White Mountain Stewardship Program
Monitoring Report

March 2013

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Executive Summary

In December 2011, the Ecological Restoration Institute at Northern Arizona University (ERI) contracted with the Apache-Sitgreaves National Forest and the White Mountain Stewardship Project (WMS) Monitoring Board to address four of the prioritized ecological monitoring questions developed for the Project (Sitko and Hurteau 2010). The questions were the following:

1. Is there a difference between pre-treatment crown fire potential and post-treatment desired fire behavior across selected analysis areas?
2. What proportion of treated acres exhibited a change in Fire Regime Condition Class (FRCC) from 2004 – 2014?
3. Are patch sizes of denser (i.e., untreated or lightly treated) areas connected? What is the range of areas and sizes of these patches?
4. Are exotics/invasive species present at landings and burn piles?

These questions were addressed for WMSP treatments completed in 2011; monitoring under this contract did not analyze data from treatments done previously. The ERI worked closely with Apache-Sitgreaves National Forest Staff to identify 2011 projects and obtain available maps, data, and other information. Nineteen task orders (projects) were identified and copies of project maps were transferred to ERI. Project maps showed treatment unit boundaries and some gave limited prescription information. No pretreatment monitoring data were identified for any of the 2011 projects. Therefore, ERI followed WMSP protocols for pretreatment plot establishment and vegetation monitoring. Treatment effects were based on estimates of pretreatment conditions (question 1) and analysis of field data (question 1 and 4) as well as remotely sensed data derived from post-treatment imagery (questions 2 and 3). This report summarizes findings related to the four monitoring questions. We also provide electronic files of project area maps, plot locations, plot photos, and raw field data archived on a separate compact disc.

Analyses of field and remotely sensed data indicated the following:

1. In general, WMS treatments resulted in reduced canopy fuel loading and potential fire behavior across the project areas. Three project areas (Task Orders) where stand structure remains dense and crowning index values are low are Alpine WUI 4&8, Block 5; Black Mesa, Porcupine Ridge; and Lakeside, Butler. Although potential fire behavior was generally reduced by treatments, resulting stand structure was further interpreted in light of forest restoration goals. WMS treatments effectively reduced potential fire behavior and appeared to restore more natural structural characteristics. Future treatments could more explicitly utilize NRV concepts and site-specific presettlement evidence.
2. WMS treatments implemented in 2011 did move forest along a trajectory towards less departed stands and more similar to historic conditions. The changes are very small, which is expected at the rates of treatments. Most of the WMS treatments occurred in the Ponderosa forest type, which evolved with frequent fire and is currently in much denser conditions across the intermountain west today than historically. Treatments in these forests can have multiple benefits: fire risk reduction is a primary objective of WMS, but restoration objectives can also be met with small diameter tree removal and the creation of openings for a more divers and resilient understory.
3. WMS treatments retained untreated and lightly treated, higher canopy cover patches but these patches showed low connectivity across project areas. Although little information is

available to guide restoration prescriptions at emulating natural landscape patterns, no research to date has indicated large patches of closed-canopied forest prior to historical fire regime disruption. Such high cover patches may provide high quality habitat for canopy dependent species such as tassel-eared squirrels, but retaining these patches may also compromise other restoration goals.

4. In answer to the question of whether invasive plant species are found on landings and slash piles, we did find a small number of plants/populations on these sites, but because of a small sample size and confounding factors (high light conditions on a road for example), particularly in the fire itself, we did not find evidence to indicate that these sites were more preferentially invaded than any other type of microsite. However, we had a small sample size to work with, particularly inside the Wallow Fire, due to the random location of our plots. It would also appear from our monitoring, that roads and skid trails have a high probability of being invaded by non-native species, probably because of the soil disturbance that occurs.

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1. Is there a difference between pre-treatment crown fire potential and post-treatment desired fire behavior across selected analysis areas (WMS monitoring question 1)?

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Methods

White Mountain Stewardship Project Treatment Areas

A total of 19 White Mountain Stewardship (WMS) Task Orders (hereafter "projects") treated in 2011 were identified for monitoring in 2012 (Table 1.1). Project maps provided by US Forest Service staff showed treatment unit boundaries and some gave limited prescription information. Project areas ranged from about 264 to 6,849 acres in size. Most projects (74%) were between 1,000 and 2,500 acres in size. No pretreatment monitoring data were identified for any of the 2011 projects. Therefore, ERI followed WMS protocol for pretreatment plot establishment in order to address monitoring questions.

As per WMS pretreatment sampling protocol (Sitko and Hurteau 2010), one cutting unit (hereafter "unit") within each project was randomly selected for monitoring. Selected unit boundaries were digitized from hardcopy maps using a geographic information system (GIS; ArcGIS 9.3). Acreage of units was determined and from three to six plots sample plot locations were randomly selected using the Hawth's Tools extension for ArcGIS. Sampling intensity was one plot per 20 acres with a minimum of three plots per unit and a maximum of six plots per unit (Table 1) (Sitko and Hurteau 2010). Sample plot locations are provided in electronic data files accompanying this report.

Field Sampling Protocols

Maps and global positioning systems (GPS) were used in the field to navigate to sample plot locations. At each location, a 0.10-acre circular sample plot was established. Plot centers were demarcated for long-term remeasurement using an 8-inch piece of steel rebar driven into the soil. Aluminum tags indicating unit and plot number were attached to rebar. In addition, a reference tag indicating direction and distance to plot center was attached to the base of a large live tree in each plot.

Variable radius sampling (10 basal area factor prism) was used at each plot center to record basal area (BA; $ft^2\ ac^{-1}$) of live and standing dead trees. Tree species was recorded as well as diameter for all "in" trees. In addition, linear distance to each cut stump was measured and a plot radius factor (2.75) was used in combination with stump diameter to determine a limiting distance for stump tallies. For all live "in" trees, total height and height to base of live crown was recorded. One transect (50 ft) was installed at each plot to sample woody surface fuels. Each transect was oriented on a due east azimuth (90^o) from plot center. Surface fuels were tallied by moisture-lag classes: 1, 10, 100, and 1000-hrs following methods given in Brown (1974). The largest class (i.e., 1000-hr fuels) was further separated into sound and rotten categories. Tree regeneration

Table 1.1. White Mountain Stewardship project areas monitored in 2012. Table shows cutting units randomly selected for monitoring (Unit ID), unit acreages, and number of monitoring plots established.

District	Project	Unit ID	Acres in unit	Number of monitoring plots
Alpine	Nutrioso 1B	10	137	6
Alpine	Nutrioso 1C	17	354	6
Alpine	Nutrioso 2	29	34	3
Alpine	WUI 4&8	W	174	6
Alpine	WUI 4&8 Block 5	E	38	3
Black Mesa	Porcupine Ridge	50	36	3
Black Mesa	Water Springs	11a	31	3
Black Mesa	West Chevelon	2	148	6
Black Mesa	Wolf A	12	132	6
Black Mesa	Wolf B	15	32	3
Lakeside	Brushy	7	243	6
Lakeside	Butler	7	157	6
Lakeside	McKay	36	66	3
Lakeside	Trap Springs	20	49	3
Springerville	Greer C	73	158	6
Springerville	Greer E	53	65	3
Springerville	Hall's Ranch	5	55.3	3
Springerville	Mineral BX	22	345	6
Springerville	Mineral BY	40	87	4

(i.e., seedlings) was tallied by species within a 0.025-acre plot centered on the sample location point. Lastly, canopy cover (%) was measured at each plot using a densitometer. Canopy cover readings were taken every 6.5 feet along a 65.6-ft transect oriented on a south (180°) azimuth for 10 total measurements at each plot.

