Birch Fire Ecological Monitoring Draft Report

Marc D. Meyer[a]* and Hugh D. Safford[b]

[a]Southern Sierra Nevada Province Ecologist, USDA Forest Service, Pacific Southwest Region, 1600 Tollhouse Road, Clovis, California 93611; 559-297-0706 ext. 4929; mdmeyer@fs.fed.us

[b]Regional Ecologist, USDA Forest Service, Pacific Southwest Region, 1323 Club Drive, Vallejo, California 94592

Photo 1. Widespread singleleaf pinyon pine (*Pinus monophylla*) mortality and vegetation change nine years following the Birch Fire (2002).

Table of Contents

Project Objectives

- Examine patterns of vegetation recovery nine years following the Birch Fire (2002) in the Inyo National Forest, including:
    - Mortality and regeneration in singleleaf pinyon pine (*Pinus monophylla*)
    - Shrub and understory plant species composition and diversity
    - Invasive species cover including cheatgrass (*Bromus tectorum*)
    - Snag retention, fuels accumulation, and downed wood cover
- Contribute to the development of restoration strategies for the Birch Fire area in the Inyo National Forest

Background

There is a critical need for post-fire monitoring of vegetation in the Sierra Nevada, which represents a unique and diverse ecoregion in California. Recent climate modeling projections have identified vegetation in this region as vulnerable to future changes in climate and climate-related stressors, such as increased wildfire activity and intensity (Lenihan et al. 2003, 2008). These projections are supported by recent observations of increased frequency, size, and severity of fires in the Sierra Nevada (Miller et al. 2009). Such changes underscore the need for post-fire vegetation monitoring in Sierra Nevada ecosystems, especially in forests and woodlands that are experiencing rapid changes in climate.

The urgency of post-fire vegetation monitoring is particularly evident on the eastern slope of the southern Sierra Nevada, where recent increased wildfire activity and cheatgrass (*Bromus tectorum*) invasions are impacting post-fire vegetation recovery. Arid woodlands and shrublands of the region are especially prone to these impacts and the potential for type conversion to non-native grassland (Mack 1986). For this reason, we selected singleleaf pinyon pine (*Pinus monophylla*) woodlands in the 2549-acre (1031 ha) Birch Fire (2002) on the Inyo National Forest to examine post-fire patterns of vegetation change. This report summarizes the nine-year post-fire vegetation patterns following the Birch Fire (2002).

Approach/Methods:

We initiated post-fire monitoring of vegetation in the Birch Fire using a 200-m grid-based sampling design developed by the Region 5 Ecology Program, including both tree regeneration plots installed every 4 ha (10 acres) and common stand exam (CSE) plots every 16 ha (40 acres) (Safford 2011). We selected singleleaf pinyon pine stands within the Birch Fire perimeter and in adjacent unburned 'control' sites for vegetation monitoring. Each regeneration plot is 60 m^2 (1/70th acre) and CSE plot is ~0.04 ha (1/10th acre) with a ~0.08 ha (1/5th acre) plot size for measuring plant species diversity and composition. Recorded variables primarily focused on:

- Site attributes (e.g., slope, aspect, elevation, substrate, vegetation type, and topographic position),
- Stand attributes (e.g., density of live and dead trees, live and dead basal area, snag density),

- Vegetation and ground cover (e.g., overstory vegetation cover, shrub and herbaceous plant cover, cheatgrass cover, litter and woody debris cover, litter depth),
- Tree regeneration (e.g., density and age structure of seedlings and saplings, sapling dbh, evidence of insects and diseases.

Monitoring focused on singleleaf pinyon pine but included data collection for coexisting tree species (e.g., Jeffrey pine, *P. jeffreyi*).

Photo 2. Pinyon pine mortality and understory shrub and herbaceous plant response approximately nine years following the Birch Fire.

Results

Stand variables and fuels accumulation

We sampled a total of 39 regeneration plots with a total sample area of 3.9 acres (~1.56 ha) in 30 burned and 9 unburned (control) sites. Within the same sampling grid, we surveyed 10 CSE plots with a total sample area of 2 acres (~0.81 ha) in 8 burned and 2 unburned sites. Approximately 97% of burned plots within the Birch Fire burned at high severity (100% tree mortality). One plot (3%) was primarily located within an unburned patch inside the Birch Fire perimeter and was classified as low-severity (light patchy burn, no detectable overstory mortality). Two control plots were located in unburned patches inside the Birch Fire perimeter. Live singleleaf pinyon pine basal area (U = 5.735, P < 0.001; Figure 1) and overstory cover ($F_{1,37}$ = 54.476, P < 0.001) were significantly lower in burned plots (mean = 0.5% cover) compared to unburned controls (32% cover).

Density of pinyon pine snags was nearly 25 times greater in burned (445 snags/ha) than unburned (18 snags/ha) plots (U = 39.00, P = 0.001); the average dbh of snags was 20.4 cm in burned plots and 15.0 cm in unburned plots. Litter depth was 3 times greater in unburned (1.5 cm) than burned plots (0.5 cm; $F_{1,37}$ = 14.138, P = 0.001), but litter cover was greater in burned (63%) than unburned plots (50%; $F_{1,37}$ = 4.637, P = 0.038). Litter cover was positively correlated with cheatgrass cover across burned and unburned plots (r = 0.53; P < 0.001). Downed wood contributed to very little total cover and was not different between unburned (3.4%) and burned plots (1.1%; $F_{1,37} = 2.039$, $P = 0.162$). One-hour fuels were greater in burned CSE plots ($F_{1,8} = 22.29$, $P = 0.001$); 10-hr fuels, 100-hr fuels, and total fuel depth were similar between burned and unburned CSE plots ($P > 0.05$; Table 1).

