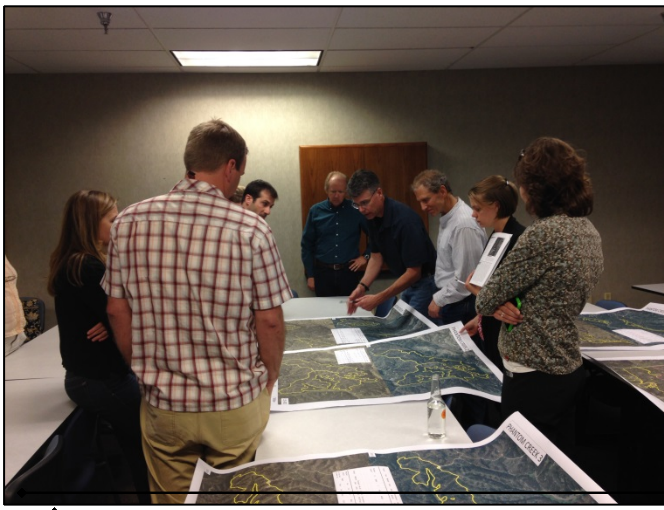
Colorado Front Range Collaborative Forest Landscape Restoration Project

Ecological Monitoring of Treatment Effects on Stand Structure and Fuels through 2013



Prepared by the Colorado Forest Restoration Institute at Colorado State University on behalf of the Front Range Roundtable

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COLORADO FOREST RESTORATION INSTITUTE

Colorado State University

Contents

SUMMARY

This report highlights accomplishments and ecological monitoring results for Front Range forest restoration treatments carried out under the Collaborative Forest Landscape Restoration Program (CFLRP) through 2013. It draws on previous monitoring reports produced by the Landscape Restoration (LR) team of the Front Range Roundtable to provide a cumulative view of treatment effects through the life of the Front Range CFLRP to date. Forest structural metrics such as tree density and fuels are the focus of this report, based on data available as part of the Forest Service's Common Stand Exam. Primary accomplishments and results through 2013 include:

- Approximately 9,000 acres have been treated across the Pike-San Isabel and Arapaho-Roosevelt National Forests through 2013, representing nearly one-third of the original 32,000 acres identified for treatment under the CFLRP.
- Treatments have consistently reduced forest density (basal areas and trees per acre) through mechanical and manual thinning.
- Tree removals have focused primarily on conifers, thus increasing the ratio of aspen to conifers within treated areas.
- Tree removals have also focused on smaller-diameter trees. Quadratic mean tree diameters have increased within treated areas as a result.
- While total live tree biomass has decreased within treatments as a result of tree removals, surface fuels have generally increased as material is redistributed to the forest floor. Use of prescribed fire to treat surface fuels should be continuously promoted by the LR team.
- The potential for active crown fire has been reduced through treatments. Crowning indices based on operational fire behavior models have increased due to treatments, meaning that higher wind speeds are necessary to sustain active crown fire now as a result of more open stand conditions created by treatments.
- Several components of the Front Range CFLRP monitoring program are *not* addressed here, including wildlife, understory vegetation, and spatial heterogeneity of forest structure at stand and landscape scales. Efforts are underway to evaluate how these components respond to treatments. Future monitoring reports will incorporate this wider range of variables to provide a more integrated picture of ecological response to treatments.
- The Collaborative has made significant strides in outlining an adaptive management process and describing key steps that should be undertaken in order to incorporate monitoring results and lessons learned into future management.

BACKGROUND AND CONTEXT

In its 2006 *Living With Fire* report, the Front Range Roundtable identified some 1.5 million acres of lower montane forests along Colorado's Front Range as in need of treatment to mitigate fire hazard, protect communities, improve forest health, and advance ecological restoration objectives (FRFTP 2006). Within this 1.5 million acre landscape, approximately

800,000 acres were deemed suitable for ecological restoration, with the overall goal of reducing forest densities, restoring spatial heterogeneity at multiple scales, and restoring a fire regime more characteristic of historical conditions. Of these priority acres, 400,000 acres are located on federally managed lands. Restoration efforts on these lands accelerated in 2010 with the awarding of a Collaborative Forest Landscape Restoration Program (CFLRP) grant to the Front Range Roundtable. Approximately 32,000 acres were identified for treatment under the CFLRP throughout the Front Range, from the Pike-San Isabel National Forest in the southern Front Range to the Arapaho-Roosevelt National Forest in the northern Front Range. The formation of the Science and Monitoring team (now known as the Landscape Restoration (LR) team) of the Roundtable followed the CFLRP grant, with a charge of describing desired conditions for Front Range forests and developing an ecological monitoring plan to assess progress in achieving these conditions.

In 2011, the LR team published its multi-party monitoring plan (Clement and Brown 2011), which provides a framework for determining whether restoration treatments are having desired impacts. Desired trends expressed in the monitoring plan are included in detail in Appendix A of this report, but in general include:

- Tree density – Are we decreasing basal area and trees per acre through restoration treatments?
- Tree sizes – Are we increasing quadratic mean tree diameters?
- Tree ages – Are we increasing the ratio of old trees (>200 years old) to transitional and young trees?
- Stand-scale spatial heterogeneity – Are we increasing the number of tree clumps and openings?
- Tree species – Are we increasing the proportion of basal area in ponderosa pine relative to other conifer species?
- Surface fuels – Are we decreasing litter, duff, and coarse woody debris?
- Fire behavior – Are we reducing crown fire potential at 90% weather conditions?
- Understory vegetation – Are we increasing grass, forb, and shrub cover?
- Wildlife – Are we increasing the occurrence of wildlife species expected in a restored landscape?