Analysis

To analyze changes in potential fire behavior within WMS cutting units, we used NEXUS 2.0 crown fire analysis software (www.fire.org). We ran the NEXUS model using inputs from post-treatment plot measurements and compared outputs to those of modeling runs using estimated pre-treatment conditions. In addition, we generated basic stand structure and fuels summaries for pretreatment and post-treatment periods. Variables summarized were species importance, trees per acre (TPA), BA, mean diameter (QMD), crown base height (CBH), crown fuel load (CFL), canopy cover, and canopy bulk density (CBD). Pretreatment estimates of forest structure (TPA, BA, CFL, and CBD) were made by reconstructing tree species and size from cut stumps observed on field sample plots. Species importance was calculated as the sum of relative TPA (unit mean) plus relative BA (unit mean) for the individual species. Thus, for a given species x:

$$I_x = (TPA_x/TPA_s *100) + (BA_x/Ba_s *100)$$

where I_x is species x importance; TPA_x is trees per acre of species x,; TPA_s is total trees per acre of the stand (plot); BA_x is basal area of species x; and Ba_s is total basal area of the stand (plot).

Canopy bulk density (and CFL) for NEXUS modeling was estimated using equations found in Cruz et al. (2003). We also used the lowest quintile live crown base height from post-treatment plot measurements and pre-treatment estimates. For both pretreatment and post-treatment modeling, we used fire weather extremes (98th - 100th percentile conditions) for the dates of June 6 – 12, 2011, from the Remote Automatic Weather Station (RAWS) in Greer, Arizona (020404). Fuel moistures for these conditions at Greer were generated by FireFamilyPlus (www.firemodels.org). We also used 33 miles per hour as the wind speed at 20 feet to parameterize NEXUS model runs. This wind speed was the average daily speed at 20 feet recorded June 6 – 12, 2011 at the Greer RAWS. We selected this date as representing an extreme fire behavior period during the Wallow Fire. We used Fuel Model 10 for pretreatment and Fuel Model 2 for post-treatment NEXUS simulations (Scott and Burgan 2005).

Results

The majority (63%) of WMS treatments in 2011 were implemented in ponderosa pine (*Pinus ponderosa*) or ponderosa pine – Gambel oak (*Quercus gambelii*) forest ecosystems. As determined by calculated importance values. Seven of the 19 (37%) projects were implemented in mixed-conifer forests, where white fir (*Abies concolor*), southwestern white pine (*Pinus strobiformis*), aspen (*Populus tremuloides*) Engelmann spruce (*Picea engelmannii*), and Douglas-fir *(Pseudotsuga menziesii*) variably occurred in addition to ponderosa pine and Gambel oak (Table 1.2). Ranges for initial stand density, BA, and mean diameter before treatment were 87-713 TPA, 60-245 ft^2 ac^{-1}, and 9-17 in., respectively (Table 1.3).

Thinning had variable effects on species composition in the seven mixed-conifer projects (Table 1.2). However, none of these units showed a post-treatment increase in ponderosa importance. Thinning reduced stand density and basal area on all sampled units, and increased mean diameter on 13 of 19 projects (68%). Ranges for post-treatment stand density, BA, and mean diameter were 7-205 TPA, 17-155 ft^2 ac^{-1}, and 10-20 in., respectively (Table 1.3).

Effects of thinning on stand structure generally translated to reductions in canopy fuels (Table 1.3). Although thinning reduced crown fuel loading and canopy bulk density on all units sampled, crown base height was increased on only 8 of the 19 (42%) projects. There was no clear relationship between changes in crown base height and forest type (Table 1.3). Reduced canopy fuel loading resulted in reductions in predicted fire behavior (Table 1.4). Most (57%) of the units showed a change from active pretreatment crown fire potential to passive post-treatment crown fire potential. Treatments reduced rate of spread on 15 of 19 sampled units (79%). Both fireline intensity and flame length were reduced and crowning index was increased by treatments on all units (Table 1.4). The greatest reductions in predicted fire behavior were found on units where tree density and basal area were lowest post-treatment.

Table 1.2. Relative importance of overstory species within sample units before (pre) and after (post) implementation of treatments. Pretreatment conditions were estimated using evidence observed on post-treatment field plots. Maximum importance value (complete dominance) is 200. Please see text for explanation of importance calculation.

			Species[1]													
			WF		PP		WP		A		ES		DF		GO	
District	Project	Sample Unit	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Alpine	Nutrioso 1B	10	40	71	129	129	0	0	0	0	0	0	31	0	0	0
Alpine	Nurtioso 1C	17	0	0	142	105	13	21	6	31	0	0	39	42	0	0
Alpine	Nutrioso 2	29	0	0	200	200	0	0	0	0	0	0	0	0	0	0
Alpine	WUI 4&8 Block 5	E	0	0	197	196	0	0	0	0	0	0	0	0	3	4
Alpine	WUI 4&8	W	0	0	153	78	0	0	0	11	0	0	5	5	42	107
Black Mesa	Porcupine Ridge	50	0	0	200	200	0	0	0	0	0	0	0	0	0	0
Black Mesa	Water Springs	11A	0	0	200	200	0	0	0	0	0	0	0	0	0	0
Black Mesa	West Chevelon	2	0	0	200	200	0	0	0	0	0	0	0	0	0	0
Black Mesa	Wolf A	12	0	0	200	200	0	0	0	0	0	0	0	0	0	0
Black Mesa	Wolf B	15	0	0	200	200	0	0	0	0	0	0	0	0	0	0
Lakeside	Brushy	7	0	0	160	97	0	0	0	0	0	0	0	0	40	103
Lakeside	Butler	7	0	0	150	111	0	0	0	0	0	0	0	0	50	89
Lakeside	McKay	36	0	0	200	200	0	0	0	0	0	0	0	0	0	0
Lakeside	Trap Springs	20	0	0	200	200	0	0	0	0	0	0	0	0	0	0
Springerville	Greer E	53	0	0	20	55	0	0	10	67	0	0	171	79	0	0
Springerville	Greer C	73	0	0	13	12	42	39	89	82	28	21	28	47	0	0
Springerville	Hall's Ranch	5	9	20	57	0	8	12	31	154	0	0	96	15	0	0
Springerville	Mineral BX	22	0	0	199	195	0	0	0	0	0	0	0	0	1	5
Springerville	Mineral BY	40	4	7	92	81	6	0	53	67	0	0	46	44	0	0

[1] Species: WF (white fir); PP (ponderosa pine); WP (southwestern white pine); A (aspen); ES (Engelmann spruce); DF (Douglas-fir); GO (Gambel oak)

Table 1.3. Structure and fuels conditions within sample units before (pre) and after (post) implementation of treatments. Pretreatment conditions were estimated using evidence observed on post-treatment field plots. Table shows means generated from field sample plots.