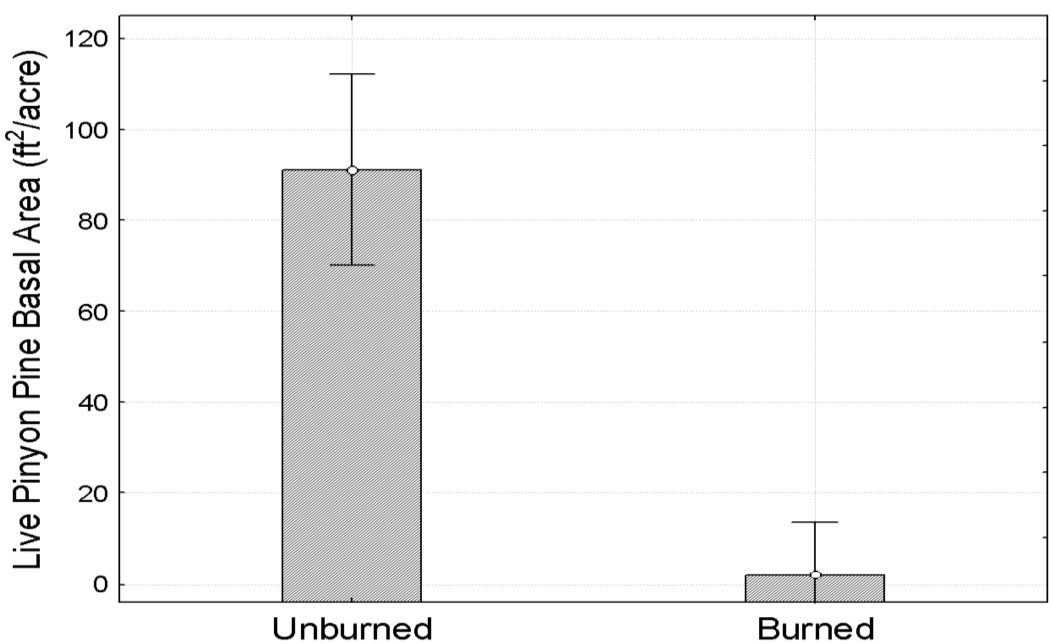

Figure 1. Mean (± 95% Confidence Interval; CI) singleleaf pinyon pine live basal area in stands burned in the Birch Fire (2002) and adjacent unburned stands.

Table 1. Mean (± Standard Error) fuel loadings in burned and unburned singleleaf pinyon pine stands of the Birch Fire, based on Common Stand Exam plots.

CSE Plot	1-hr fuels*	10-hr fuels	100-hr fuels	Fuel depth (cm)
Unburned (*n*=2)	3.08 ± 0.30	0.55 ± 0.18	0.03 ± 0.02	2.3 ± 1.4
Burned (*n*=8)	0.59 ± 0.25	0.35 ± 0.08	0.04 ± 0.01	3.2 ± 0.2

*$P < 0.05$ for comparison between burned and unburned plots.

Tree regeneration

Singleleaf pinyon pine regeneration was more than two orders of magnitude greater in unburned compared to burned plots ($U = 5.803$, $P < 0.001$; Figure 2). Pinyon pine regeneration occurred in 100% of unburned plots but only 3% of burned plots, and regeneration was positively related to live pinyon pine basal area (overall model: $F_{3,35} = 33.610$, $R^2 = 0.72$, $P < 0.001$; live basal area: $\beta = 0.84$, $R_{partial} = 0.80$, $P < 0.001$; Figure 3). Percentage rock cover ($P = 0.127$) and slope ($P = 0.113$) were included in the overall model but these factors were not significantly related to pinyon pine regeneration. Distance to the nearest singleleaf pinyon pine seed source was nearly two orders of magnitude greater in burned (mean = 113.8 m) compared to unburned plots (mean = 1.2 m) ($F_{1, 37} = 4.147$, $P < 0.001$). Pinyon pine regeneration consisted predominantly of seedlings (91% of total regeneration) with a mean seedling age of 4.3 years. Saplings consisted of 9% of total regeneration and had a mean sapling age of 19.3 years.

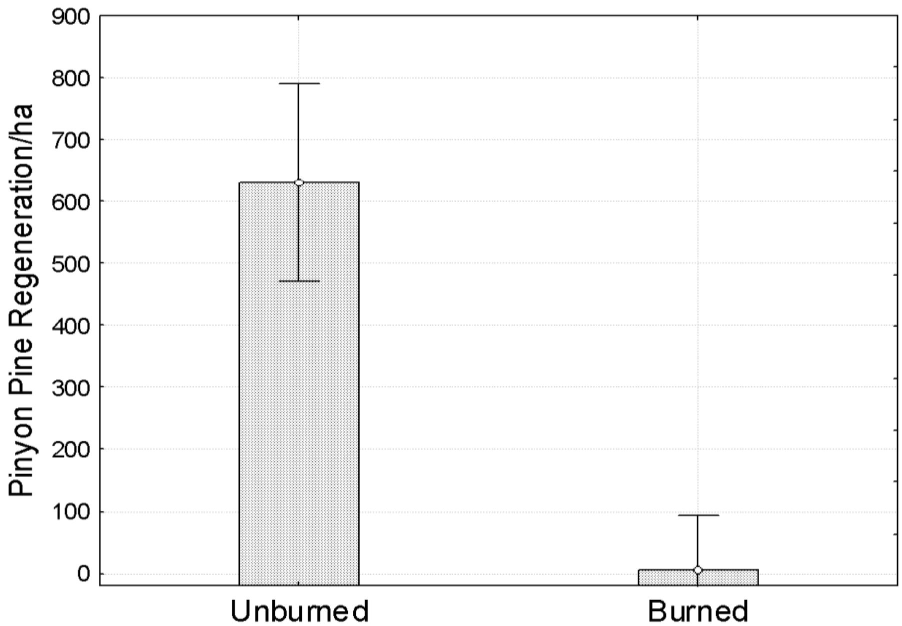

Figure 2. Mean (± 95% CI) singleleaf pinyon pine regeneration in burned and unburned stands of the Birch Fire.

