot, we recorded all native and non-native species, and counted numbers of individual non-native plants by species. We also recorded numbers and measured diameters (dbh) of trees and snags and calculated basal area. Finally, we recorded landscape characteristics, including elevation, slope, and aspect.

We performed logistic regression on the most common non-native species found, bull

Table 1. Frequency distribution of plots where non-native species were found. Also shown are total plots sampled of each burn severity level and physiographic location and percent of plots sampled within each category with non-natives present.

Severity Level		Plots with non-natives	Bull thistle	Prickly lettuce	Yellow salsify	Spiny sowthistle	Common sheep sorrel	Total plots sampled	Percent with non-natives
High	Upland	3	2	1	1	1	0	9	33%
	Riparian	8	5	2	2	1	1	11	73%
Moderate	Upland	1	0	0	0	1	0	10	10%
	Riparian	5	3	1	1	3	0	10	50%
Low	Upland	4	3	0	1	0	0	10	40%
	Riparian	1	1	0	0	1	0	10	10%

thistle (*Cirsium vulgare* [Savi] Ten.), using presence and absence data from the lowland plots. Before fitting regression models, predictor variables were standardized by subtracting the mean and dividing by the standard deviation such that:

$$x_{std} = \frac{x - \bar{x}}{s}. \quad (1)$$

We used six independent variables as predictors: elevation, burn severity class, slope, post burn basal area, aspect (transformed as a measure of "southness"), and total plant species richness. We tested all combinations of models, including interactions. We used the Akaike Information Criterion (AIC_c) score to define the models with the most support (Burnham and Anderson 2002). Final models included only two-way interactions for ease of interpretation. Models were fit in R version 2.8 using the MASS package (R Development Core team, http://www.r-project.org/).

RESULTS

Overall, non-native species richness and abundance was low throughout the study area. Of the 60 plots sampled, 22 (37%) had at least one non-native species (Table 1). We found five non-native species: bull thistle, prickly lettuce (*Lactuca serriola* L.), spiny sowthistle (*Sonchus asper* [L.] Hill), yellow salsify (*Tragopogon dubius* Scop.), and common sheep sorrel (*Rumex acetosella* L.). All five species are on the Yosemite priority non-native species list (Gerlach *et al*. 2003). Bull thistle was the most widely recorded non-native, occurring in 14 plots (Table 1).

The majority of non-natives occurred in lowland plots. Bull thistle was present in nine of 30 lowland plots: five high severity, three moderate severity, and one low severity plot. We used logistic regression to predict occurrence of bull thistle. Four of the top five models included the variables elevation, burn severity class, and species richness (Table 2), where the probability of bull thistle presence at lowland sites increased with increasing burn severity and species richness and decreasing elevation. Our top logistic regression model explains 64% of the variation in bull thistle presence in lowlands.

DISCUSSION

The paucity of non-native plants we found indicates that they are a relatively minor issue at this time in the area burned in the wildfire. This coincides with the Klinger *et al*. (2003) survey of an elevational gradient in the park. However, the potential exists for populations of non-natives to remain low for some time and then quickly expand (Sakai *et al.* 2001). Bull thistle is recognized as a common post-

Table 2. Top five lowland models predicting *Cirsium vulgare* presence, ranked by AIC_c. Also included are the number of parameters included in the model, the change in AIC_c, model weights, residual deviance, residual degrees of freedom, and percent variance explained. Model parameter abbreviations are as follows: burn severity (BSlevel; +1 = high, 0 = moderate, -1 = low), elevation (elev), transformed aspect (Taspect; -1 = north, +1 = south), species richness (SR), post burn basal area (post). Elevation, species richness, and post burn basal area are all standardized around the mean.

Model ranking	No. of param.	AIC_c	ΔAIC_c	Model weights	Residual deviance	df	Var. exp.
BSlevel, SR, elev, Taspect	5	25.533	0.000	0.29	13.033	25	64%
BSlevel, SR, elev	4	25.747	0.214	0.26	16.147	26	56 %
BSlevel, SR, elev, post	5	26.677	1.144	0.17	14.177	25	61%
BSlevel, SR, elev, BSlevel×SR	5	26.959	1.426	0.14	14.459	25	61%
BSlevel, Taspect, elev	4	27.064	1.531	0.14	17.464	26	52%

fire non-native plant in the Sierra Nevada (Klinger *et al*. 2006). This species occurred most frequently in our lowland plots; however, density was sparse, with three or less individuals per plot. As with many non-native species, as elevation increased throughout our study site, the probability of bull thistle presence decreased (Klinger *et al*. 2006). In addition, bull thistle probability increased with increasing burn severity and increasing plant species richness. A similar study at a lower elevation found an increased number of non-natives with increasing burn severity and increased native species richness (Forwalt *et al*. 2010).

Overall, three years post fire, within the mid-elevation range of the Sierra Nevada, non-natives are minor constituents of the forest community. We attributed this to low propagule pressure and unsuitable habitat due to elevation. However, although not highly abundant, the potential still exists for seed dispersal into new sites within the burn area and beyond. Because early detection is important in combating the spread of non-natives, park managers can use this research to refine their search areas. Given limited resources and time, we recommend prioritizing high severity burned sites in lowlands at lower elevation upper montane forests for monitoring non-native species.

ACKNOWLEDGMENTS

Thank you to A. Leeman for assistance in data collection, and T. Veblen, T. Seastedt, K. McShea, and M. Rose for comments on the initial thesis. We also wish to thank the anonymous reviewers, who greatly improved the manuscript. Funding was provided by the National Park Service Sierra Nevada Inventory and Monitoring Network. Any use of trade names is for descriptive purposes only and does not imply endorsement by the US government.

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