			Trees per acre		Basal area (ft^2 ac^{-1})		Mean diameter (in)		Crown base height (ft)		Crown fuel load (lb ft^{-2})		Crown bulk density (lb ft^{-3})	
District	Project	Sample Unit	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Alpine	Nutrioso 1B	10	208	17	140	20	12	15	15.6	17.8	0.22	0.03	0.012	0.001
Alpine	Nutrioso 1C	17	301	39	190	38	11	14	17.0	27.7	0.31	0.05	0.016	0.002
Alpine	Nutrioso 2	29	87	12	60	24	13	19	21.7	24.6	0.10	0.03	0.006	0.001
Alpine	WUI 4&8 Block 5	E	340	205	174	110	10	10	15.3	13.1	0.28	0.18	0.019	0.012
Alpine	WUI 4&8	W	423	179	105	32	10	11	16.5	16.3	0.20	0.06	0.017	0.006
Black Mesa	Porcupine Ridge	50	713	84	200	120	11	16	18.2	20.9	0.33	0.18	0.028	0.008
Black Mesa	Water Springs	11A	113	29	137	50	16	17	12.6	12.2	0.20	0.07	0.009	0.003
Black Mesa	West Chevelon	2	210	63	189	55	13	13	17.7	19.7	0.29	0.09	0.015	0.004
Black Mesa	Wolf A	12	139	25	182	48	16	20	20.7	28.3	0.27	0.07	0.012	0.002
Black Mesa	Wolf B	15	96	16	140	17	17	14	25.0	9.1	0.21	0.03	0.009	0.001
Lakeside	Brushy	7	289	126	150	38	11	11	11.2	8.4	0.24	0.07	0.017	0.005
Lakeside	Butler	7	308	174	127	70	9	11	9.7	5.7	0.21	0.12	0.016	0.009
Lakeside	McKay	36	202	7	127	36	11	13	16.6	2.3	0.20	0.01	0.012	0.001
Lakeside	Trap Springs	20	170	32	173	40	14	17	20.7	25.7	0.26	0.06	0.013	0.003
Springerville	Greer E	53	109	14	90	20	14	16	17.7	16.2	0.12	0.02	0.004	0.001
Springerville	Greer C	73	206	137	134	88	12	12	16.4	15.5	0.20	0.13	0.008	0.005
Springerville	Hall’s Ranch	5	239	82	218	75	14	18	14.8	4.7	0.31	0.07	0.011	0.003
Springerville	Mineral BX	22	324	52	207	37	12	12	15.2	8.9	0.33	0.06	0.020	0.003
Springerville	Mineral BY	40	212	96	245	155	15	17	14.4	27.4	0.34	0.18	0.011	0.005

Table 1.4. Changes in potential fire behavior from pretreatment (pre) to post-treatment conditions on sample cutting units. Pretreatment conditions were estimated using evidence observed on post-treatment field plots. Potential fire behavior was modeled using NEXUS crown fire hazard analysis software.

			Crown fire potential		Rate of spread[1] (ch hr^{-1})		Fireline intensity[2] (BTU ft^{-1} sec^{-1})		Flame length[3] (ft)		Crowning index (mi hr^{-1})	
District	Project	Sample Unit	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Alpine	Nutrioso 1B	10	Active	Passive	214.1	158.0	13,573.7	2,420.5	113.6	24.4	13.0	115.3
Alpine	Nutrioso 1C	17	Active	Passive	214.1	183.3	16,023.2	3,665.3	126.5	40.1	11.1	76.3
Alpine	Nutrioso 2	29	Active	Passive	151.7	167.4	7,577.7	2,850.0	69.2	29.8	42.9	106.1
Alpine	WUI 4&8 Block 5	E	Active	Active	214.1	214.1	15,304.3	8,197.0	122.1	80.6	10.6	12.9
Alpine	WUI 4&8	W	Active	Passive	214.1	194.1	12,717.7	4,035.0	108.4	44.0	14.4	35.8
Black Mesa	Porcupine Ridge	50	Active	Active	214.1	214.1	16,751.0	8,090.0	130.9	80.5	7.3	16.7
Black Mesa	Water Springs	11A	Active	Passive	214.1	195.3	12,968.7	4,410.0	110.3	48.3	15.1	39.8
Black Mesa	West Chevelon	2	Active	Active	214.1	213.3	15,546.2	5,310.5	124.1	60.4	10.1	25.9
Black Mesa	Wolf A	12	Active	Passive	214.1	195.4	14,920.3	4,289.8	121.1	47.5	11.6	44.4
Black Mesa	Wolf B	15	Active	Passive	214.1	169.0	13,010.7	2,660.7	110.5	28.7	15.2	106.1
Lakeside	Brushy	7	Active	Active	214.1	194.1	14,169.2	4,291.2	116.4	47.7	11.0	39.0
Lakeside	Butler	7	Active	Active	214.1	213.3	13,227.2	6,266.0	111.6	66.9	10.1	20.4
Lakeside	McKay	36	Active	Passive	214.1	144.0	12,833.7	1,900.7	108.9	17.3	13.2	168.5
Lakeside	Trap Springs	20	Active	Passive	214.1	173.2	14,764.3	3,669.3	120.3	37.2	10.8	57.9
Springerville	Greer E	53	Active	Passive	159.2	140.5	8,416.3	1,817.0	74.6	15.9	45.2	138.5
Springerville	Greer C	73	Active	Active	214.1	213.3	12,882.8	6,494.3	109.8	68.7	16.5	25.5
Springerville	Hall’s Ranch	5	Active	Passive	214.1	174.2	16,313.7	3,345.7	127.9	34.5	14.2	58.4
Springerville	Mineral BX	22	Active	Active	214.1	208.5	16,690.5	4,323.0	130.3	51.2	8.2	31.1
Springerville	Mineral BY	40	Active	Active	214.1	214.1	17,079.0	8,161.3	131.5	80.8	15.4	23.9

[1] 214.1 = model maximum

[2] Flaming front

[3] Head fire

Discussion

In general, treatments resulted in reduced canopy fuel loading and potential fire behavior across the project areas. Three sites where stand structure remains dense and crowning index values are low are Alpine WUI 4&8, Block 5; Black Mesa, Porcupine Ridge; and Lakeside, Butler (Table 1.4). Although potential fire behavior was generally reduced by treatments, resulting stand structure can be further interpreted in light of forest restoration goals.

Two central goals of the White Mountain Stewardship Project are to restore forest health and reduce the threat of uncharacteristic wildfire (Sitko and Hurteau 2010). Prior to Euro-American settlement and the intensive land uses that commenced in the late 19th century, ponderosa pine and dry mixed-conifer forests of the Southwest were generally less dense and more open in structure than forests of today (Covington and Moore 1994). These open forest conditions both supported and were a product of frequent surface fires burning through fine understory fuels (Covington 2003). With settlement and intensive land use, historical fire regimes were disrupted and forest structure eventually became drastically altered (Moore et al. 1999). Restoration of forest health in its most basic sense calls for treatments that result in stand structures that fall within natural ranges of variability (NRV). NRV characterizes ecosystem function prior to fire regime disruption. For example forest reconstruction analysis and historical surveys have indicated that density and basal area of stands ranged about 11-137 TPA, and 16-124 ft^2 ac^{-1}, respectively, before settlement (Stoddard 2011). It should be noted that 75% of the reconstructed values fall between about 22 and 74 TPA, and between 38 and 81 ft^2 ac^{-1} BA (Stoddard 2011). These central areas of the probability distributions would be suitable guides for developing basic restoration prescriptions where site-specific reference information is lacking.

Based on field data from sample monitoring plots, 79% of the units were outside NRV for TPA (Table 1.3). After treatment, TPA in 16% of the units remained higher than NRV and 5% fell below NRV. Only 31% of the units showed mean TPA to be within the central area of the NRV probability distribution and about 50% of the sites showed tree densities that corresponded to the tails of NRV. Before treatment, 84% of the sites showed BA outside NRV (Table 1.3). Treatments reduced 95% of the units to within NRV for BA and none fell below NRV (Table 1.3). Of the 19 sites, 42% showed BA to be within the central area of the NRV probability distribution. About 53% of the sites showed mean BA values corresponding to the tails of NRV.