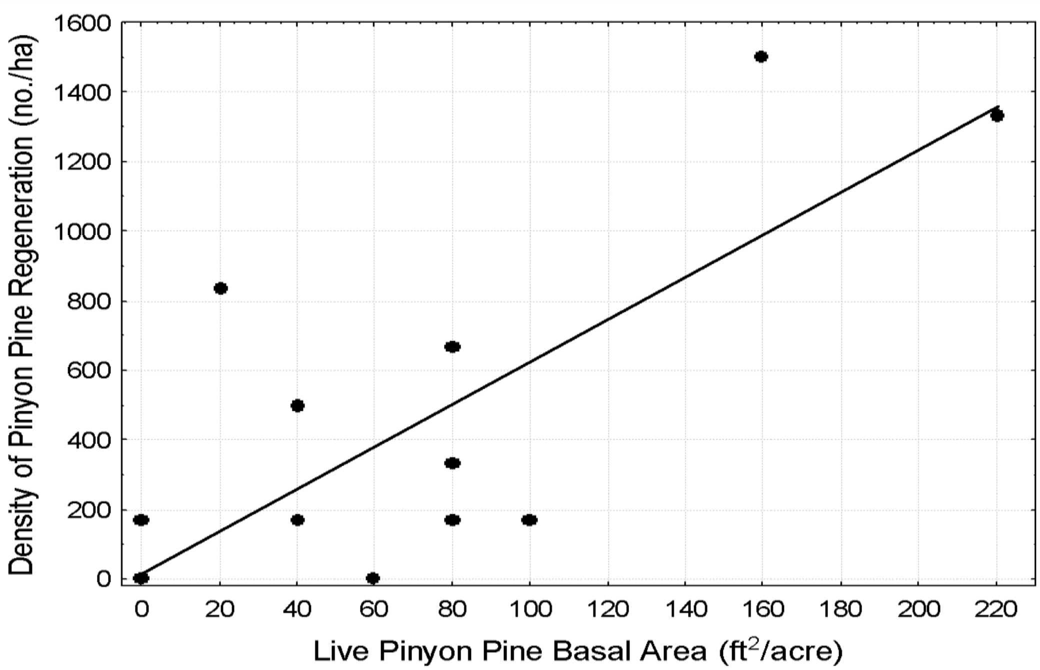

Figure 3. Relationship between density of pinyon pine regeneration and live pinyon pine basal area in the Birch Fire.

Understory vegetation

Species richness of shrubs ($F_{1, 37}$ = 7.875, P = 0.008) was greater in burned than unburned plots (Figure 4). Shrub species that were found exclusively in burned areas included desert ceanothus (*Ceanothus greggii*), yellow rabbitbrush (*Chrysothamnus viscidiflorus*), rubber rabbitbrush (*Ericameria nauseosa*), spineless horsebrush (*Tetradymia canescens*), and desert peach (*Prunus andersonii*). Species encountered in both burned and unburned areas but more frequently encountered in unburned areas included basin sagebrush (*Artemisia tridentata*), antelope bush (*Purshia tridentata*), curl-leaf mountain-mahogany (*Cercocarpus ledifolius*), and roundleaf snowberry (*Symphoricarpos rotundifolius*). Shrub cover trended toward greater cover in burned areas, but this trend was not significant ($F_{1, 37}$ = 3.036, P = 0.09; Figure 4). Cover of native herbaceous plants was 6.4 times greater in burned than unburned plots (U = -2.090, P = 0.037), although in CSE plots the species richness of native herbaceous plants was similar among burned (mean = 17.5) and unburned (mean = 15.5) plots ($F_{1, 8}$ = 0.179, P = 0.684). Overall, understory native species composition was similar between burned and unburned CSE plots (Appendix A).

Cheatgrass cover was 38 times greater in burned than unburned plots (U = -3.634, P < 0.001) (Figure 5). Cheatgrass was absent or in trace coverage (≤0.1%) in 89% of unburned plots (one plot contained 5% cover), but 50% of burned plots had >25% cheatgrass cover. Cheatgrass cover was negatively related with native herbaceous plant cover, live basal area of pinyon pine, and shrub cover (overall model: $F_{3, 35}$ = 15.311, R^2 = 0.53, P < 0.001; native herbaceous plant cover: β = -0.71, $R_{partial}$ = -0.65, P < 0.001; live basal area: β = -0.66, $R_{partial}$ = -0.60, P < 0.001; shrub cover: β = -0.32, $R_{partial}$ = -0.30, P = 0.010; factors log_{10}-transformed).

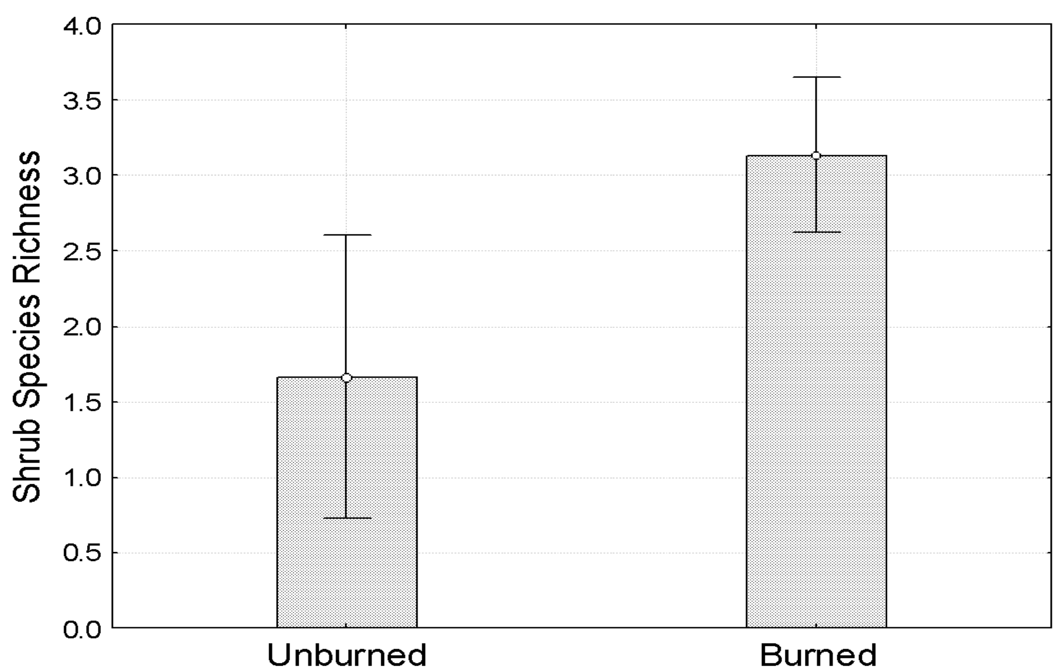

Figure 4a. Mean (± 95% CI) shrub species richness in burned and unburned plots of the Birch Fire.

