

An Evaluation of Whiskeytown's Shaded Fuelbreaks

Summary Report 2001 - 2002



Abstract - Whiskeytown National Recreation Area has implemented a progressive and ambitious fuels management program that protects high value areas through a multi-faceted approach. As a portion of this program, the park is proposing a six year construction and maintenance schedule of 1,940 acres of shaded fuelbreaks. The combination of fire and ground disturbing activities associated with the construction and maintenance of these fuelbreaks may create conditions favorable to the invasion of non-native plant species. As most public agencies have discovered, there is a lack of information on how to minimize the spread of non-native species while simultaneously reducing hazardous fuels. This project is a preliminary examination of the effects of shaded fuelbreaks on vegetation, and evaluation of what structural characteristics minimize the introduction and spread of non-native plant species. From the data that collected in 2001 and 2002, we found that canopy cover, the percent cover of litter, and litter depth were the most important variables for distinguishing “desirable” and “undesirable” conditions on the park’s shaded fuelbreaks. The location and age of the fuelbreak also played a role in the presence of non-native plant species, however, their relative importance could not be determined by this preliminary evaluation.

Introduction

Problem Statement:

There is concern that the disturbance associated with the construction and maintenance of shaded fuelbreaks in chaparral, knobcone pine, and oak woodland plant communities may act as a conduit for the introduction and spread of non-native and invasive plant species within Whiskeytown National Recreation Area. Greater than 25% of Whiskeytown's flora is comprised of non-native plant species. The connection between disturbance and fire with the invasion of non-native plant species is becoming increasingly clear and the continued construction and maintenance of fuelbreaks may exacerbate the already existing problem. Not only does National Park Service Policy (2001) state that "exotic species will not be allowed to displace native species if displacement can be prevented", there is also a growing emphasis to monitor and manage these invasive species from a regional and local level. However, funding to treat invasive plants is limited.

Project Objectives

The goal of this project is to investigate the role of shaded fuelbreaks in the introduction and spread of non-native plant species and evaluate what thinning practices and structural characteristics minimize this spread into chaparral, knobcone pine, and oak woodland plant communities. The three primary objectives are as follows:

1. Characterize Whiskeytown's low-elevation fuelbreaks in terms of the percent cover of native and non-native plant species, vegetation structure, species composition, and such site attributes as slope, aspect, elevation, proximity to nearest road or trail, and canopy cover.
2. Examine the patterns and relationships between different fuelbreaks, thinning practices, and site characteristics that contribute to the spread of non-native plant species. Based on the observed patterns, these relationships will be tested.
3. Educate and inform resource and fire managers as to what thinning practices and prescriptions minimize the introduction and spread of non-native plant species. This baseline information will be useful in understanding the relationships between invasive plant species, microhabitat attributes, and fuel management techniques in chaparral, knobcone pine, and oak woodland plant communities.

Background

Invasions by non-native plant and animal species are generally considered to be one of the greatest threats to biological diversity in natural areas (Soule 1990). The present distribution and spread of non-native plant species, and the potential threats to native ecosystems, are critical issues for most parks. In chaparral ecosystems, non-native plant species pose at least two threats: 1) competitive interactions with native species; and 2) an alteration of the processes that control ecosystem functioning (e.g., the fire disturbance regime). More specifically, exotic annual grasses not only compete against native herbaceous and woody species by reducing soil light and competing for water and available nutrients, but also can lead to compressed fire return intervals. The increased fire frequency can eventually result in a vegetation type-conversion into an invasive alien community (Brooks 2001, Young and Allen 1997) and promote exotic annuals (Giessow and Zedler 1996). From a fire management perspective, preventing the establishment of exotic grasses and other plants that provide fine fuels in the understory is critical in reducing the rates of spread (Agee et al. 2000).

Low-elevation parks, such as Whiskeytown, have a very high level of invasion. In fact, over 25% of the flora in Whiskeytown is believed to be non-native. Many of the non-native plant species that have become established in the park are highly invasive and are located in developed areas such as campgrounds, trails, and roadsides. It is expected that the infestations that have been successfully treated will require monitoring and re-treating indefinitely. At present, the most troublesome species include Scotch broom (*Cytisus scoparius*), French broom (*Genista monspessulana*), tree of heaven (*Ailanthus altissima*), Himalayan blackberry (*Rubus discolor*), and yellow star thistle (*Centaurea solstitialis*). Exotic annual grasses that have been found to benefit from fire within the park include perennial rye (*Lolium perenne*), cheatgrass (*Bromus tectorum*), medusahead (*Taeniatherum caput-medusa*), *Vulpia* spp., and *Bromus* spp.