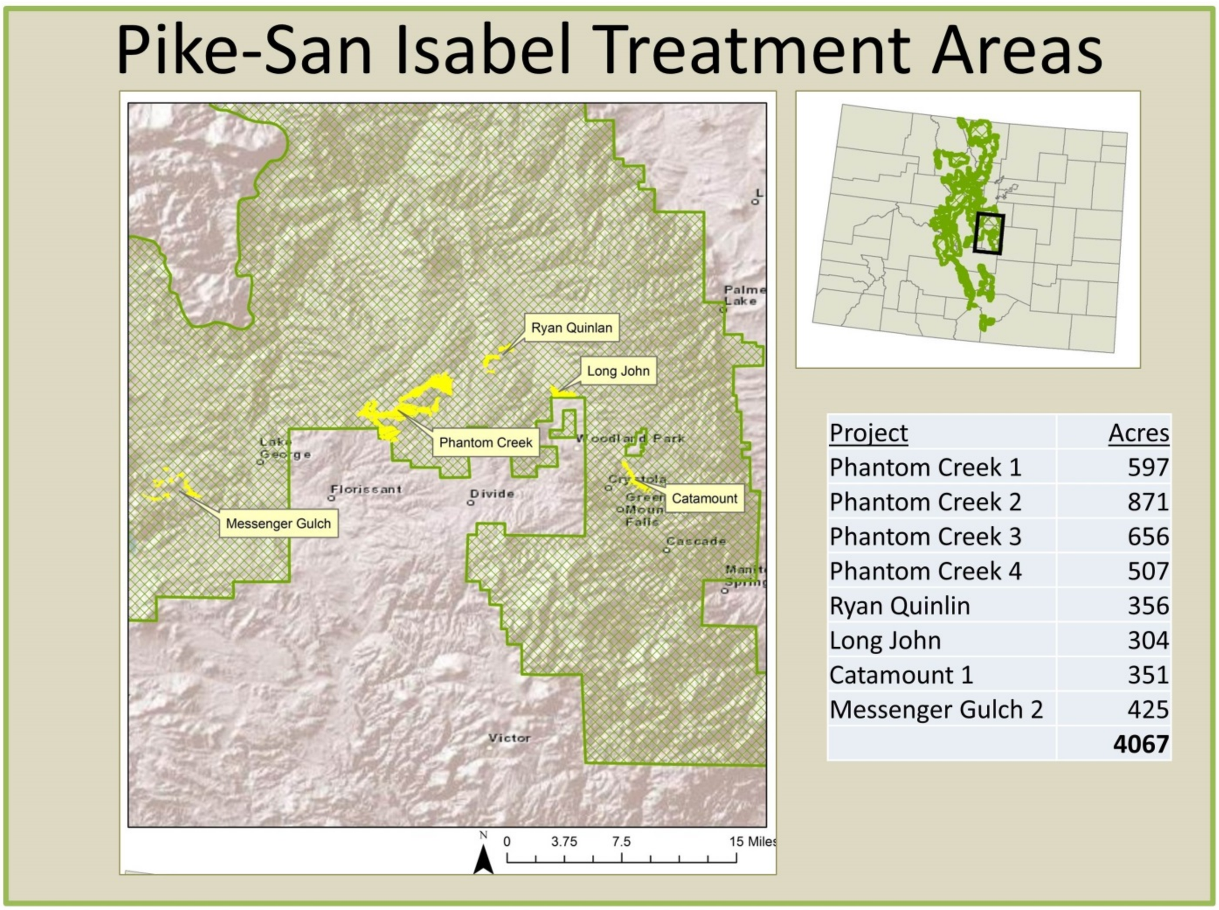
SCOPE OF THIS REPORT

This report deals with a subset of the desired trends described above for projects implemented in both the Pike-San Isabel and Arapaho-Roosevelt National Forests through 2013. Forest structure and fuels are the primary emphases of this report – including tree density, tree sizes, tree species composition, surface fuels, and fire behavior – based on data that is available through the Forest Service's Common Stand Exam (CSE) approach to assessing forest conditions.

Previous ecological monitoring reports produced by the Colorado Forest Restoration Institute (CFRI) include an evaluation of pre-treatment data through 2011 by Wudtke and Cheng (2012), as well as initial pre- to post-treatment analysis through 2012 by Young et al. (2013). These reports are available on CFRI's webpage (http://coloradoforestrestoration.org).

The current report builds on results presented in the two earlier reports and deals primarily with projects that were sampled in 2013. For the Pike-San Isabel, these projects include Catamount 1, Long John, Phantom Creek 4, and Messenger Gulch 2. For the Arapaho-Roosevelt, 2013 data primarily include pre-treatment sampling for upcoming projects Boulder Heights, Forsythe, and Gold Hill. In total, approximately 9,000 acres have been treated across Forests (Figures 1A and 1B), representing nearly a third of the original 32,000 acres identified for treatment in the Front Range CFLRP proposal.

While data presented in earlier reports is not included here, the discussion of the data is intended to be somewhat cumulative to provide a sense of general trends observed through the life of the CFLRP. Eventually, the Landscape Restoration team envisions an integrated ecological monitoring report that incorporates information from various facets of the program, including monitoring efforts that are beginning to come to fruition, such as spatial heterogeneity and wildlife monitoring.



Project	Acres
Phantom Creek 1	597
Phantom Creek 2	871
Phantom Creek 3	656
Phantom Creek 4	507
Ryan Quinlin	356
Long John	304
Catamount 1	351
Messenger Gulch 2	425
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Figure 1A. Location of CFLRP treatment areas to date in the Pike-San Isabel National Forest. Yellow polygons represent treatment areas; green hatching represents the Forest boundary.