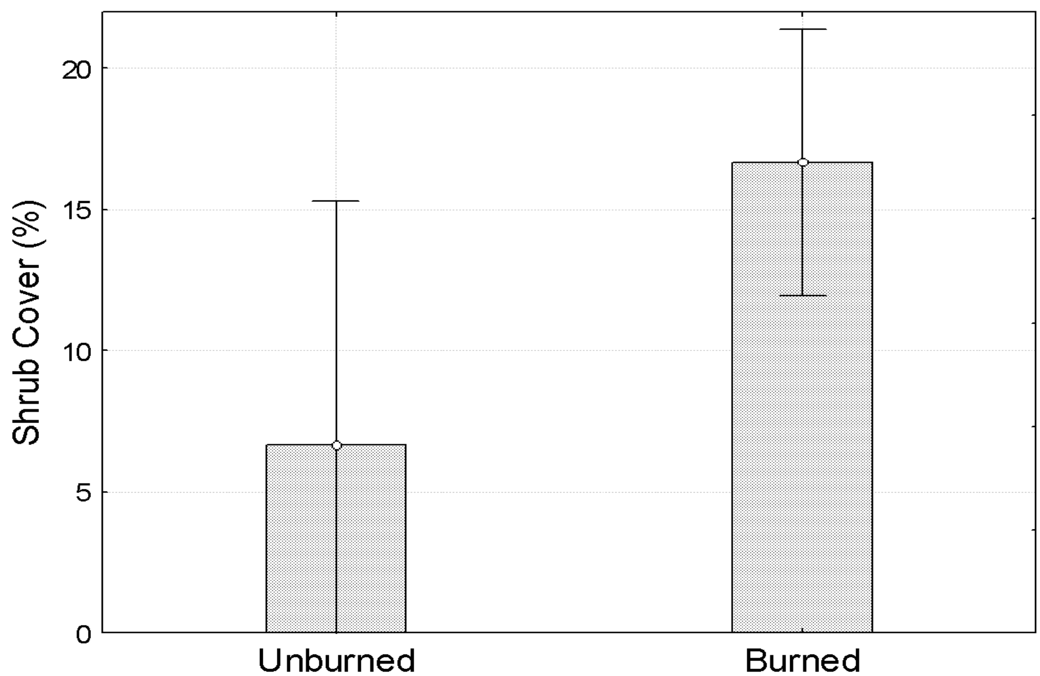

Figure 4b. Mean (± 95% CI) shrub species cover in burned and unburned plots of the Birch Fire.

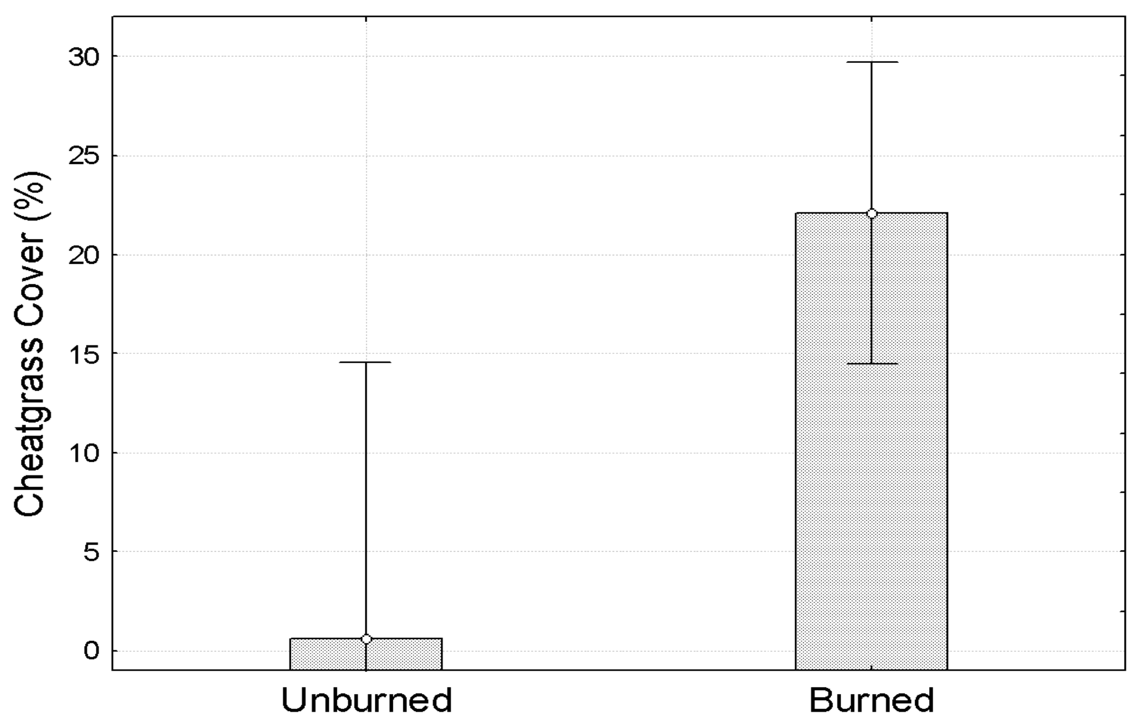

Figure 5. Mean (± 95% CI) cheatgrass cover in burned and unburned plots of the Birch Fire.

Photo 3. Burned plot in the Birch Fire with extensive cheatgrass (Bromus tectorum) cover. Note the relatively low cover of native herbaceous plants and shrubs at this site.

Monitoring plots with greater (>20%) cheatgrass cover tended to occur in the mid to upper topographic position of slopes (χ^2 = 70.792; $P < 0.001$), especially in southeastern portion of the Birch Fire (Figure 6). The only other non-native plant species detected within the Birch Fire was Russian thistle (*Salsola tragus*), which had a mean cover of 0.5% in burned plots and 0% cover in unburned plots.