Mandates that require direct action to monitor and control the spread of exotics include the 1916 National Park Service (NPS) Organic Act, NPS Policy (2001), and the General Management Plan for the Whiskeytown Unit (1999). The maintenance of healthy ecosystems, hazard fuel reduction, and the control of exotic plant species are priorities for Whiskeytown's resource and fire management programs. It is imperative that park staff develop site-specific information in order to accomplish all of these objectives simultaneously. This project serves as a pilot study for further research and provides initial information to land managers on how to refine fuels reduction prescriptions in ways that minimize the spread of invasive species.

Materials and Methods

A stratified random approach has been used to select vegetation plots within fuelbreaks that exist along roadsides and ridgelines. Five 30 meter transects were randomly located within treatments, and five one-square meter quadrants were randomly selected along each transect. Vegetation sampling in plots consisted of cover estimates for substrate and of all higher plant species (Daubenmire 1959) in addition to the percent cover and depth of litter, large woody debris, and distance to the nearest road, trail, or known infestation. The heights of the tallest grass, herb, shrub, and tree were also collected. A densiometer was used to calculate the percent canopy coverage within each plot. To characterize the transect itself, microhabitat data on slope, aspect, and elevation was taken.

Within the chaparral, knobcone pine, and oak woodland plant communities, fuelbreaks were grouped into three categories: 1) "**Desirable**", representing ideal ecological conditions; 2) "**Marginal**", representing intermediate conditions; and 3) "**Undesirable**", representing the least desirable conditions for a fuelbreak. A "desirable" fuelbreak met fire management objectives, had few patches of bare or hydrophobic soil, and had few invasive plants. An "undesirable" fuelbreak had a reduced overstory, signs of erosion, bare or hydrophobic soils, and established invasive plant species. It is assumed that the Pacific Gas & Electric lines would be the worst-case-scenario, and were included to provide a frame of reference when compared to the other fuelbreaks. The purpose of this spectrum of condition categories was to identify and quantify what makes up a desirable and undesirable fuelbreak from ecological and fire management perspectives. Relationships between fuels reduction techniques and non-native plant species were tested using multivariate analysis. With the desirable fuelbreaks serving as the ecological goal for fuelbreaks within each plant community, data from these fuelbreaks were compared.

Results

For each of the shaded fuelbreaks and control plots sampled, a "condition rating" was developed to quantify the cover of non-native species relative to native within each fuelbreak:

$$\text{Condition Rating} = \frac{\% \text{ cover of non-native species}}{(\% \text{ cover of native} + \% \text{ cover of non-native species}) * 100}$$

As seen in Figure 1, The Shasta Divide, Lower Mule, and Orofino fuelbreaks were characterized as "undesirable" and had the highest percent cover of non-native plant species with respect to the cover of native plant species. The Orofino Control plots and the Buck fuelbreak were in the best condition (desirable) and intermediate, between the two extremes, were the PGE, Whiskey, Sunshine, and Kennedy fuelbreaks, and the Lower Mule control plots.

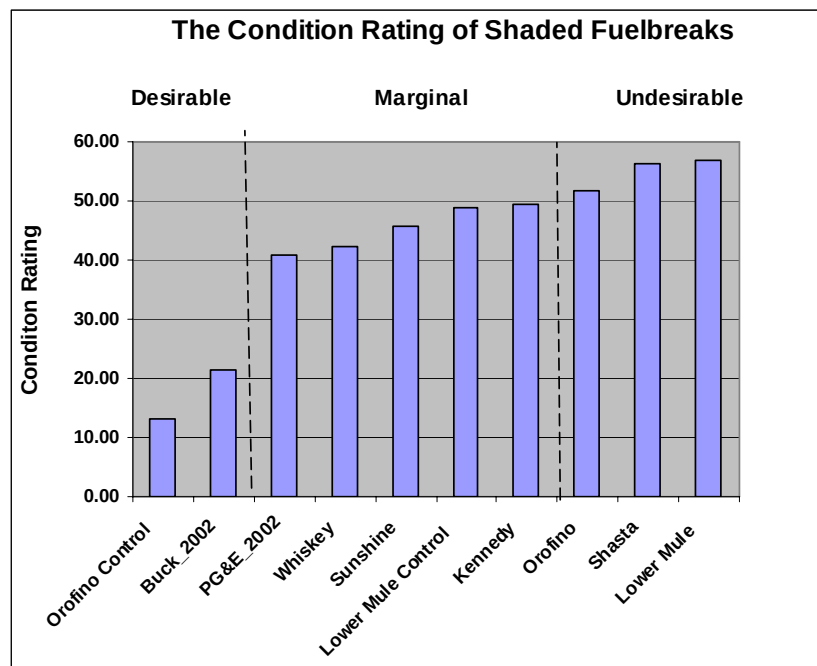


Figure 1. Condition Rating of Shaded Fuelbreaks.