Treatments increased mean diameter on the majority (68%) of sampled project units (Table 1.3). This indicates that smaller trees were targeted in thinning prescriptions and diameter distributions were shifted toward larger classes. Mean diameter was not affected by treatments on 26% of the units, which suggests thinning was done across all size classes. Several studies have indicated that stand structures prior to fire regime disruption were typically made up of all sizes and ages of trees and not dominated by smaller, younger trees as shown in most contemporary forests (Fulé et al. 1997, Mast et al. 1999, Roccaforte et al. 2010). Thus, WMS treatments in general appeared to be effective at moving stands closer to NRV in diameter distribution.

In summary, WMS treatments effectively reduced potential fire behavior and appeared to restore more natural structural characteristics. Future treatments could more explicitly utilize NRV concepts and site-specific presettlement evidence.

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2. What proportion of treated acres exhibited a change in Fire Regime Condition Class (FRCC) from 2004 – 2014 (WMS monitoring question 4)?

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Methods

Analysis Extent

The area used in this analysis was the administrative boundary of the Ranger Districts within the Apache-Sitgreaves National Forest where White Mountain Stewardship Projects were implemented in 2011. This included the Alpine, Black Mesa, Springerville and Lakeside Ranger Districts. Over 40 forest, woodland and grass/shrub types (plant association groups, modified to Biophysical Setting (BpS)) were found in this 1,609,528-acre landscape. However, White Mountain Stewardship treatments were consistently implemented in no more than 4 BpS's with majority of treatments implement in the Southern Rocky Mountain Ponderosa Pine Woodland BpS (Table 2.1).

Table 2.1. Forest and woodland types monitored on Ranger Districts of Apache-Sitgreaves National Forest.

Ranger District	Vegetation (Forest) Type	Fire Regime	Acres Treated	Total Acres Treated
Alpine	***Ponderosa Pine (So. Rocky Mountain Ponderosa Pine Woodland)***	I	5,109	11,456
	Mixed Conifer (S. Rocky Mountain Mesic Montain Mixed Conifer)	I	3,885	
	Other (too small for analysis)		2,462	
Black Mesa	***Ponderosa Pine (So. Rocky Mountain Ponderosa Pine Woodland)***	I	8,535	9,224
	Other (too small for analysis)		689	
Lakeside	***Ponderosa Pine (So. Rocky Mountain Ponderosa Pine Woodland)***	I	5,665	5,924
	Other (too small for analysis)		259	
Springerville	***Ponderosa Pine (So. Rocky Mountain Ponderosa Pine Woodland)***	I	6,294	11,012
	Aspen-Mixed Conifer (Intermouuntain Basins Aspen-Mixed Conifer Forest and Woodlands	I	1,827	
	Rocky Mountain SubAlpine Dry-Mesic Spruce Fir Forest and Woodland	IV - V	1,004	
	Other (too small for analysis)		1,887	

Fire Regime Condition Class

The Fire Regime Condition Class (FRCC) concept was developed to help land managers assess ecological conditions. FRCC is a landscape metric that incorporates a simple designation of the degree of departure of current vegetation composition and fire regimes from historical vegetation composition and fire regimes. FRCC can only be assessed at landscapes large enough to incorporate a “natural disturbance event”. Therefore, changes within smaller projects need to be cumulatively addressed in the larger landscape. A 100-acre treatment does not change FRCC.

The FRCC Departure index is developed using reference conditions from the historical range of variability (HRV), within which dynamic ecosystems generally remain over time (Morgan et al. 1994). Reference conditions in the Southwest were created by local experts and available literature for many ecosystems with Vegetation Dynamic Development Tool (VDDT) (LANDFIRE mapping process). Although FRCC encompasses both departure in system structural conditions and departure in fire regime, the standardized index used across the US incorporates only structural condition departure. This is done by assessing the current distribution of a coarse delineation of successional (or seral) stages for each vegetation type and comparing with the expected distribution from reference conditions (Schmidt et al. 2002).

We used the FRCC Ecological Departure standardized index to develop the departure of current forest structure stage distributions from historic successional stage distributions. Across much of our federal lands, late successional stages are much rarer on the landscape than historically as a result of past harvest management. Much of our forested federal lands are composed of trees classified as “mid-successional”, but represent a range of densities.

Condition Class simply categorizes the ecological departure index into 3 categories (Table 2.2, conditional class 1 = 1-33% departure; condition class 2 > 33% departure and < 66% departure; and condition class 3 > 66% departure; Rice et al. 2007). The higher the condition class, the more altered the system is, implying significant alteration of stand and landscape function.

Table 2.2. Condition Class index (Hann et al. 2005).

	Condition Class	**Description Potential Risks**
Condition Class 1	Within the natural (historical) range of variability of vegetation characteristics; fuel composition; fire frequency, severity and pattern; and other associated disturbances.	Fire behavior, effects, and other associated disturbances are similar to those that occurred prior to fire exclusion (suppression) and other types of management that do not mimic the natural fire regime and associated vegetation and fuel characteristics. Composition and structure of vegetation and fuels are similar to the natural (historical) regime. Risk of loss of key ecosystem components (e.g. native species, large trees, and soil) is low.
Condition Class 2	Moderate departure from the natural (historical) regime of vegetation characteristics; fuel composition; fire frequency, severity and pattern; and other associated disturbances.	Fire behavior, effects, and other associated disturbances are moderately departed (more or less severe). Composition and structure of vegetation and fuel are moderately altered. Uncharacteristic conditions range from low to moderate; Risk of loss of key ecosystem components are moderate.
Condition Class 3	High departure from the natural (historical) regime of vegetation characteristics; fuel composition; fire frequency, severity and pattern; and other associated disturbances.	Fire behavior, effects, and other associated disturbances are highly departed (more or less severe). Composition and structure of vegetation and fuel are highly altered. Uncharacteristic conditions range from moderate to high. Risk of loss of key ecosystem components is high.

Mapping and Assessment Tools

The technical team used the LANDFIRE data layers to assess pre-treatment conditions on the Apache-Sitegreaves National Forest and to capture the reference conditions. We used the administrative boundaries of the Ranger Districts (with the exception of Clifton RD) for the analysis area. The data layers used included:

Spatial Data:
1. Biophysical Setting (BpS, Vegetation Type, LANDFIRE)
2. Current Succession Classes (LANDFIRE)
3. Landscape Analysis Units (Ranger Districts, Apache-Sitgreaves NF)
4. 2011 White Mountain Stewardship treatment polygons (Apache-Sitgreaves NF and ERI staff)

Tabular Data:
5. Reference Condition Table (LANDFIRE)
    a. lists Succession Class percents for each BpS
    b. lists appropriate landscape level for each BpS

Assumptions and Known Issues

1. Biophysical Setting (BpS): The BpS includes the area's native species – determined according to our best understanding of the historical or nature range of variation including disturbances. Each BpS can be associated with a Fire Regime (see Table 2.1), describing the characteristic fire frequency and severity for that BpS. Known issues in Region 3 for Landfire mapping include BpS designation and scaling errors. Where there was a lack of ground-data to inform the national mapping effort, LANDSAT imagery was difficult to interpret and assign appropriately. As a result, BpS maps are best used at district-level to regional scales, and not for project-level planning. Local data sets are best for project planning. LANDFIRE BpS's were used for this analysis because successional stage data, needed for FRCC Ecological Departure mapping, were not available from local data sets. The Condition Class (CC) analysis was done for each BpS (e.g. ponderosa pine) where White Mountain Stewardship projects were implemented in 2011, within each Ranger District.

2. Current Succession Classes: To efficiently use the mapping tool, each vegetation type was broken down into different successional classes. For example, ponderosa pine was broken into 5 successional classes (Table 2.3).

Table 2.3. Successional classes for ponderosa pine.