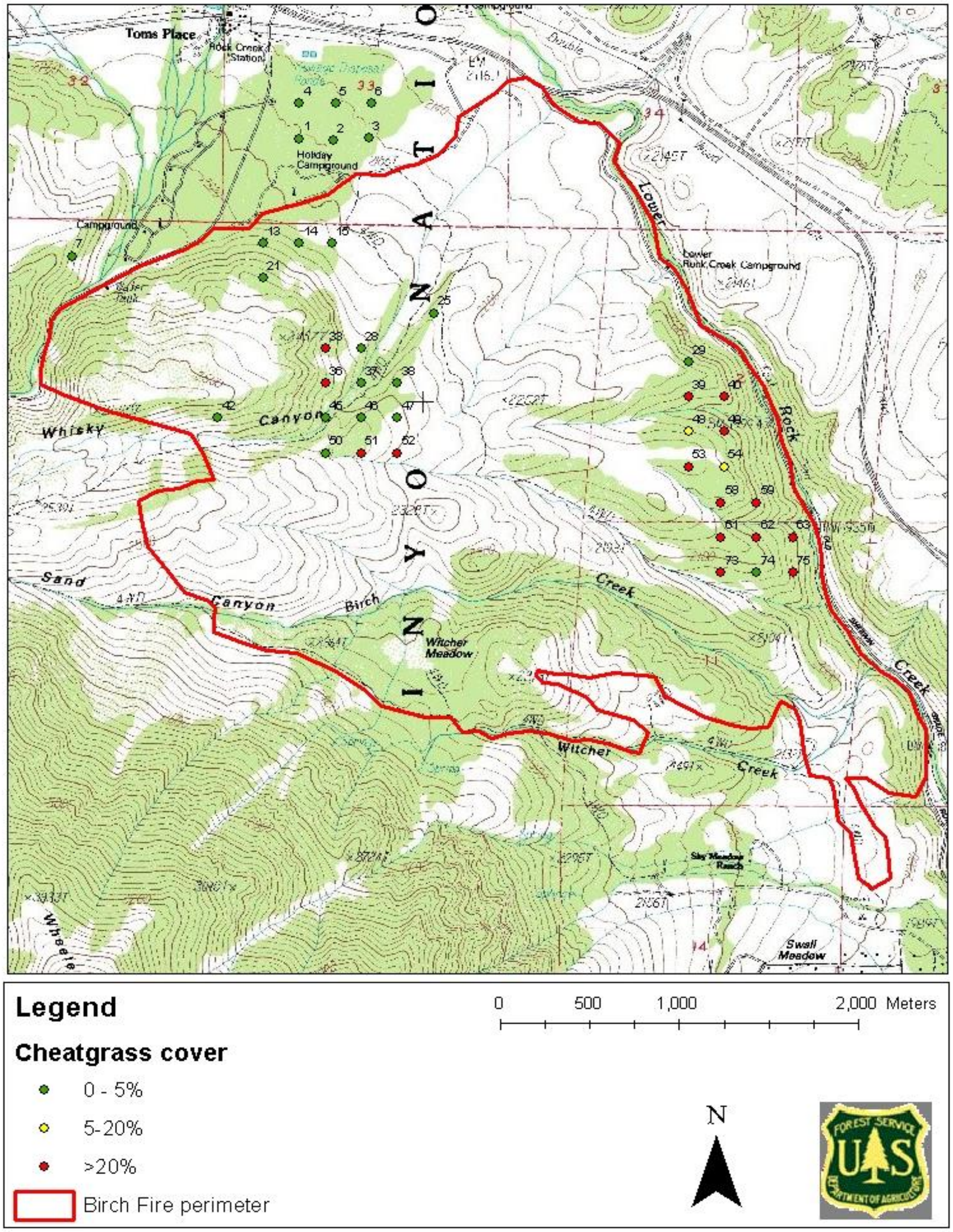

Figure 6. Map of Birch Fire and vegetation monitoring plots with low (green), moderate (yellow), and high (red) cheatgrass cover. Numbers denote the monitoring plot identifier. Plots 1-7, 42, and 74 are unburned (control) plots.

Conclusions

The Birch Fire resulted in nearly complete tree mortality of singleleaf pinyon pine, a result consistent with previous studies of severe post-fire effects to pinyon pine woodlands in California (Keeley and Zedler 1998, Brooks and Minnich 2006). Miller and Thode (2007) found that 94% of burned plots in the Birch Fire (2002) were classified as high severity (i.e., high to complete mortality of vegetation), based on a combination of remote-sensing and field plot data.

Pinyon pine regeneration was also extremely low in the Birch Fire, with only 3% of burned plots containing pinyon pine regeneration. Seedling mortality is generally high following fire, although a few cached seeds may survive in favorable microsites with lower surface fuels (Chambers et al. 1999). Burned pinyon pine stands often require several decades before nurse shrubs and trees provide suitable microsites for the establishment of pinyon pine seedlings (Minnich 1999). However, in large burned areas singleleaf pinyon pine re-colonization may take many decades due to the extended distance from seed source (Billings 1994). The absence of shaded microsites nine years after the Birch Fire, increased distance to seed source, and regional climate warming (Safford et al. 2012), have likely created conditions unsuitable for pinyon pine seedlings and resulted in the near absence of regeneration from our burned plots.

In contrast to pinyon pine, the diversity and cover of native understory vegetation was greater in burned than unburned areas of the Birch Fire, even though shrub and herbaceous plant cover was typically sparse (i.e., less than 35% cover) for most (90%) burned plots. The exception was herbaceous plant diversity, which was similar between burned and unburned CSE plots; our inability to detect a difference in herbaceous richness may have been a result of our low sample size of CSE plots (2 unburned plots, 8 burned). Increased shrub and herbaceous plant dominance following wildfire is typical of early post-fire succession patterns in singleleaf pinyon pine stands of Southern California (Wangler and Minnich 1996) and the Great Basin (Koniak 1985).