A Principal Components Analysis (PCA), which is a multivariate statistical technique used to detect patterns and not test actual hypotheses, was used to characterize the fuelbreaks in terms of the percent cover of native and non-native plant species and such microhabitat characteristics

as canopy cover and litter (Figure 2). The analysis included data from fuelbreaks that were sampled in 2001 and 2002, as well as data from control plots. Factor 1 explains 35.67% of the total variance and Factor 3 explained 13.87% of the total variance. The loadings for Factor 1 (Table 1) indicated that the percent cover of plant species (native and non-native alike) was inversely proportional to canopy cover, percent cover of litter, and litter depth. The loadings for Factor 3 were positive and indicated that the percent cover of native grasses increased with canopy cover.

Shaded fuelbreaks with low Factor 1 scores were considered "desirable" and had a very low percent cover of exotic plant species, a high percent cover of litter, a lot of canopy cover, and the litter layer was deep. These fuelbreaks include the Buck fuelbreak (for 2001 and 2002 data), PG&E_01, and the control plots along the Orofino and Lower Mule fuelbreaks.

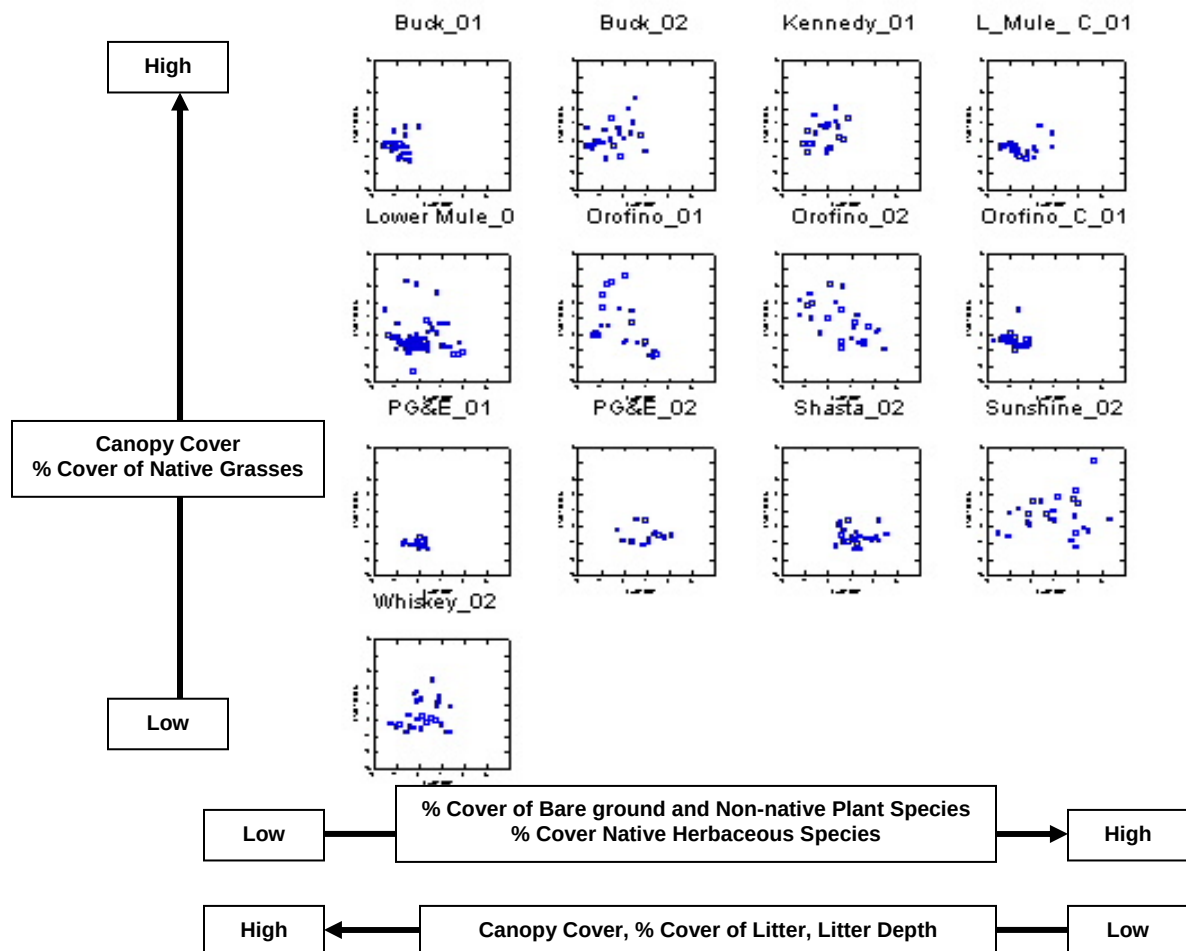


Figure 2. Principal Components Analysis of shaded fuelbreak data collected in 2001 and 2002 for treated areas and controls. The name of the fuelbreak is above each individual graph and the numbers next to the name of the fuelbreak indicates the year that data was collected. A "C" located before the year specifies control plots located outside of the fuelbreak.