Ponderosa pine		
Successional Stage code	**Successional Stage**	**Successional Stage Definition**
A	ES	Early successional = regenerating stands following a disturbance (like fire), characterized in ponderosa pine by seedlings and saplings
B	MSC	Mid-successional closed = "middle aged" stands characterized in ponderosa pine by pole – sized trees. Closed refers to canopy cover – in this case, closed canopies are characterized by canopies with greater than 40% closure (many of these stands have interlocking crowns).
C	MSO	Mid-successional open = "middle aged" stands characterized in ponderosa pine by pole – sized trees. Open refers to canopy cover – in this case, open canopies are characterized by canopies with less than 40% closure.
D	LSO	Late-successional open = old-growth stands characterized in ponderosa pine by the large diameter, orange-bark trees. Open canopy as above.
E	LSC	Late-successional closed = old-growth stands characterized in ponderosa pine by the large diameter, orange-bark trees. Closed canopy as above.

The distribution of these successional stages across the landscape was calculated for current forests for each vegetation type, and then compared with historic successional stage distributions for each vegetation type. The historic successional stage distributions are not spatially explicit, but in tabular form.

A departure index was calculated for each vegetation type based on the similarity of these distributions (see results Tables 2.5 -2. 8. See www.frcc.gov for more information on the departure index calculations).

3. Known Issues of LANDFIRE Region 3 successional class include mis-classifications into the late-successional, closed-canopy successional stage (Code E). The height cut-offs of late successional in this region were 10 m (~33ft). Therefore, any stand with tree heights over 33ft were classified as late-successional. Ground data confirm that multiple "mid-successional" stages were mis-classified as late, because of this height cut-off.

4. Landscape Analyses Units: Ranger District classification, no known issues.

5. Historic successional stage distribution can be estimated from a variety of data; the best data are found in stands still existing with their natural fire regime intact. If no intact stands are available, historic stand structure is calculated from dendrochronology studies (tree ring counts), fire history studies, and/ or ecological modeling. We used the LANDFIRE regional modeling results (http://landfire.cr.usga.gov) to determine historic successional stage distributions. Known issues include small data availability for non-ponderosa pine forest types with greater utilization of local expert knowledge.

Results

The results from the Condition Class mapping tool were summarized to assess departure across all treated vegetation types (BpS's) for Alpine, Black Mesa, Springerville, and Lakeside Ranger Districts on the Apache-Sitgreaves NF.

Treatment effects on Ecological Departure

White Mountain Stewardship Treatments were developed from Apache-Sitgreaves NF spatial data that were either acquired from the forest, or digitized from paper maps received from forest staff.

Because FRCC is a landscape metric, large areas of the landscape would need to see changes to show significant differences in pre-treatment and post-treatment ecological departure. What can be expected from smaller treatment areas are small shifts that can suggest trends along the ecological departure scale.

Assumptions were made to determine treatment impacts on successional stage distributions. Because White Mountain Stewardship treatments focus on smaller diameter tree removal and reductions in canopy cover and ladder fuels, we can make assumptions that treatments move stands from closed canopy to open canopy (Table 2.4). Treatments do not affect mid or late-successional stage transitions – the mid- and late-successional transitions are surrogates for "age of stand" and are time dependent. A clear-cut treatment would move mid- or late-successional stands to early successional; however those are not typical of White Mountain Stewardship treatments.

Table 2.4

Treated Successional Stage	**Post-treatment Successional Stage**
Early Successional (ES)	Early Successional (ES)
Mid-Successional Closed Canopy (MSC)	Mid-Successional Open (MSO)
Mid-Successional Open Canopy (MSO)	Mid-Successional Open (MSO)
Late-Successional Open Canopy (LSO)	Late-Successional Open (LSO)
Late-Successional Closed Canopy (LSC)	Late-Successional Closed (LSC)

Tables 2.5 - 2.8 represent the ecological successional stage distribution before and after treatment, and the association changes in ecological departure for each Ranger District.

Table 2.5. Alpine Ranger District

Vegetation Type	**Successional Stage**	**Historic Distribution (%)**	**Pre-Treatment Distribution (%)**	**Post-Treatment Distribution (%)**	**Ecological Departure**	
					Pre - treatment	**Post-treatment**
Ponderosa Pine (So. Rocky Mountain Ponderosa Pine Woodland)	ES	10	1	1	29	27
	MSC	2	0	1		
	MSO	10	2	2		
	LSO	75	65	66		
	LSC	3	30	29		
Mixed Conifer (S. Rocky Mountain Mesic Montain Mixed Conifer)	ES	10	1	1	59	50
	MSC	30	88	79		
	MSO	30	1	10		
	LSO	20	1	1		
	LSC	10	8	8		

Table 2.6. Black Mesa Ranger District

Vegetation Type	**Successional Stage**	**Historic Distribution (%)**	**Pre-Treatment Distribution (%)**	**Post-Treatment Distribution (%)**	**Ecological Departure**	
					Pre - treatment	**Post-treatment**
Ponderosa Pine (So. Rocky Mountain Ponderosa Pine Woodland)	ES	10	0	0	14	13
	MSC	2	0	0		
	MSO	10	8	9		
	LSO	75	78	79		
	LSC	3	12	11		

Table 2.7. Lakeside Ranger District

Vegetation Type	**Successional Stage**	**Historic Distribution (%)**	**Pre-Treatment Distribution (%)**	**Post-Treatment Distribution (%)**	**Ecological Departure**	
					Pre - treatment	**Post-treatment**
Ponderosa Pine (So. Rocky Mountain Ponderosa Pine Woodland)	ES	10	1	1	24	21
	MSC	2	0	0		
	MSO	10	6	7		
	LSO	75	66	68		
	LSC	3	21	19		

Table 2.8. Springerville Ranger District

Vegetation Type	**Successional Stage**	**Historic Distribution (%)**	**Pre-Treatment Distribution (%)**	**Post-Treatment Distribution (%)**	**Ecological Departure**	
					Pre - treatment	**Post-treatment**
Ponderosa Pine (So. Rocky Mountain Ponderosa Pine Woodland)	ES	10	6	6	24	21
	MSC	2	0	0		
	MSO	10	6	6		
	LSO	75	61	64		
	LSC	3	26	23		
Aspen-Mixed Conifer (Intermouuntain Basins Aspen-Mixed Conifer Forest and Woodlands	ES	60	0	0	82	82
	MSC	25	3	3		
	MSO	4	42	43		
	LSO	10	52	52		
	LSC	1	2	1		
Rocky Mountain SubAlpine Dry-Mesic Spruce Fir Forest and Woodland	ES	15	1	1	57	55
	MSC	20	0	0		
	MSO	15	1	1		
	LSO	20	11	13		
	LSC	30	87	84		

Trends

2011 White Mountain Stewardship treatments did move forests along a trajectory towards less departed stands and more similar to historic conditions. The changes are very small, which is expected at the rates of treatments. Most of the WMS treatments occurred in the ponderosa forest type, which evolved with frequent fire and is currently in much denser conditions across the intermountain west today than historically. Treatments in these forests can have multiple benefits: fire risk reduction is a primary objective of WMS, but restoration objectives can also be met with small diameter tree removal and the creation of openings for a more divers and resilient understory.

Future analysis

The FRCC Departure Index is a landscape metric. As such, it is best assessed in large time frames, at least every 5 years. Knowledge of treatment effects is important to understand the transitions between successional stages. In addition, local data corrections to LANDFIRE data seem to be the best source for accurate successional stage determinations. We expect that some more recent R3 data layers may better inform this analysis, including the R3 Mid-scale Vegetation Analysis.