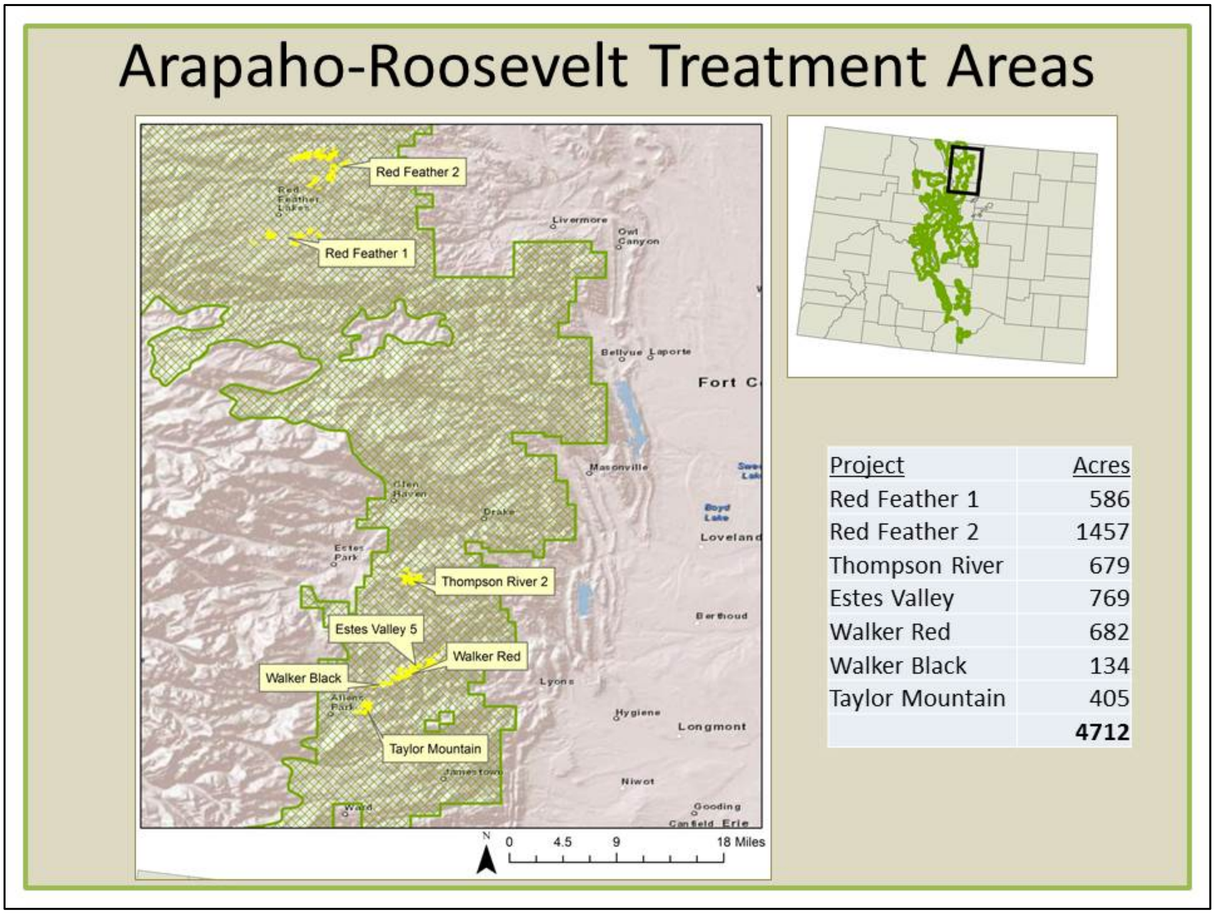

Figure 1B. Location of CFLRP treatment areas to date in the Arapaho-Roosevelt National Forest. Yellow polygons represent treatment areas; green hatching represents the Forest boundary.

DATA COLLECTION AND ANALYSES

The Forest Service's standard forest inventory known as the Common Stand Exam (CSE) was adopted by the Collaborative for use in monitoring forest structure and fuels. The CSE is a plot-based sampling approach that uses a variable-radius plot for overstory measurements, combined with fixed-area plots for tree regeneration and transects for fuels measurements. Additional details about the CSE sampling protocol can be found in the Front Range CFLRP monitoring plan (Clement and Brown 2011), as well as on the Forest Service's Field Sampled Vegetation (FSVeg) webpage (http://www.fs.fed.us/nrm/fsveg/index.shtml).

CSE data are collected each year from June to October by Forest Service contractors. In the Pike-San Isabel, a total of 156 plots were sampled in treated areas in 2013, enabling a comparison of pre- and post-treatment conditions. In the Arapaho-Roosevelt, a total of 203 plots were sampled in 2013 in areas slated for future treatment. Commonly encountered tree species (and their codes) are shown in Table 1.

Table 1. Common names, scientific names, and codes of tree species encountered in the CSE.

Common name	Scientific name	Code
Rocky Mountain Juniper	*Juniperus scopulorum*	JUSC
Lodgepole Pine	*Pinus contorta*	PICO
Engelmann Spruce	*Picea engelmannii*	PIEN
Limber Pine	*Pinus flexilis*	PIFL
Ponderosa Pine	*Pinus ponderosa*	PIPO
Colorado Blue Spruce	*Picea pungens*	PIPU
Aspen	*Populus tremuloides*	POTR
Douglas-fir	*Pseudotsuga menziesii*	PSME

CSE data are extracted by the Forest Service from the USFS FSVeg Database and delivered to CFRI as a Microsoft Access database containing tree, plot, and stand tables. For the analyses here, data were exported from Access into Statistical Analysis Software (SAS v.9.3) and Sigma Stat (v12.0) for summary and analysis. The Fire and Fuels Extension (FFE) of the Forest Vegetation Simulator (FVS; Suppose v2.02) was used for summarizing fuels data and generating fire behavior metrics. Fire weather data (90^{th} percentile conditions) were compiled using FireFamily Plus (v.4.1), a statistical software package capable of synthesizing weather data from Remote Automated Weather Stations (RAWS) (Bradshaw and Tirmenstein 2010). Weather stations at Lake George and the Cheesman reservoir were used for the Pike-San Isabel, whereas the Arapaho-Roosevelt used RAWS data from Red Feather, Estes Park, and Sugarloaf stations. Weather data were summarized from May 1 to Sep 30 (to represent the typical fire season) over a twenty year period from 1993 to 2013 (Table 2).

Table 2. 90^{th} percentile weather and fuel conditions for the Pike-San Isabel and Arapaho Roosevelt National Forests generated using FireFamily Plus.

Variable	Pike-San Isabel	Arapaho-Roosevelt
1-hr fuel moisture (%)	2	3
10-hr fuel moisture (%)	4	4
100-hr fuel moisture (%)	7	7
1000-hr fuel moisture (%)	10	10
Duff moisture (%)*	15	15
Herb fuel moisture (%)	10	8
Woody fuel moisture (%)	60	60
Air temperature (°F)	86	85
Wind speed (mph)	12.5	11.3

*Duff moisture is not included in the FireFamily Plus output. A value of 15% was used for this variable, representing the default value in FVS under the "very dry" scenario.

In 2012, the Landscape Restoration team recommended that both Forests use a Basal Area Factor (BAF) 10 prism for overstory sampling. In some cases in the 2013 sample, a different BAF prism was used for individual plots from pre to post treatment as crews transitioned to the use of a BAF 10 prism. We chose to avoid direct comparisons from pre to post treatment at the plot level, but felt that differences associated with the use of a different prism would be diluted at larger scales, such as the project scale. In general, data are presented at the project scale within the body of the report, though more detailed plot-level data can be found in Appendices B, C, and D. We used a paired t-test to determine if project-scale differences between pre- and post-treatment were statistically significant at $\alpha = 0.05$. In most cases data conformed to assumptions of normality and constant variance, however, a Wilcoxon signed-rank test was used in a few instances where data could not be normalized.