Shaded fuelbreaks with high Factor 1 scores were considered to have "undesirable" characteristics. These fuelbreaks had a high percent cover of bare ground, a high percent cover of exotic grass and herbaceous species, and the grass is tall. These fuelbreaks have very little canopy cover, a low percent cover of litter, shallow litter depth, and there were very few shrubs. These fuelbreaks include the Shasta Divide, Sunshine, and Orofino_02 fuelbreaks. Fuelbreaks that were considered to be "marginal" in condition have intermediate mean Factor 1 scores. These include the Kennedy, Lower Mule, Orofino, and PG&E_02 fuelbreaks.

When taking into account the latest data for each fuelbreak, the mean Factor 1 scores were graphed into the "Desirable", "Marginal", and "Undesirable" fuelbreaks (Figure 3). Shaded fuelbreaks with negative mean factor scores (-0.025 - -0.75) were considered desirable in terms of exotic plant species and canopy cover. These fuelbreaks include the Orofino and Lower Mule control plots, and the Buck fuelbreak. Fuelbreaks that were considered marginal in condition are those that have mean Factor 1 scores in the intermediate range (-0.25 - 0.25). These marginal fuelbreaks include Kennedy, Lower Mule, and the Whiskey fuelbreaks. Shaded fuelbreaks that had high mean Factor 1 scores (0.025 - 1.25) were in poor condition and had a high percent cover of non-native plant species and canopy cover. These fuelbreaks included the Orofino, Sunshine, PG&E, and Shasta Divide fuelbreaks. The Shasta Divide fuelbreak was in the worst condition of the fuelbreaks sampled and the Buck was considered to be in the best condition.

Variable	Factor 1	Factor 3
Canopy Cover	-0.689	0.382
Bare Ground	0.597	0.131
Percent Cover of Litter	-0.644	0.111
Litter Depth	-0.577	-0.129
Percent Cover of Exotic Grasses	0.719	0.109
Percent Cover of Exotic Herbaceous species	0.635	0.187
Percent Cover of Native Grasses	0.081	0.899
Percent Cover of Native Herbaceous species	0.609	0.255
Percent Variance Explained by Factor	35.67	13.87

Table 1. PCA Component Loadings and Percent Variance Explained. Highly correlated variables were not included in the analysis and loadings that were less than the absolute value of 3 were excluded from the interpretation of the data.

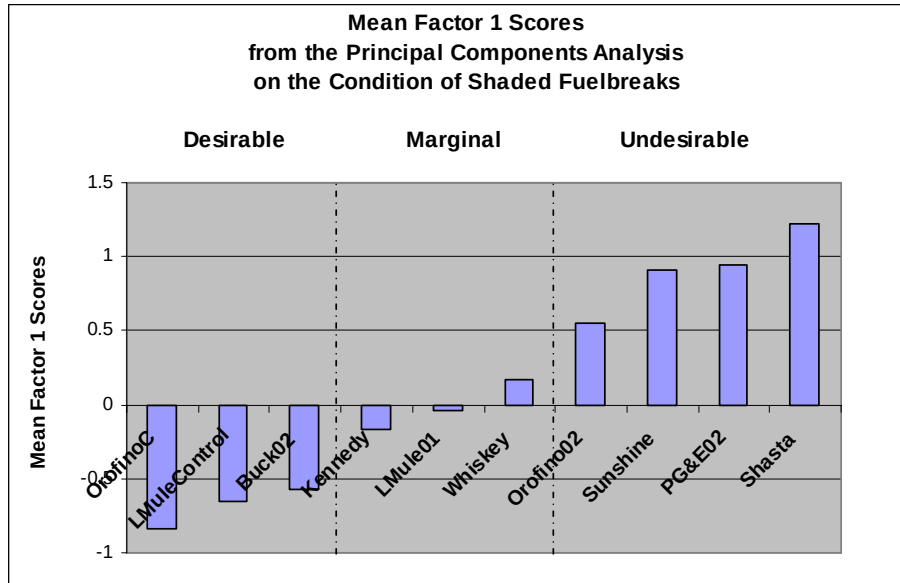


Figure 3. Mean Factor 1 scores of the Principal Components Analysis in Figure 1.