Addition Issues

Using a standardized index brings up a variety of concerns. Above we have clarified potential uses of a condition class analysis. A primary area of concern is the misconception that a Condition Class analysis is equivalent to a fire risk map; a CC analysis includes no information on fuels and is based entirely on overstory canopy information. This creates the following issues (for more detail, see Merriam et al. 2006):

1. Areas mapped as CC III (red) may have no fuels-related issues at all. For example, our analysis showed Dry Ponderosa Pine with highly departed (CCIII) abundances of closed-canopy, mid-successional stands today than historically. These areas may also have a higher potential of crown fire and high severity fire (analysis not done in this report).
2. Conversely, areas mapped as CC I (green) may have major fuels-related issues. Since the vegetation map provides no information on understory vegetation, this information is invisible to the FRCC calculation: FRCC cannot map what it does not know.
3. Because the Condition Class measure is driven by overstory canopy conditions, and because it does not explicitly include information on surface and ladder fuels, fuels treatments which do not significantly modify canopy cover and/or size-class are unlikely to change condition class, even where they have significantly reduced expected flame lengths or spread rates. Many of our fuels reduction treatments in Wildland Urban Interface do not change overstory structure enough to alter Condition Class, but still are effective to reduce fuels.

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3. Are patch sizes of denser (i.e., untreated or lightly treated) areas connected? What is the range of areas and sizes of these patches (WMS monitoring question 8)?

Joe Crouse and Dave Huffman

Methods

To address this monitoring question, we analyzed post-treatment forest canopy cover on 19 project areas (Task Orders, see Ch 1.) treated under WMS in 2011. We used Landsat TM5 imagery, Landsat scene Path 35, Row 36, acquired October 21, 2011, to develop a canopy cover GIS "layer" for project areas on the Apache National Forest and scene Path 36, Row 36, acquired October 12, 2011, for projects located on the Sitgreaves National Forest. These two scenes were the best available (cloud and haze-free) post-treatment datasets available.

Project maps provided by USFS were scanned and georeferenced. Project boundaries were then digitized and the resulting spatial layer was used to clip the Landsat imagery. Canopy cover data collected during the 2012 field season were used to "train" canopy cover classification performed with the imagery. We used these supervised classifications to identify four canopy cover classes: 1) 1-20%, 2) 21-50%, 3) 51-80%, and 4) non-forest. We found no areas with canopy cover great than 80% using a minimum mapping unit of 323 ft^2 (30 m^2). Classified maps were then analyzed using FRAGSTATS (McGarigal et al. 2012). Outputs examined to address the WMS monitoring questions were average (area-weighted; see Turner et al. 2001), minimum, and maximum patch sizes. Because the monitoring question is focused on connectivity of "untreated or lightly treated areas", we assumed that these were represented by patches of canopy cover class 3 (51-80%). In addition to the above patch metrics, we analyzed the proportion of the project area comprised of cover class 3 and calculated an index of connectivity according to methods described in Turner et al. (2001). This index provides an estimate of the relative mean patch size and is calculated as:

$$C_i = LC_i / (p_i * E)$$

where C_i is connectivity index for patch type i; LC_i is the size of the largest patch of type I; p_i is the proportion of the landscape in patch type i, and E is the extent of the analyzed landscape. Thus, for any patch type, greater connectivity is indicated as C_i approaches 1.0 (relative patch size increases). Conversely, low connectivity is indicated by values of C_i close to 0 (dispersed smaller patches).

Results

As previously described, WMS project areas ranged 264-6,849 acres in size; most (74%) were between 1,000 and 2,500 acres (Table 3.1). Mean patch size of cover class 3 (51-80% cover) across all areas post-treatment ranged 1.5-161.9 acres. Fifty-three percent of the projects

Table 3.1. Patch sizes and connectivity for canopy cover class 3 (51-80% cover) within White Mountain Stewardship project areas.

District	Project	Total project area (ac)	Patch size (ac)		Percent of project area (%)	Connectivity[2]
			Mean[1]	Maximum		
Alpine	Nutrioso 1B	1504.3	2.3	135.8	9.0	1.00
Alpine	Nutrioso 1C	1240.7	13.6	25.6	10.3	0.20
Alpine	Nutrioso 2	6849.1	8.8	39.3	8.9	0.06
Alpine	WUI 4&8 Block 5	1685.0	8.2	29.6	13.1	0.13
Alpine	WUI 4&8	264.5	2.0	6.0	11.0	0.21
Black Mesa	Porcupine Ridge	2884.1	4.4	22.0	17.3	0.04
Black Mesa	Water Springs	1567.0	17.7	40.9	10.0	0.26
Black Mesa	West Chevelon	2085.0	14.2	55.1	19.9	0.13
Black Mesa	Wolfe A	1356.3	1.7	4.9	6.0	0.06
Black Mesa	Wolfe B	2137.4	9.1	34.9	15.2	0.11
Lakeside	Brushy	1325.1	18.0	47.8	13.2	0.27
Lakeside	Butler	1093.5	3.0	12.4	9.9	0.12
Lakeside	McKay	1715.5	29.3	71.8	22.5	0.19
Lakeside	Trap Springs	1860.0	42.3	94.3	18.9	0.27
Springerville	Greer E	2482.6	1.5	6.0	3.3	0.07
Springerville	Greer C	1836.6	5.5	14.9	11.2	0.07
Springerville	Halls Ranch	3286.9	161.9	302.6	35.1	0.26
Springerville	Mineral BX	2966.1	28.6	116.0	21.6	0.18
Springerville	Mineral BY	1537.2	45.1	116.0	25.5	0.30

[1] Area-weighted mean

[2] Values closer to 1.0 indicate greater connectivity among patches. See text for description of Connectivity Index.

showed cover class 3 mean patch sizes of less than 10 acres (Table 3.1). Maximum cover class 3 patch sizes ranged 4.9-302.6 acres. Most sites (58%) showed maximum cover class 3 patch sizes less than 50 acres, and 21% showed maximum patch sizes greater than 100 acres (Table 3.1). As a proportion of the project area extents, cover class 3 made up 3.3-35.1%. Most (63%) project areas showed 10-25% in cover class 3 (Table 3.1). Although some projects showed larger patch size, and most projects showed notable proportions comprised of cover class 3, connectivity was generally low (Table 3.1). Connectivity index was 1.0 at one site (Alpine, Nutrioso 1B), whereas the remained of the project areas showed index values less than 0.30.

Discussion

Connectivity of untreated and lightly treated areas was general low across the WMS project areas treated in 2011. The combination of low connectivity index values and notable proportions of project areas comprised of cover class 3 (51-80% canopy cover) patches suggests that patches of this class were mostly small and scattered. The WMS monitoring question addressed here implies that stakeholders desire connectivity of higher canopy cover areas, likely due to concerns over habitat of canopy-dependent wildlife species (Andrén 1994). For example, Prather et al. (2006) recommended patches of >395 acres where canopy cover is >40% be retained in forest treatment areas for tassel-eared squirrel recruitment in northern Arizona ponderosa pine forests.

Although such considerations may seem overly focused on individual species and fail to acknowledge many other goals of ponderosa pine forest restoration (e.g., characteristic fire, understory plant production, soil processes, hydrologic function, etc.), little information is available concerning reference landscape patterns that may be used as guides for restoration treatments. Most information on canopy cover prior to Euro-American settlement and fire regime disruption has been summarized at scale of the site or tree group. For example, Sánchez Meador et al. (2011) reconstructed presettlement canopy cover on 2.5-acre ponderosa pine and pine-oak plots in northern Arizona and found cover ranged 10.2-18.8%. Similarly, White (1985) reported that canopy cover in presettlement ponderosa pine groups averaged 21.9%. No studies to date have documented presettlement high canopy cover in large patches.