RESULTS

TREE DENSITY – *Are we reducing basal area and trees per acre through treatments?*

Past years' monitoring presented by Young et al. (2013) showed a clear decrease in both tree basal areas and trees per acre from pre to post treatment for projects in both the Pike-San Isabel and Arapaho-Roosevelt National Forests. For example, basal area decreased by an average of 32% across units within the Phantom Creek treatment area in the Pike San-Isabel forest, and by 25% across projects in the Arapaho-Roosevelt forest. Projects analyzed here through 2013 in the Pike-San Isabel forest continued to show decreases in both basal area and trees per acre as a result of treatments (Figures 2A and 2B). Across projects, average basal area was reduced from 109 ft^2/acre to 62 ft^2/acre, while average trees per acre decreased from 215 to 96. In all cases, treatments brought basal areas within the desired range of 40 – 80 ft^2/acre, as expressed in the monitoring plan. Most of the trees removed were conifers, thus increasing the proportion of aspen relative to conifers across projects.

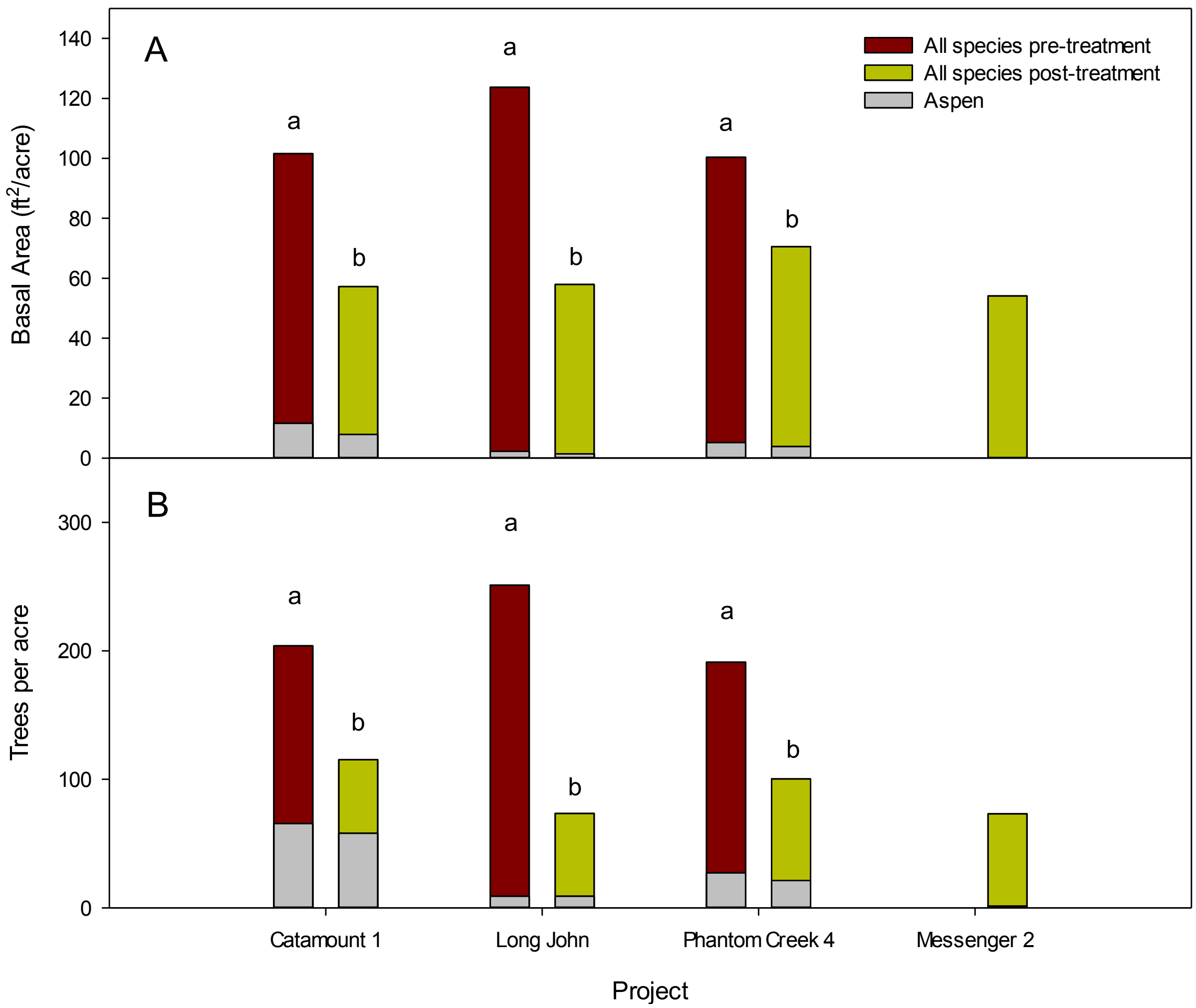

Figure 2. (A) Basal area and (B) trees per acre pre and post treatment for trees greater than 2.5 inches in DBH for 2013 projects in the Pike-San Isabel National Forest. Significant differences between pre and post treatment (at $\alpha = 0.05$) within projects are denoted by different letters.

Projects slated for future treatment in the Arapaho-Roosevelt National Forest averaged 78 ft^2/acre basal area and 246 trees per acre in 2013 (Figures 3A and 3B). The Forsythe treatment area was particularly dense (385 trees per acre, mostly in smaller diameter trees) prior to treatment.