A One-Way Analysis of Variance on the PCA Factor 1 scores characterizing non-native plants on the fuelbreaks determined that there was a significant difference ($P < 0.001$) between fuelbreaks (Table 2). The first contrast from the ANOVA illustrated a significant difference ($P = 0.010$) between control plots and plots located within the fuelbreak, for the Orofino and Lower Mule fuelbreaks specifically. Control plots had significantly lower Factor 1 scores (desirable conditions) when compared to plots located in the adjacent fuelbreak. The second contrast demonstrated that there were significant differences ($P = 0.016$) in the mean Factor 1 scores between roadside fuelbreaks and ridgeline fuelbreaks (Figure 4). With the exception of the Buck fuelbreak, fuelbreaks that are located along roadsides had low Factor 1 scores and have been described as having "desirable" conditions. The third contrast found that there was a significant difference ($P < 0.001$) between old fuelbreaks (e.g., Lower Mule, Orofino, Sunshine, and Shasta Divide) and fuelbreaks that have been constructed within the past 5 years (e.g., Buck, Kennedy, and Whiskey Creek fuelbreaks) (Figure 5). Fuelbreaks that have been constructed recently, had more desirable conditions (low Factor 1 scores) when compared to older fuelbreaks.

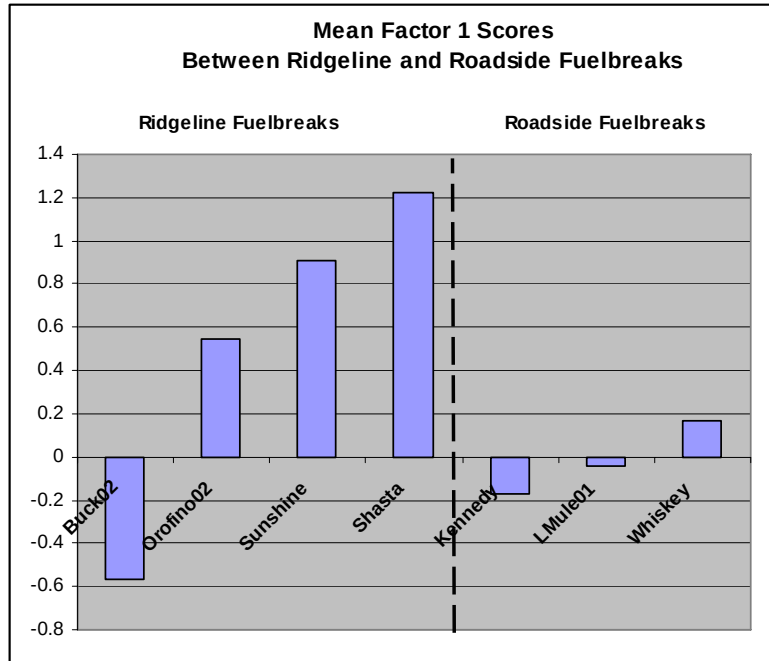


Figure 4. The Mean Factor 1 scores for fuelbreaks located along ridgelines and roadsides. Fuelbreaks located along the roadsides had more desirable conditions (low Factor 1 scores) when compared to the ridgeline fuelbreaks.

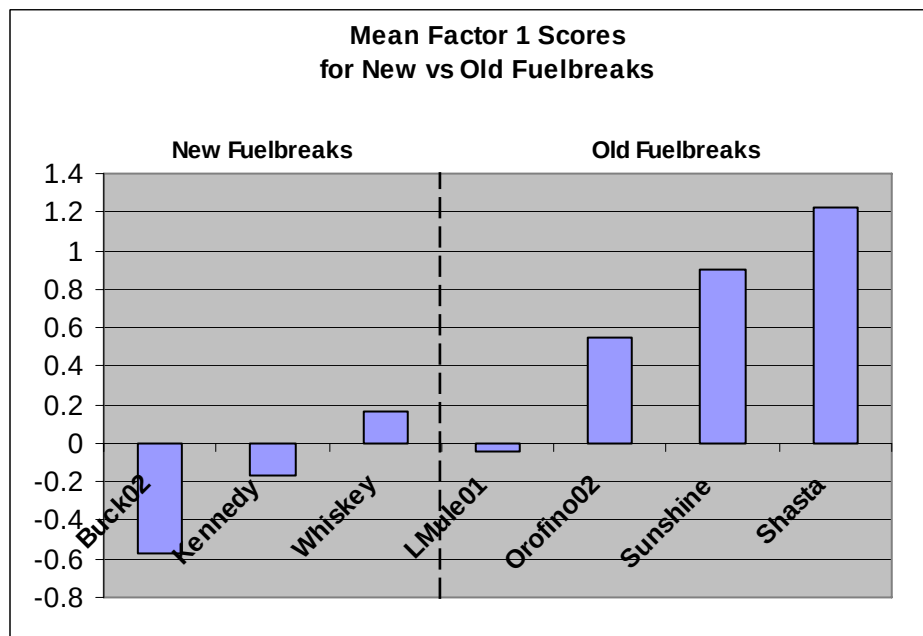


Figure 5. Mean Factor 1 scores for old fuelbreaks and fuelbreaks that have been constructed within the past 5 years. Newly constructed fuelbreaks had more desirable conditions when compared to older fuelbreaks.