Cheatgrass cover was substantially greater in burned compared to unburned sites in the Birch Fire area, a result consistent with Inyo NF post-fire vegetation monitoring of the Birch Fire (Slaton 2011). These post-fire patterns of rapid cheatgrass spread are similar to other severely-burned pinyon and juniper woodlands in the Intermountain West, where the removal of overstory canopies results in the alteration of understory nutrient, light, water, and temperature regimes (Blank et al. 1994, West et al. 1998). Also noteworthy was the positive relationship between cheatgrass cover and litter cover and the negative relationship between cheatgrass cover and the cover of native shrubs, herbaceous plants, and live pinyon pine (from basal area estimation). Cheatgrass invasion in pinyon and juniper woodlands can be inhibited by sufficient cover of native perennial plants (Barney and Frischknecht 1974, Chambers et al. 2007). The presence and reestablishment of native shrub and herbaceous plant communities can effectively inhibit and control the spread of cheatgrass in arid vegetation of the Intermountain West (D'Antonio et al. 2009). Conversely, the abundant and continuous litter produced from dried cheatgrass biomass creates flammable fuels that increase fire frequency and perpetuate cheatgrass dominance in arid ecosystems (D'Antonio and Vitousek 1992).

Contrary to studies in other regions (e.g., Banks and Baker 2011), our analyses did not detect a relationship between cheatgrass cover and proximity to roads (potential dispersal routes for cheatgrass). However, cheatgrass cover was greater on mid- to upper-slope topographic positions, where fire severity can often be greater than the lower third of slopes and drainage bottoms (Beaty and Taylor 2008).

Photo 4. Unburned singleleaf pinyon pine plot in the Birch Fire with a high cover of live pinyon pine.

Photo 5. Burned singleleaf pinyon pine plot in the Birch Fire that contained high native herb (especially prickly poppy; *Argemone munita*) and shrub cover. Note the high density of pinyon pine mortality in the background.

Management Recommendations (adapted from D'Antonio et al. 2009 and other sources)

- ***Prescribed fire and/or mechanical thinning treatments in unburned pinyon pine stands***– Preventative management in unburned arid woodlands can be used to increase resistance to severe wildfire, drought, and cheatgrass invasion by reintroducing disturbance in the form of fire or fire surrogate treatments. Prescribed fire and thinning treatments can increase the ecological resilience of pinyon pine communities by:
    - Increasing the diversity and abundance of understory native grasses and forbs through competitive release from pinyon pine,
    - Reducing woody fuel loads that greatly increase risk of high-severity fires and subsequent cheatgrass invasion, and
    - Prioritizing stands with relatively low cheatgrass densities for treatment, since fuel treatments may be less effective at reducing cheatgrass densities where pre-existing cover is high.
- ***Reestablish native plant communities within burned stands invaded by cheatgrass***– Control of cheatgrass populations may be accomplished through the establishment of native plant communities that are resistant to cheatgrass. Post-fire monitoring analyses from this report emphasize the importance of native understory vegetation for reducing cheatgrass invasion in the Birch Fire area. Successful native plant reestablishment requires:
    - Enhancement of established native plant species that may effectively inhibit cheatgrass invasion.
    - Identification of native shrub and herbaceous plant species that establish readily and are highly competitive with cheatgrass.
    - Acquisition of adequate native plant seed collections for restoration of burned stands targeted for restoration.
    - Selection of functionally diverse species for restoration mixtures, including with varying life forms (shrubs, grasses, and forbs), rooting depths, and phenologies to maximize resistance to cheatgrass invasion.
    - Application of restoration techniques in specific target areas heavily invaded by cheatgrass or with high potential to inhibit cheatgrass spread across the landscape, such as the leading edge of cheatgrass invasion or in more ecologically sensitive areas. These areas could include more isolated cheatgrass populations (e.g., higher elevations) or occurrences in sensitive or priority vegetation types (e.g., riparian habitats, Jeffrey pine forest).
- ***Minimize grazing by livestock in burned areas***–Grazing by livestock has been suggested as a means of controlling cheatgrass seed production, but field trials show that the annual grass has highly plastic growth and produces seeds even after repeated short clipping (Hempy-Mayer and Pyke 2008). Herbage removal is therefore not effective in eliminating cheatgrass, and repeated removal of cheatgrass biomass by livestock can harm resident native plant species.
- ***Limit herbicide application, if used, to heavily-invaded stands***–Herbicides, such as glyphosate, can be an effective method for achieving high levels of cheatgrass mortality

when properly applied (Vallentine 2004). However, herbicide application can be expensive over large areas and may inadvertently remove existing native vegetation. Consequently, herbicides may best be used in a few strategic locations that are highly invaded by cheatgrass and have high potential to serve as seed source populations. Herbicide application should be followed with native plant community restoration and other methods outlined above and below to achieve long-term effectiveness.

- ***Consider new biocontrol agents in conjunction with other management tools to restore heavily-invaded stands***–In several field trials, Meyer et al. (2010) demonstrated that the fungus, *Pyrenophora semeniperda*, can be effective at killing virtually all cheatgrass seeds in the seed bank. Provided thorough field testing demonstrates that this virulent fungus is safe to use in native plant communities, an effective strategy for control of cheatgrass in heavily-invaded stands would involve the following steps outlined in Meyer et al. (2010):
    - Prescribe burn cheatgrass foliage in the spring, before seed fall.
    - Apply the biocontrol agent to kill dormant seeds.
    - Spray herbicide as needed to remove remaining plants.
    - Let the site lie fallow for a year, ensuring that the fungus has died out and the cheatgrass is gone.
    - In the fall, with the onset of rainfall, seed or plant the area with suitable native plants. Use fungicide-treated seeds if necessary to dispel any lingering fungal effects.
- ***Monitor changes in post-fire vegetation and incorporate information in restoration plans***– Use of monitoring plots as shown in this study or the Inyo National Forest Ecology plots (Slaton 2011) can be valuable sources of information to track post-fire vegetation changes following wildfires. The use of pre- and post-fire comparisons from the Inyo National Forest Ecology plot data can be especially informative in identifying reference (e.g., pre-fire/cheatgrass invasion) vegetation conditions as well as patterns of post-fire vegetation succession. Such information is critical in the determination of existing conditions, desired conditions, and restoration objectives for the Birch Fire and other post-fire landscapes on the Inyo National Forest.