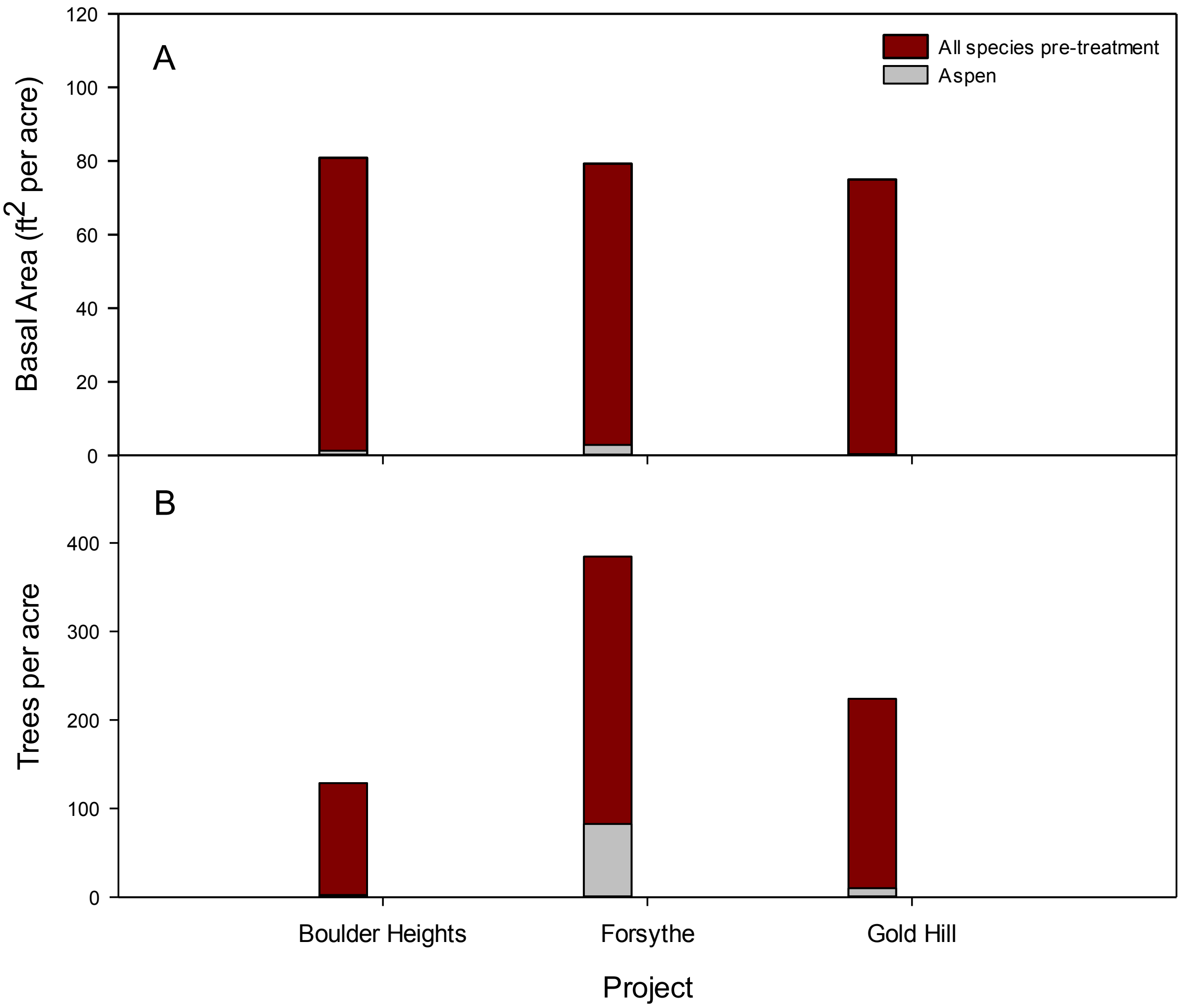

Figure 3. (A) Basal area and (B) trees per acre pre-treatment for trees greater than 2.5 inches in DBH for 2013 in the Arapaho-Roosevelt National Forest.

TREE SIZES – *Are we increasing quadratic mean tree diameter through treatments?*

Tree removals generally have been concentrated in smaller diameter tree classes, as shown across Forests through 2012 by Young et al. (2013), as well through 2013 here for the Pike-San Isabel National Forest (Figure 4). The majority of trees removed were less than 12.5 inches in diameter. As a result of these small-tree removals, quadratic mean tree diameters (QMD) have increased within treated areas. Young et al. (2013) documented an increase across treatments from 10.0 inches pre-treatment to 11.0 inches post-treatment in the Pike-San Isabel, and from 9.2 to 10.3 inches in the Arapaho-Roosevelt. Similarly for 2013 data in the

Pike-San Isabel, QMD increased from 13.1 inches pre-treatment to 14.6 inches post-treatment (Table 3). The Long John project was the only project where the increase in QMD was statistically significant, however.