A Canonical Correlation was used to determine which microhabitat characteristics were related to the percent cover of non-native plant species (Figure 6, Table 3). Root 1 non-native plant cover scores were negatively related to canopy cover, the percent cover of litter, and litter depth, and positively related to the percent cover of bare ground. High percent cover values for non-native plant species was associated with low canopy cover, low percent cover of litter, and very little litter depth.

Source	Sum-of-Squares	df	Mean-Square	F-Ratio	P
Fuelbreak	113.738	9	12.638	17.575	<0.001
Roadsides vs. Ridgelines	4.237	1	4.237	5.892	0.016
Old vs. New	20.331	1	20.331	28.276	<0.001
Control vs. Treatment	4.857	1	4.857	6.755	0.010
Error	165.381	230	0.719		

Table 2. One way Analysis of Variance with contrasts of differences among fuelbreaks of the mean Factor 1 PCA scores.

Canonical Root 1	R(exotic*environmental) = 0.477		P<0.001
Exotic Plant Variables	Loadings	Microhabitat Variables	Loadings
Percent Cover of Exotic Grass species	0.885	Canopy Cover	-0.969
Percent Cover of Exotic Herbaceous species	0.943	Bare Ground	0.288
		Litter Depth	-0.246
		Percent Cover of Litter	-0.546

Table 3. Canonical Correlation Analysis of the percent cover of non-native plant species in relation to canopy cover, percent cover of litter, litter depth, and bare ground.

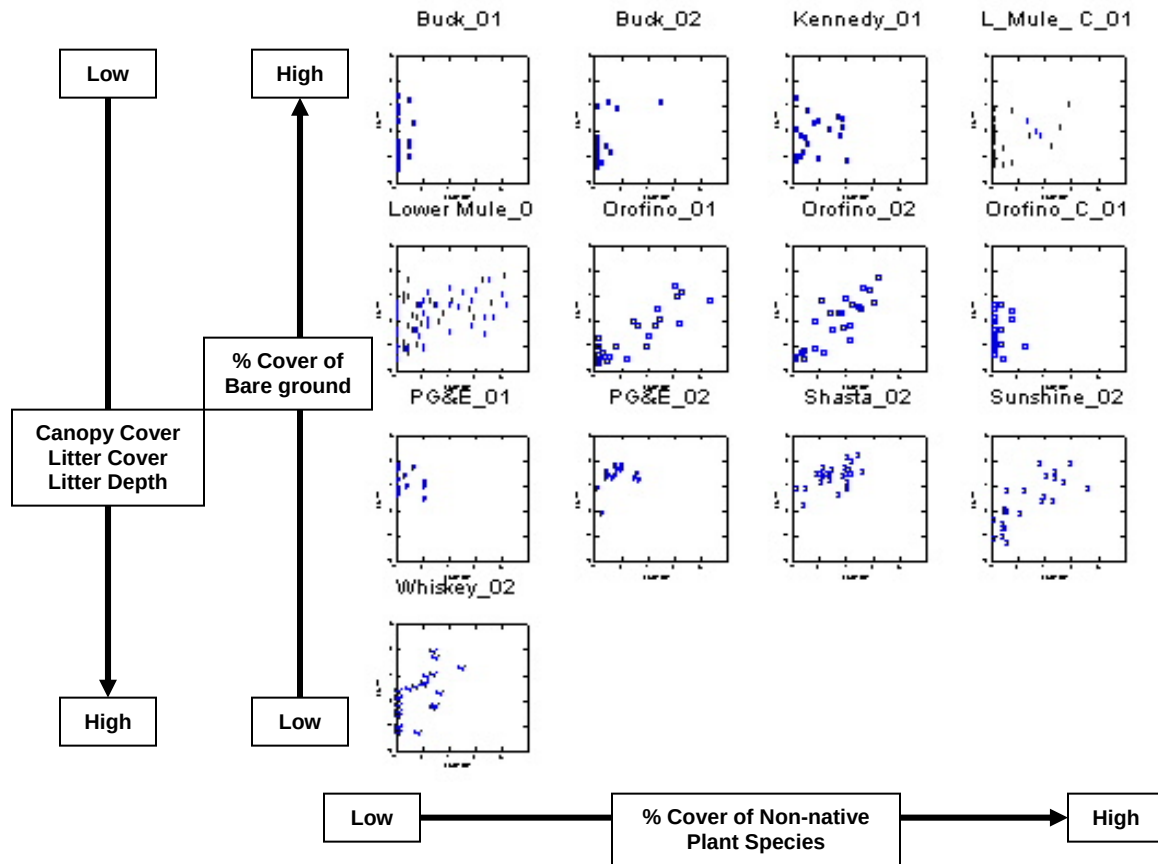


Figure 6. Canonical Correlation Analysis of the percent cover of non-native plant species relative to such microhabitat characteristics as the percent cover of litter, litter depth, canopy cover, and bare ground. Data distributed to the right, along the x-axis, indicates a high percent cover of non-native plant species. The name of the fuelbreak is above each individual graph, and the numbers next to the name of the fuelbreak indicates the year that data was collected. A "C" located before the year specifies control plots located outside of the fuelbreak.