In summary, WMS treatments retained untreated and lightly treated, higher canopy cover patches but these patches showed low connectivity across project areas. Although little information is available to guide restoration prescriptions at emulating natural landscape patterns, no research to date has indicated large patches of closed-canopied forest prior to historical fire regime disruption. Such high cover patches may provide high quality habitat for canopy dependent species such as tassel-eared squirrels, but retaining these patches may also compromise other restoration goals.

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4. Are exotics/invasive species present at landings and burn piles (WMS monitoring question 11)?

Judith D. Springer

Introduction

Invasive exotic plant species may invade disturbed areas following tree thinning, prescribed burning, or wildfire due primarily to the increased availability of resources (including sunlight, nutrients and moisture) and decreased tree competition. Most of these species are early successional or ruderal species and capitalize quickly on the newly available niches. Determining if there are certain land management practices that are contributing to increased abundance or invasion of these species is key to modifying thinning and burning practices in an effort to decrease their spread following ecological restoration treatments.

The original question asked by the White Mountain Stewardship Board was designed to ascertain if exotic invasive species were present at landings and burn piles. The ERI modified the question to also examine if these species are found in the WMS project area, inside or outside of the Wallow Fire perimeter, and in what density. The White Mountain Stewardship Project offers an opportunity to monitor for invasion on a landscape scale in areas that have been thinned only (or thinned and pile burned), as well as in areas that have been burned by the Wallow Fire.

Methods

Monitoring Design

Project areas and sample plots used in this study are described above in Chapter 1 (Chancellor et al. *this report*).Each plot was established as a long-term monitoring plot, with a monumented center and a reference tree for relocating the center. On each plot, we measured overstory characteristics, surface fuels, and regeneration. We also conducted a rapid assessment to determine if invasive non-native species were present on the plot, and if so, we recorded microsite and a rough estimate of density and abundance of each subpopulation.

From the plot center, we ran a 100 m tape in all four cardinal directions to form four triangular quadrants, for a total plot area of 2500 m^2. We then searched each quadrant for the non-native species of concern (listed in Appendix A of this report), using roughly a 5 x 5 m unit in which to estimate density (low density = <10 individuals, medium density = 10-50 individuals, high density = 50-100 individuals, and very high = >100 individuals). Observations were also recorded for the predominant microsite and whether the plants were clumped together (dense), uniformly distributed, scattered, or widely scattered. Photographs of plants or populations were collected for documentation, and specimens were collected to confirm identification. Although included on the list of species of concern, *Verbascum thapsus* (common mullein) was not included in surveys because of its ubiquitous and generally ephemeral nature in aboveground vegetation on the landscape. In addition, we did not collect information on non-native species, such as *Taraxacum officinale* (common dandelion) that are not considered to be invasive in this region.

For analysis, we used the midpoint of the density classes, so that the numbers of plants in each subpopulation are very likely inflated (for example, a single plant would have been recorded as five plants, which is the midpoint of the low density class).

Results

The types of microsites containing invasive species differed between areas inside and outside the perimeter of the Wallow Fire. The vast majority of invasive non-native plants and populations were found in areas where the tree canopy was relatively open (predominately full sun). Approximately 88% of plants/populations were detected in areas of open canopy/predominantly full sun inside the perimeter of the Wallow Fire, and 90% were found in full sun outside of the burn (Table 4.1).

Table 4.1. Percentage of microsites in which non-native invasive species were detected inside and outside of the perimeter of the Wallow Fire.

Microsite	Inside	Outside
Canopy Cover		
Full sun	88	90
Partial sun	12	10
Predominant Ground Cover		
Bare soil	68	47
Litter	32	49
Mix of litter/bare soil	0	4
Management Disturbance*		
Landing	0	1
No evidence of landing	100	99
Slash pile	0	2
No evidence of slash pile	100	98
Scattered slash	0	13
No evidence of slash	100	87
Road	2	31
No evidence of road	98	69

* Landings and slash piles were mostly obliterated during the fire and difficult to locate on the ground

The majority of non-native invasive species were detected in areas containing predominately bare mineral soil inside the burn (68%), but outside of the burned area, invasives were found equally in areas of predominately bare soil or organic material (including litter and duff).

Because the fire obliterated much of the evidence of previous landings or slash piles, we were not able to observe if invasives were growing on landings within the burned area, and there was very little slash left following the fire, so no invasives were detected in slash piles or areas of scattered slash (slash created during thinning operations but not deliberately scattered) following the fire. Outside of the fire, invasives were more commonly found in areas of scattered slash than on slash piles or landings. However, almost a third of the time, invasives were found on roads (including decommissioned roads) and skid trails.

In answer to the question of whether invasive species are found on landings and slash piles, we did find a small number of plants/populations on these sites, but because of a small sample size and confounding factors (high light conditions on a road for example), particularly in the fire itself, we did not find evidence to indicate that these sites were more preferentially invaded than any other type of microsite. However, we had a small sample size to work with, particularly inside the fire, due to the random location of our plots. It would also appear from our monitoring, that roads and skid trails have a high probability of being invaded by non-native species, probably because of the soil disturbance that occurs.

We observed five invasive non-native species from the list in Appendix A within the nineteen cutting units: *Bromus tectorum* (cheatgrass), *Carduus nutans* (musk thistle), *Cirsium vulgare* (bull thistle), *Convolvulus arvensis* (bindweed) and *Erodium cicutarium* (redstem filaree) (Table 4.2). *Carduus nutans* is a Class A Noxious Weed with a treatment priority of 1. The remaining four species fall under Class C, treatment priority 3. All five species were found in the perimeter of the Wallow Fire, but only *Cirsium vulgare* and *Erodium cicutarium* were found outside of the perimeter.

Table 4.2. Average density of non-native invasive species per acre within cutting units of the White Mountain Stewardship Project.

Cutting Unit	Species	Mean/ Acre	Wallow Fire
Alpine WUI 4&8	*Carduus nutans*	1.3	Yes
	Cirsium vulgare	43.2	Yes
	Erodium cicutarium	1.3	Yes
Alpine WUI 4&8 Block 5	*Cirsium vulgare*	2.7	Partial
Alpine Nutrioso 1B	*Bromus tectorum*	5.1	Yes
	Cirsium vulgare	16.1	Yes
	Convolvulus arvensis	16.2	Yes
	Erodium cicutarium	2.7	Yes
Alpine Nutrioso 1C	No species detected		Yes
Alpine Nutrioso 2	*Bromus tectorum*	2.7	Yes
	Carduus nutans	5.4	Yes
	Cirsium vulgare	5.4	Yes
Black Mesa Porcupine Ridge	*Cirsium vulgare*	148.4	No
Black Mesa Water Springs	*Cirsium vulgare*	70.1	No
Black Mesa West Chevelon	*Cirsium vulgare*	782.4	No
Black Mesa Wolfe A	*Cirsium vulgare*	108	No
Black Mesa Wolfe B	*Cirsium vulgare*	16.9	No
Lakeside Brushy	*Cirsium vulgare*	2.7	No
Lakeside Butler	*Cirsium vulgare*	9.45	No

Table 4.2 cont.

Cutting Unit	Species	Mean/ Acre	Wallow Fire
Lakeside McKay	*Cirsium vulgare*	21.6	No
Lakeside Trap Springs	*Cirsium vulgare*	29.7	No
Springerville Greer C	No species detected		No
Springerville Greer E	*Carduus nutans*	10.8	Yes
Springerville Hall's Ranch	No species detected		No
Springerville Mineral BX	*Cirsium vulgare*	85	No
	Erodium cicutarium	28.3	No
Springerville Mineral BY	*Cirsium vulgare*	6.1	No

Bromus tectorum was found mostly on bare soil (67% of subpopulations) and in full sun (83%). We found it only in the Nutrioso 1B cutting unit, which had been artificially seeded with a seed mix, and one occurrence was detected in the Nutrioso cutting unit 2.