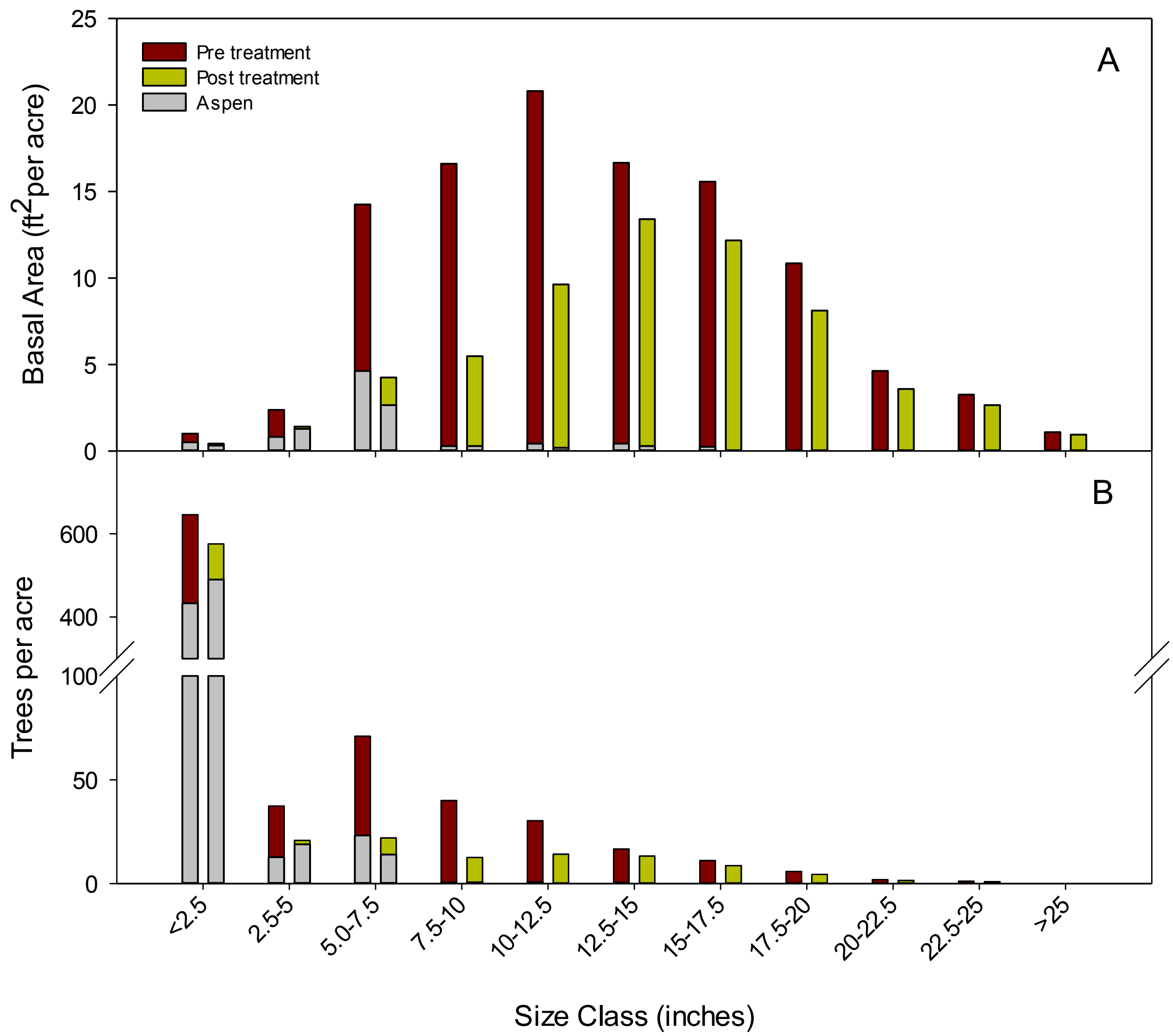

Figure 4. (A) Basal area and (B) trees per acre pre and post treatment by size class in the Pike-San Isabel National Forest. Data are summarized across 2013 projects to illustrate that small trees are preferentially removed.

Table 3. Quadratic mean tree diameter (QMD) for trees greater than 2.5 inches DBH pre- and post-treatment for 2013 projects in the Pike-San Isabel National Forest. Values represent means (±1 standard error in parentheses) per project. Means with different letters from pre- to post-treatment within projects are significantly different at α = 0.05.

	QMD (inches)	
Project	**Pre-treatment**	**Post-treatment**
Catamount 1	13.7 (0.6)[a]	14.8 (0.7)[a]
Long John	12.9 (0.6)[a]	15.2 (0.5)[b]
Phantom Creek 4	12.7 (0.6)[a]	13.8 (0.4)[a]
Messenger Gulch 2	--	13.7 (0.3)

Tree Species Composition – *Are treatments increasing the proportion of basal area in ponderosa pine?*

Data presented through 2012 by Young et al. (2013) showed a modest increase in ponderosa pine for Pike-San Isabel treatment units relative to other conifer species such as Douglas-fir, while results for the Arapaho-Roosevelt showed a small increase in the proportion of both ponderosa pine and Douglas-fir at the expense of lodgepole pine. Data analyzed here for projects through 2013 in the Pike-San Isabel showed a small increase in the proportion of both ponderosa pine and Douglas-fir at the expense of blue spruce (Figure 5A).

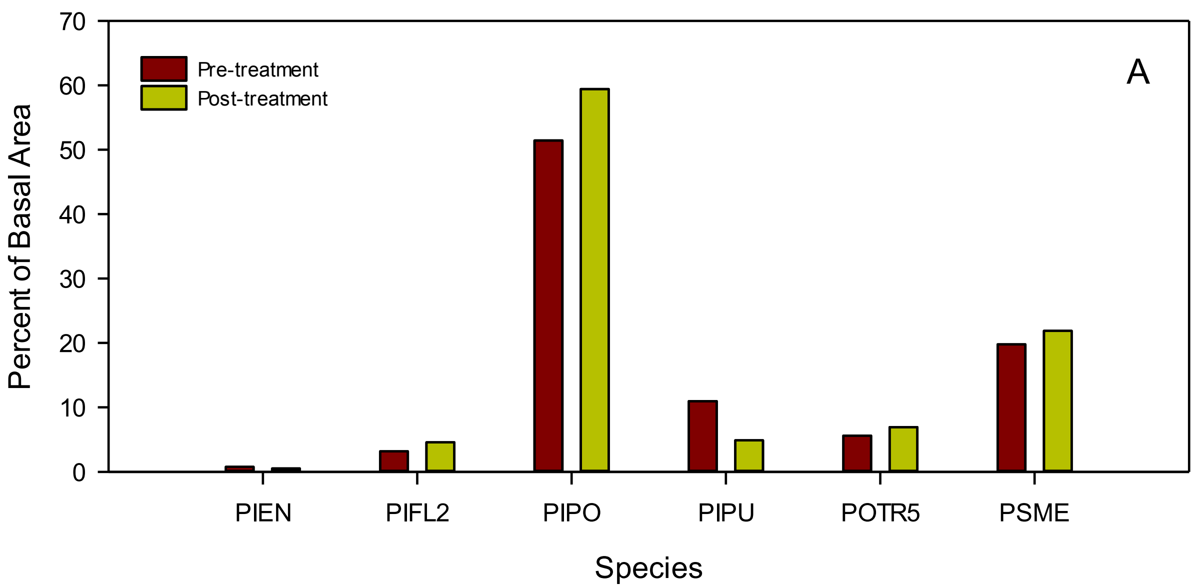

Figure 5. (A) Percent of basal area by species across projects on the Pike-San Isabel National Forest. See Table 1 for definitions of species codes.

Large increases in the ratio of ponderosa pine to other conifer species have not been consistently observed across projects, potentially because ponderosa pine often makes up the majority of basal area to begin with and demonstrating a proportional increase would require substantial removal of other species (Figure 5B). Complete removal of Douglas-fir is not a treatment objective; projects that have little Douglas-fir initially may wish to retain this species, especially in ecologically appropriate areas such as on north-facing slopes. Such projects likely would not demonstrate an increase in the proportion of basal area in ponderosa pine, yet they may be appropriate based on site conditions. Species composition as a metric for judging restoration success should perhaps be interpreted with more nuance than other metrics; while patterns generally suggest that ponderosa pine is favored for retention over other conifer species, additional investigation that considers the influence of both pre-treatment species composition and site conditions may be warranted. Also, evaluating changes in basal area by species in absolute terms (rather than relative terms) may be a more informative means of assessing species compositional changes related to treatments in future analyses.