Of the shaded fuelbreaks sampled, approximately 23% of the grass and herbaceous species were non-native (Table 4). Plots with a high percent cover of non-native plant species, coincidentally had high species richness. The most diverse fuelbreak for native and non-native grass and herbaceous species was the Lower Mule, followed by the Orofino, Sunshine, and Whiskey fuelbreaks. There were no non-native shrub, subshrub, or tree species found within the fuelbreaks sampled. Non-native species with the highest cover include *Aira caryophyllea* (silver hair grass), *Vulpia bromoides* (fescue), *Gnaphalium luteo-album* (fragrant everlasting), *Hypochaeris radicata* (hairy cats ears), *Bromus madritensis* (foxtail chess), and *Gastridium ventricosum* (nit grass). Native species with the highest cover included *Heteromeles arbutifolia* (toyon), *Toxicodendron diversilobum* (poison oak), *Ceanothus lemmonii* (Lemmon's ceanothus),

Styrax officinalis (snowdrop bush), *Lotus micranthus* (small flowered lotus), and *Aristolochia californica* (California pipevine) in the PG&E lines in 2001.

Fuelbreak	% Non-native Plant* Cover (all plots)	% Non-native Plant* Cover (in plots where they occur)	Number of Species*	Number of Non-native* Species	Number of Native* Species
Buck_01	0.24	1.20	22	4	18
Buck_02	1.40	5.81	25	4	21
Kennedy_01	11.41	15.21	27	12	15
Lower Mule Control_2001	5.32	12.09	22	12	20
Lower Mule_01	13.96	16.80	57	21	36
Orofino Control_01	0.67	2.38	16	6	10
Orofino_01	15.35	20.20	39	11	28
Orofino_02	13.85	15.74	45	13	32
PG&E_01	1.55	3.88	11	8	3
PG&E_02	4.43	4.74	24	10	14
Shasta_02	11.48	11.96	38	11	27
Sunshine_02	12.66	14.38	44	12	32
Whiskey_02	6.92	13.31	42	11	31
TOTAL			123	28	95

Table 4. Summary of the percent cover of plant species. (*For grass and herbaceous species only.)

Fuelbreak	Highest Cover (Native)	Highest Cover (Non-native)
Buck_2001	<i>Toxicodendron diversilobum</i>	<i>Vulpia bromoides</i>
Buck_2002	<i>Heteromeles arbutifolia</i>	<i>Gnaphalium luteo-album</i>
Kennedy_2001	<i>Ceanothus lemmonii</i>	<i>Aira caryophyllea</i>
Lower Mule Control_2001	<i>Heteromeles arbutifolia</i>	<i>Hypochaeris radicata</i>
Lower Mule_2001	<i>Heteromeles arbutifolia</i>	<i>Aira caryophyllea</i>
Orofino Control_2001	<i>Styrax officinalis</i>	<i>Aira caryophyllea</i>
Orofino_2001	<i>Styrax officinalis</i>	<i>Aira caryophyllea</i>
Orofino_2002	<i>Lotus micranthus</i>	<i>Aira caryophyllea</i>
PG&E_2001	<i>Aristolochia californica</i>	<i>Bromus madritensis</i>
PG&E_2002	<i>Heteromeles arbutifolia</i>	<i>Gastidium ventricosum</i>
Shasta_2002	<i>Ceanothus lemmonii</i>	<i>Aira caryophyllea</i>
Sunshine_2002	<i>Toxicodendron diversilobum</i>	<i>Aira caryophyllea</i>
Whiskey_2002	<i>Heteromeles arbutifolia</i>	<i>Vulpia bromoides</i>

Table 5. The highest cover of native and non-native grass and herbaceous species.

Discussion

This study suggests that the strongest correlation between non-native and invasive plant species and shaded fuelbreaks is the amount of canopy cover and litter at each sample site. As the Canonical Correlation demonstrated, non-native plant cover scores were inversely related to canopy cover, the percent cover of litter, and litter depth. The reduction of overstory trees and shrubs through hand-thinning and prescribed burning increased the amount of direct sunlight and reduced the amount of litter on the soil surface. Research on fire alone has demonstrated that recently burned areas are considered vulnerable to exotic invasion because competition from established plants may be reduced after fire (Tyler and D'Antonio 1995) and fire can dramatically increase the amount of bare ground available for germination and establishment (Boyd et al. 1993).