Only five subpopulations of *Carduus nutans* were found, and these were also growing in full sun, but only two of the subpopulations were on bare soil. All five were within the Wallow Fire perimeter.

We detected two subpopulations of *Convolvulus arvensis*, both in full sun on eroded, bare soil. *Erodium cicutarium* was detected in small amounts inside and outside of the fire. In the fire, 75% of occurrences were found in full sun and 100% were on bare soil. Outside of the fire, it was found in full sun 100% of the time, but plants were detected in a range of microsites including bare soil, on a skid trail, in a drainage and in an area of scattered slash.

We found *Cirsium vulgare* in large numbers inside and outside the fire. Outside of the perimeter, 90% of plants/populations were found in full sun, 37% were on bare soil and 35% were found on areas where the soil had been disturbed, such as on roads, skid trails or areas of erosion. Eleven percent were found in areas of scattered slash or on slash piles and <.5% were on landings or burned slash piles. Within the fire, 98% of plants were found in full sun and 100% were found on bare soil, or soil with only small amounts of organic matter. Eighteen percent of plants were found on disturbed or eroding soils.

During monitoring there was a small number of species that we could not identify to species based on nonflowering basal rosettes. In Alpine WUI 4&8 there was an Apiaceae that was rather numerous. At Hall Ranch, there was a *Cirsium* with no flowers and only small basal rosettes. Finally, at Hall Ranch there was also a *Potentilla* species that could not be identified even after consulting the expert on this genus. It has the potential to be a rare species or hybrid and should be revisited in the future for this reason.

Discussion

Through our monitoring efforts, we observed non-native invasive species on landings and burn piles, but in very small numbers, and only outside of the Wallow Fire perimeter. Opening up the tree canopy through thinning promotes an increase of non-native species because of the increased availability of sunlight and other resources. We did not conduct a research study comparing thinned to unthinned areas, but published research studies generally support this trend of increased numbers of understory plants, including invasives, following thinning and/or burning. This trend is apparent here as well.

Cirsium vulgare (bull thistle) is particularly prevalent in the Black Mesa and Lakeside areas following thinning activities. Seed production in this species is fairly prolific with hundreds of seed per flowerhead and possibly hundreds of heads per plant. Seeds fall to the ground around adult plants in downy masses, from which they are easily wind dispersed. Our monitoring of microsites indicates that these wind-dispersed seeds are probably captured by slash, litter, logs and soil depressions.

Following wildfires and ecological restoration activities of thinning and prescribed burning, adult plants do not remain for long in the aboveground vegetation. However, it is quite possible that this species will form a persistent soil seed bank which may allow plants to colonize an area following soil disturbance. According to the Fire Effects Information System (Zouhar 2002), there is some evidence to indicate that deeply buried seeds experience induced dormancy and break dormancy when exposed to sunlight. Regardless of the mechanism of invasion at a site, whether it is through wind-dispersal or from a buried seed bank, the presence of bull thistle should be expected following thinning and burning activities across the landscape.

Bromus tectorum (cheatgrass) was primarily found in a unit that was artificially seeded following the fire. Cheatgrass is known to occur in seed mixes (Barclay et al. 2004), so regardless of whether or not the seed mix or seeding operations introduced the cheatgrass, or it entered in some other manner, this may be an area of monitoring that warrants increased attention.

References

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Appendix A. Non-Native Plant Species of Concern

List of surveyed species (obtained from White 2008)

Noxious and invasive weeds arranged alphabetically by genera within each treatment/priority class	
Class A, Treatment Priority 1	
Russian Knapweed	*Acroptilon repens* (L.) DC
Lens-podded hoarycress	*Cardaria chalepensis* (L.) Hand.-Maz.
Hairy whitetop	*Cardaria pubescens* (C.A. Mey.) Jarmolenko
Plumeless thistle	*Carduus acanthoides* L.
Musk thistle	*Carduus nutans* L.
Purple starthistle	*Centaurea calcitrapa* L.
Diffuse knapweed	*Centaurea diffusa* Lam.
Iberian starthistle	*Centaurea iberica* Trev. ex Spreng.
Yellow starthistle	*Centaurea solstitialis* L.
Spotted knapweed	*Centaurea stoebe* L. ssp. *micranthos* (Gugler) Hayek
Sicilian starthistle	*Centaurea sulphurea* Willd.
Squarrose knapweed	*Centaurea virgata* Lam. ssp. *squarrosa* (Willd.) Gugler
Rush skeletonweed	*Chondrilla juncea* L.
Canada thistle	*Cirsium arvense* (L.) Scop.
Teasel	*Dipsacus fullonum* L.
Russian olive	*Elaeagnus angustifolia* L.
Leafy spurge	*Euphorbia esula* L.
Black henbane	*Hyoscyamus niger* L.
Dyers woad	*Isatis tinctoria* L.
Dalmatian toadflax	*Linaria genistifolia (L.) P. Mill. ssp. dalmatica (L.) Maire & Petitm.*
Yellow toadflax	*Linaria vulgaris P. Mill.*
Purple loosestrife	*Lythrum salicaria L.*
Scotch thistle	*Onopordum acanthium L.*
Tansy ragwort	*Senecio jacobaea L.*
Carolina horsenettle	*Solanum carolinense L.*
Class B, Treatment Priority 2	
Jointed Goatgrass	*Aegilops cylindrica* Host
Camelthorn	*Alhagi pseudoalhagi* (Bieb.) Desv. ex B. Keller & Schaparenko
Whitetop	*Cardaria draba* (L.) Desv.
Halogeton	*Halogeton glomeratus* (Bieb.) C.A. Mey.
Texas blueweed	*Helianthus ciliaris* DC
Morning-glory	*Ipomoea* spp. L.
Perennial pepperweed	*Lepidium latifolium* L.
African rue	*Peganum harmala* L.
Salt cedar	*Tamarix* spp. L.
Class C, Treatment Priority 3	

Red Brome	*Bromus rubens* L.
Cheatgrass	*Bromus tectorum* L.
Southern sandbur	*Cenchrus echinatus* L.
Field sandbur	*Cenchrus incertus* M. Curtis
Bull thistle	*Cirsium vulgare* (Savi) Ten.
Field bindweed	*Convolvulus arvensis* L.
Hounds tongue	*Cynoglossum officinale* L.
Weeping lovegrass	*Eragrostis curvula* (Schrad.) Nees
Lehmann lovegrass	*Eragrostis lehmanniana* Nees
Redstem filaree	*Erodium cicutarium* (L.) L'Hér. ex Ait.
Oxeye daisy	*Leucanthemum vulgare* Lam.
Burclover	*Medicago polymorpha* L.
White sweetclover	*Melilotus albus* (L.) Lam.
Yellow sweetclover	*Melilotus officinalis* Medik.
Purslane	*Portulaca oleracea* L.
Himalayan blackberry	*Rubus armeniacus* Focke
Russian thistle	*Salsola* spp*. L.*
Perennial sowthistle	*Sonchus arvensis* L.
Johnsongrass	*Sorghum halepense* (L.) Pers.
Puncture-vine	*Tribulus terrestris* L.
Siberian elm	*Ulmus pumila* L.
Mullein*** - do not record	*Verbascum thapsus* L.
Cocklebur	*Xanthium strumarium* L.