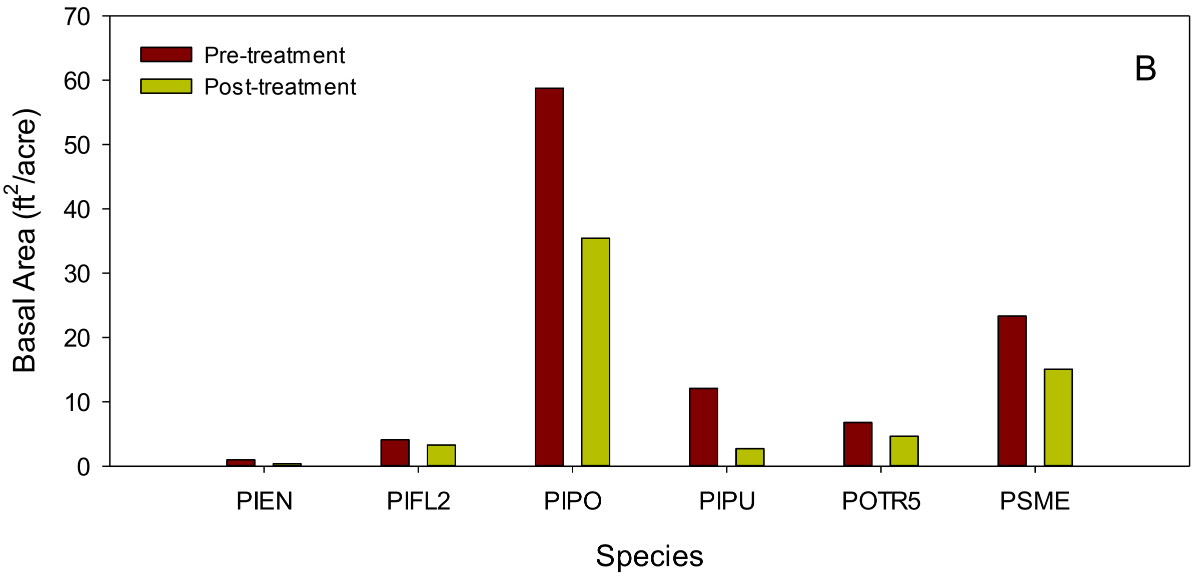

Figure 5. (B) Actual basal area by species across projects before and after treatment in the Pike-San Isabel National Forest, demonstrating that ponderosa pine (PIPO) makes up the majority of the basal area before treatment.

FUELS AND FIRE BEHAVIOR – *Are we decreasing fuel loads and reducing the potential for crown fire?*

In the Pike-San Isabel National Forest, 2013 marked the first year that fuels data were available both before and after treatment for evaluating treatment effects on fuel loads and fire behavior. In general, surface fuels (especially fine wood, 0-3" in diameter) increased as a result of treatments redistributing material to the forest floor (Table 4). While this outcome is not necessarily desirable, it is to be expected following mechanical treatments and highlights the need for longer-term monitoring (5 to 7 years post treatment) to evaluate how this metric changes following future slash treatments such as broadcast burning.

Treatments successfully reduced canopy fuels: mean canopy base height increased while canopy bulk density decreased across projects (Table 4). These changes in canopy conditions reduce the likelihood of active crown fire, as shown by the crowning index (crowning index is defined as the wind speed necessary to sustain active crown fire). Across projects in the Pike-San Isabel, crowning indices increased from an average 26 mph before treatment to 46 mph after treatment, theoretically meaning that a wind speed of 46 mph would now be required to sustain active crown fire (Figure 6).

Table 4. Surface and canopy fuels pre- and post-treatment for 2013 projects in the Pike-San Isabel NF. Means with different letters from pre- to post-treatment are significantly different at α = 0.05.

Surface Fuel Component *(tons/acre)*	**Catamount 1**		**Long John**		**Phantom Creek 4**		**Messenger Gulch 2**	
	Pre	*Post*	*Pre*	*Post*	*Pre*	*Post*	*Pre*	*Post*
Total surface fuels	11.1^{a}	21.2^{b}	13.5^{a}	16.9^{a}	12.5^{a}	17.6^{a}	--	17.0
Litter	1.0^{a}	0.6^{b}	1.0^{a}	0.4^{b}	0.9^{a}	0.7^{a}	--	0.6
Duff	4.4^{a}	6.0^{b}	5.9^{a}	7.6^{a}	4.1^{a}	5.2^{a}	--	8.1
Fine Wood (0-3" dia.)	1.5^{a}	5.9^{b}	2.3^{a}	4.8^{b}	2.3^{a}	6.6^{b}	--	4.1
Coarse Wood (>3" dia.)	3.5^{a}	7.9^{b}	3.5^{a}	3.8^{a}	4.7^{a}	4.8^{a}	--	3.9
Live Herbaceous	0.2^{a}	0.3^{b}	0.2^{a}	0.3^{b}	0.2^{a}	0.2^{a}	--	0.2
Live Shrub	0.4^{a}	0.4^{a}	0.4^{a}	0.1^{b}	0.4^{a}	0.2^{b}	--	0.1
Canopy Fuel Component								
Canopy base height *(ft)*	5.3^{a}	8.9^{b}	6.2^{a}	20.0^{b}	6.3^{a}	8.8^{a}	--	8.4
Bulk density *(kg/m^3)*	0.15^{a}	0.05^{b}	0.10^{a}	0.03^{b}	0.09^{a}	0.06^{b}	--	0.06