Disturbance is believed to enhance the probability of non-native plant establishment in native plant communities and the combination of fire and treatment with hand crews could have a cumulative effect (Rejmanek 1989, Hobbs 1991). The repeated disturbance of maintaining fuelbreaks every 2-3 years could continue to support these infestations or spread them throughout the fuelbreak. The activities associated with hand crews may favor invasions by transporting propagules, disturbing the soil surface, and creating gaps that allow the spread of invasives into uninfested areas (Brooks 2001). This is supported by examining both old and relatively new fuelbreaks. Older fuelbreaks had greater non-native plant cover than newly constructed fuelbreaks. However, most of the old fuelbreaks sampled in this study reside along ridgelines. Because of this design constraint, it was difficult to distinguish the age of the fuelbreak from the location. Future sampling should take into consideration equal combinations of location and age of the fuelbreaks.

For desirable conditions, the Buck fuelbreak (Figure 7) was considered ideal for both the Principal Components Analysis and the Condition Class Rating system (Table 6). The Orofino (Figure 8) and Shasta Divide (Figure 9) fuelbreaks were considered undesirable and in need of some form of rehabilitation. Because the Buck fuelbreak was considered ideal in condition for both analyses, the average canopy cover ($X = 70\%$) was used as a target for the other fuelbreaks. In order for the Shasta Divide ($X = 7\%$) and Orofino fuelbreaks ($X = 55\%$) to reach this target condition, canopy cover should be increased by 63% on the Shasta Divide and 15% on the Orofino fuelbreak. Fuelbreaks that were somewhat marginal in condition, such as the Sunshine ($X = 60\%$) and Lower Mule ($X = 55\%$), canopy cover could be increased by 10% and 15%, respectively (Figures 10 and 11). For all of these fuelbreaks, thinning and broadcast burning within the fuelbreak is not recommended for the next few years. Despite a very low canopy cover ($X = 11\%$), the PG&E lines (Figure 12) were considered marginal according to the PCA and Condition Class Rating. The results from this treatment were an anomaly in that there was very

little live plant cover or litter, but there was a high percent cover of bareground. This suggests that the upper layers of the soil may have been lost, possibly from repeated treatments, or even bull-dozing.

Desirable		Marginal		Undesirable	
PCA	Condition Rating	PCA	Condition Rating	PCA	Condition Rating
Orofino Control	Orofino Control	Kennedy	PG&E_02	Orofino_02	Orofino_02
Lower Mule Control	Buck_02	Lower Mule	Whiskey	Sunshine	Shasta
Buck_02		Whiskey	Sunshine	PG&E_02	Lower Mule
			Lower Mule Control	Shasta	
			Kennedy		

Table 6. Comparison table of the fuelbreaks analyzed with the Principal Components Analysis and the Condition Class Rating.



Figure 7. The Buck fuelbreak had an average canopy cover of 70% and represented desirable conditions.



Figure 8. The Orofino Fuelbreak had undesirable conditions.



Figure 9. The Shasta fuelbreak had an average canopy cover of 7% and represented undesirable conditions.



Figure 10. The Sunshine fuelbreak represented marginal conditions.



Figure 11. The Lower Mule Fuelbreak represented marginal conditions.



Figure 12. Despite a low canopy cover of 11%, the PG&E lines had very little live plant cover and litter.

Whiskeytown is located within the Klamath Mountain physiographic province and is an area of significant diversity due to proximity to the Cascade Range, Coast Range, and Sacramento Valley. The great heterogeneity of the region's biodiversity is due to the area's rugged topography, very complex geology and soils, and strong gradients in climate and elevation, and an extensive history of natural and anthropogenic disturbance. Because of this complexity, the park's low elevation plant communities (e.g., chaparral, knobcone pine, mixed oak woodlands, and scattered ponderosa pines) often integrate with one another so that distinct vegetation types are difficult to discern. This variability is another design constraint for monitoring and it is recommended that further analyses be conducted so that the plant communities can be stratified and management recommendations be made on a plant community basis.

It is unknown as to whether non-native plant species that have become established within fuelbreaks will become permanent infestations, or if they will eventually be selected against if the

overstory vegetation was allowed to recover. Because of this, the long-term monitoring of shaded fuelbreaks is recommended for the early detection of change over time and for efficient and cost-effective management of non-native plant species. The monitoring protocol should also remain flexible and adaptable to the needs of the Natural Resource and Fire Management programs at Whiskeytown. Thinning prescriptions can be refined and implemented in such a way that will enable them to achieve the described desirable conditions.

Acknowledgements

Thanks to the Redwood Fire Effects crew (Jen Hooke, Karen Webster, Dana Sandifer, Jen Prince, Christy Frenzen, Rachael Roditti, Todd Erdody, and Nunally Benzing) for identifying and collecting two years worth of shaded fuelbreak data in adverse climatic conditions, rugged terrain, and surrounded by TODI. Also, a special thanks to Windy Bunn for her data entry, outstanding quality control and overall data management and assistance.



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