Summary

There is a critical need to understand post-fire vegetation changes in the eastern Sierra Nevada, where recent increased wildfire activity and cheatgrass (*Bromus tectorum*) invasions are impacting post-fire vegetation recovery in arid woodlands and shrublands. Our objective was to examine patterns of vegetation recovery nine years following the Birch Fire (2002) in singleleaf pinyon pine (*Pinus monophylla*) stands of the Inyo National Forest. We sampled a total of 39 regeneration plots (30 burned, 9 unburned) and 10 stand exam plots (8 burned, 2 unburned) in the Birch Fire. Approximately 97% of burned plots burned at high severity. Live singleleaf pinyon pine basal area and overstory cover were significantly lower in burned plots (mean = 0.5% cover) compared to unburned controls (32% cover). Singleleaf pinyon pine regeneration was more than two orders of magnitude greater in unburned than burned plots, and regeneration was positively related to live pinyon pine basal area. Species richness of shrubs was greater and shrub cover was marginally greater in burned than unburned plots. Cover of

native herbaceous plants was 6.4 times greater in burned than unburned plots, although species composition was similar overall between sites. Cheatgrass cover was 38 times greater in burned plots. Cheatgrass was absent or in trace coverage (≤0.1%) in 89% of unburned plots, but 50% of burned plots had >25% cheatgrass cover. Cheatgrass cover was negatively related with native herbaceous plant cover, live basal area of pinyon pine, and shrub cover. Plots exceeding 20% cheatgrass cover tended to occur in the mid to upper topographic position of slopes. Our results are consistent with previous studies in the Interior West documenting high pinyon pine mortality, increases in understory cover, and cheatgrass invasion following wildfire.

Acknowledgements

We thank Kathleen Nelson, Heather Stone, and Michele Slaton of the Inyo National Forest, for providing technical advice and support for this project. We are grateful to Amy Brown, Edward Stephan, and Ray Gutteriez of the Southern Sierra Province Ecology Program field crew for data collection in the Birch Fire. Lastly, we thank the USDA Forest Service Pacific Southwest Region for providing support for this project.

References

Banks, R., and W.L. Baker. 2011. Scale and pattern of cheatgrass (*Bromus tectorum*) invasion in Rocky Mountain National Park. Natural Areas Journal 31:377-390.

Barney, M.A., and N.C. Frischknecht. 1974. Vegetation changes following fire in the pinyon-juniper type of west-central Utah. Journal of Range Management 27:91-96

Beaty, R.M., and A.H. Taylor. 2008. Fire history and the structure and dynamics of a mixed conifer forest landscape in the northern Sierra Nevada, Lake Tahoe Basin, California, USA. Forest Ecology and Management 255:707-719.

Billings, W.D. 1994. Ecological impacts of cheatgrass and resultant fire on ecosystems in the western Great Basin. Pages 22-30 In: Monsen, S.B., and S.G. Kitchen, compilers. Proceedings--ecology and management of annual rangelands; 1992 May 18-22; Boise, ID. USDA Forest Service Intermountain Research Station General Technical Report INT-GTR-313. Ogden, UT.

Blank, R.R., L. Abraham, and J.A. Young. 1994. Soil heating, nitrogen, cheatgrass, and seedbed microsites. Journal of Range Management 47:33-37.

Brooks, M.L., and R.A. Minnich. 2006. Southeastern Deserts Bioregion. Pp. 391-414 In: Sugihara, N.G., J.W. van Wagtendonk, K.E. Schaffer, J. Fites-Kaufmann, and A. Thode, editors. Fire in California's Ecosystems. The University of California Press, Berkeley.

Chambers, J.C., E.W. Schupp, and S.B. Vander Wall. 1999. Seed dispersal and seedling establishment of pinon and juniper species within the pinon-juniper woodland. Pages 29-34 In: Monsen, S.B., and R. Stevens, compilers. Sustaining and restoring a diverse ecosystem: Proceedings: ecology and management of pinyon-juniper communities within the Interior West; 1997 September 15-18; Provo, UT. USDA Forest Service Rocky Mountain Research Station Proceedings RMRS-P-9. Ogden, UT.

Chambers, J.C., B.A. Roundy, R.R. Blank, S.E. Meyer, and A. Whittaker. 2007. What makes Great Basin sagebrush ecosystems invasible by *Bromus tectorum*? Ecological Monographs 77:117–145.

D'Antonio C.M., and P.M. Vitousek. 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. Annual Review of Ecology and Systematics 23:63–87.

D'Antonio, C.M., J.C. Chambers, R. Loh, and J.T. Tunison. 2009. Applying ecological concepts to the management of widespread grass invasions. Pages 123-149 In: Inderjit, R.J., editor. Management of Invasive Weeds. Springer, Netherlands.

Hempy-Mayer, K., and D.A. Pyke. 2008. Defoliation effects on *Bromus tectorum* seed production – implications for grazing. Rangeland Ecology and Management 61:116–123.

Hickman, J.C. (editor). 1993. The Jepson manual: higher plants of California. University of California Press, Berkeley.

Keeley, J.E., and P.H. Zedler. 1998. Evolution of life histories in pines. Pages 219-250 In*:* Richardson, D.M. editor. Ecology and Biogeography of *Pinus*. Cambridge University Press, Cambridge.

Koniak, S. 1985. Succession in pinyon-juniper woodlands following wildfire in the Great Basin. The Great Basin Naturalist 45(3):556-566

Lenihan, J. M., R. Drapek, D. Bachelet and R. P. Neilson. 2003. Climate change effects on vegetation distribution, carbon, and fire in California. Ecological Applications 13:1667-1681.

Lenihan, J. M., D. Bachelet, R. P. Neilson, and R. Drapek. 2008. Response of vegetation distribution, ecosystem productivity, and fire to climate change scenarios for California. Climate Change 87 (Suppl. 1):S215-S230.

Mack R. N. 1986. Alien plant invasion into the intermountain west: a case history. Pages 191-213 In: Mooney H. A., and J. A. Drake (editors) Ecology of biological invasions of North America and Hawaii. Springer, New York.

Meyer, S.E., P.S. Allen, and J. Beckstead. 2010. Annual Brome Biocontrol after Wildfire Using a Native Fungal Seed Pathogen. Final report: Joint Fire Science Program Project No. 07-1-3-10. www.firescience.gov/

Miller, J. D., and A. Thode. 2007. Quantifying burn severity in a heterogeneous landscape with a relative version of the delta Normalized Burn Ratio (dNBR). Remote Sensing of Environment 109:66-80.

Miller, J. D., H. D. Safford, M. Crimmins, and A. E. Thode. 2009. Quantitative evidence for increasing forest fire severity in the Sierra Nevada and southern Cascade Mountains, California and Nevada, USA. Ecosystems 12:16-32.

References Continued

Minnich, R.A. 1999. Vegetation, fire regimes, and forest dynamics. Pages 44-80 In: Miller, P. R.; McBride, J. R., editors. Oxidant air pollution impacts in the montane forests of southern California: a case study of the San Bernadino Mountains. Ecological Studies: Analysis and Synthesis. Vol. 134. Springer-Verlag, New York.

Safford, H.D., M. North, and M.D. Meyer. 2012. Climate change and the relevance of historical forest conditions. Pages 23-45 In: North, M. (editor). Managing Sierra Nevada forests. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station General Technical Report PSW-GTR-237. Albany, CA.

Slaton, M. 2011. Fiscal Year 2011 Monitoring Report for Inyo National Forest Ecology Plots. USDA Forest Service Internal Report, Bishop, CA.

Vallentine, J.F. 2004. Herbicides for plant control. Pages 89-100 In: Monson S.B., R. Stevens, and N.L. Shaw, compilers. Restoring western ranges and wildlands. USDA Forest Service Rocky Mountain Research Station General Technical Report RMRS-GTR-136. Fort Collins, CO.

Wangler, M. J., and R.A. Minnich. 1996. Fire and succession in pinyon-juniper woodlands of the San Bernadino Mountains, California. Madroño 43(4): 493-514.

West, N.E., R.J. Tausch, and P.T. Tueller. 1998. A management-oriented classification of pinyon-juniper woodlands of the Great Basin. USDA Forest Service Rocky Mountain Research Station General Technical Report RMRS-GTR-12. Ogden, UT.

Appendix A. Herbaceous plant species composition in Common Stand Exam (CSE) plots. Percentage of CSE plots containing each species is presented in the right columns. Average percentage cover of individual species was ≤2% for all species, with the exception of Bromus tectorum, which had an average cover of 38% in burned CSE plots.

Table 2. Forb composition in burned and unburned areas.

Forbs in Burned Areas (*n* = 8)	% of plots	Forbs in Unburned Areas(*n* = 2)	% of plots
Allium parvum	12.5	*Allium* sp.	50
Argemone munita	75	*Caulanthis pilosus*	100
Calochortus bruneaunis	12.5	*Chenopodium* sp.	50
Castilleja linarifolia	12.5	*Cryptantha maritima*[a]	50
Caulanthis pilosus	75	*Eriogonum brachyanthum*	50
Chaenactis douglasii var. *douglasii*	12.5	*Eriogonum microthecum*	100
Chenopodium sp.	12.5	*Eriastrum wilcoxii*	100
Cryptantha circumscissa	50	*Gayophytum diffusum*	50
Cryptantha maritima[a]	12.5	*Gilia leptantha*	100
Cryptantha mojavensis	50	*Leptosiphon nuttallii*[c]	50
Dieteria canescens[b]	37.5	*Linanthus pungens*[d]	50
Eriogonum microthecum	87.5	*Lotus* sp.	50
Eriastrum wilcoxii	62.5	*Lupinus* sp.	50
Gayophytum diffusum	62.5	*Monardella linoides*	50
Galium hypotrichium	50	*Penstemon patens*	50
Gilia brecciarum	12.5	*Stephanomeria exigua*	50
Gilia leptantha	37.5		

Forbs in Burned Areas (*n* = 8)	% of plots	Forbs in Unburned Areas(*n* = 2)	% of plots
Layia glandulosa	12.5		
Leptosiphon nuttallii[c]	12.5		
Linanthus pungens[d]	50		
Lomatium dissectum	25		
Lotus sp.	12.5		
Lupinus argenteus ssp. *heteranthus*	25		
Monardella linoides	100		
Oenothera californica	12.5		
Oxytheca dendroidea	12.5		
Penstemon humilis	12.5		
Penstemon patens	87.5		
Phacelia distans	25		
Phacelia fremontii	37.5		
Phacelia ramosissima	37.5		
Salsola tragus[e]	50		
Stephanomeria exigua	50		
Pleiacanthus spinosus[f]	12.5		

[a] Species identified to *C. maritima* but nearest confirmed record is located ~80 km to the south.
[b] *Machaeranthera canescens* in Hickman (1993)
[c] *Linanthus nuttallii* in Hickman (1993)
[d] *Leptodactylon pungens* in Hickman (1993)
[e] Non-native
[f] *Stephanomeria spinosa* in Hickman (1993)

Table 3. Graminoids present in burned and unburned areas.

Graminoids in Burned Areas (n = 8)	% of plots	Graminoids in Unburned Areas(n = 2)	% of plots
Stipa hymenoides × *Stipa occidentalis*[a]	50	*Stipa hymenoides* × *Stipa occidentalis*[a]	50
Stipa hymenoides[b]	100	*Stipa hymenoides*[b]	100
Stipa speciosum[b]	100	*Stipa speciosum*[b]	50
Bromus tectorum[c]	100	*Bromus tectorum*[c]	100
Elymus elymoides	67.5	*Elymus elymoides*	100
Heperostipa comata	12.5		

[a] Hybrid Stipa x bloomeri
[b] Previously recognized as Achnatherum in Hickman (1993)
[c] Non-native

Appendix B. Regional vicinity map of the 2002 Birch Fire (red flag).