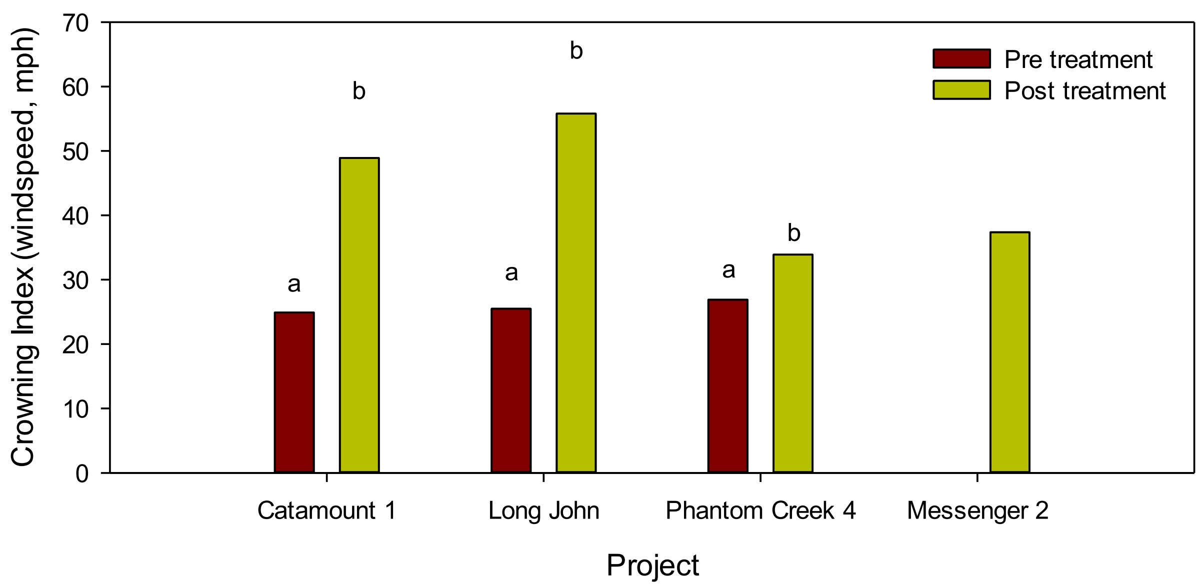

Figure 6. Crowning index pre- and post-treatment for projects in the Pike-San Isabel National Forest. The crowning index represents the wind speed necessary to sustain an active crown fire; a higher index means that higher wind speeds are necessary to carry fire from tree crown to tree crown. Significant differences between pre and post treatment (at α = 0.05) within projects are denoted by different letters.

Pre-treatment fuel loads in the Arapaho-Roosevelt National Forest ranged from 12.4 to 19 tons/acre across projects sampled in 2013 (Table 5). Crowning index averaged 29 mph across treatments. Changes in theses metrics will be assessed next year as post-treatment data is collected and made available.

Table 5. Pre-treatment surface and canopy fuels for projects sampled in 2013 in the Arapaho-Roosevelt National Forest.

Surface Fuel Component *(tons/acre)*	**Boulder Heights** *Pre*	*Post*	**Forsythe** *Pre*	*Post*	**Gold Hill** *Pre*	*Post*
Total surface fuels	13.6	--	19.0	--	12.4	--
Litter	0.5	--	0.7	--	0.6	--
Duff	8.5	--	9.9	--	7.3	--
Fine Wood (0-3” dia.)	1.2	--	3.6	--	2.1	--
Coarse Wood (>3” dia.)	2.7	--	3.9	--	1.8	--
Live Herbaceous	0.3	--	0.3	--	0.3	--
Live Shrub	0.4	--	0.5	--	0.6	--
Canopy Fuel Component						
Canopy base height (*ft*)	14.4	--	6.3	--	6.0	--
Bulk density (kg/m^3)	0.07	--	0.11	--	0.09	--

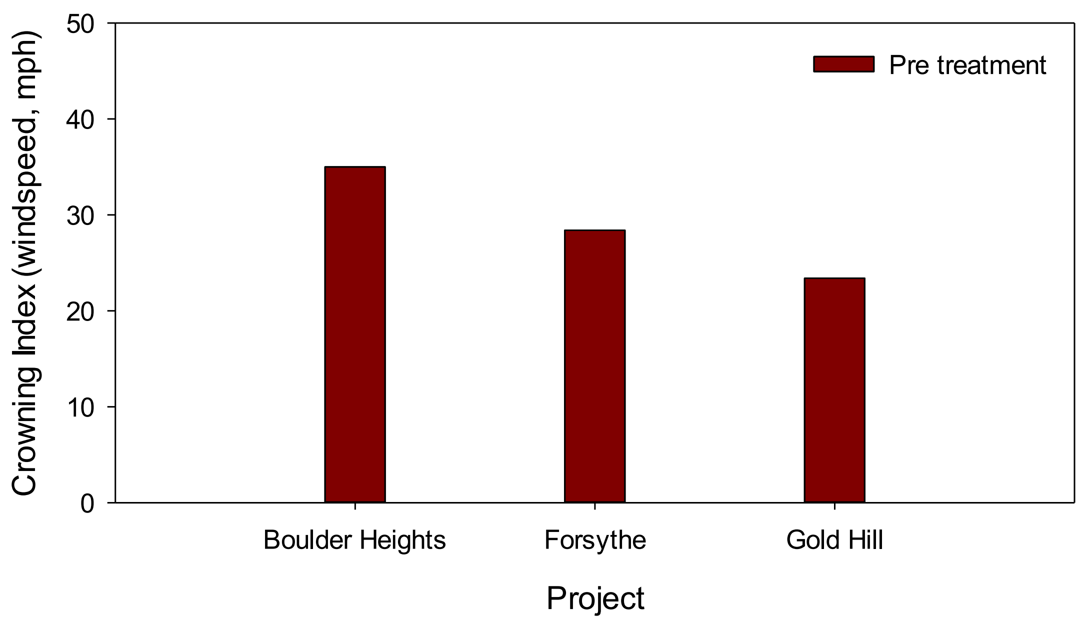

Figure 7. Pre-treatment crowning index for projects sampled in 2013 in the Arapaho-Roosevelt National Forest.

DISCUSSION

The Front Range CFLRP aims to restore lower montane forest structure and function by reducing forest densities, creating diverse patterns of forest structure at stand and landscape-scales, and reducing the potential for uncharacteristically severe wildfire. Common Stand Exam data analyzed here through 2013 suggest that many of the stand structural and fire hazard metrics identified in the Front Range CFLRP monitoring plan are moving in desired directions as a result of treatments. Treatments have been effective in reducing forest densities, bringing basal areas within a desired range of 40-80 ft^2/acre. Smaller-diameter trees have been the focus of removals, thus improving the balance of tree size class distributions and increasing stand quadratic mean diameters. The change in stand structure brought about by treatments has resulted in favorable changes in modeled fire behavior as well. The increase in crowning index brought about by treatments is encouraging as it means that higher winds speeds would be necessary to sustain an active crown fire in treated stands currently compared to before treatment. This change in crowning index is likely due to the decrease in canopy bulk density. Overall, results presented here corroborate those of Young et al. (2013) as well as Briggs et al. (2014), who independently sampled several of the Front Range CFLRP treatment sites and found a 30% reduction in basal area, a 50% reduction in trees per acre, and an increase in canopy openness and opening sizes as a result of treatments.

The reduced potential for active crown fire is an important outcome of treatments that should be highlighted by the LR team, as wildfire mitigation has been a driver of much of the restoration work in the Front Range. Despite the reduced potential for crown fire, however, treatments have generally increased surface fuel loads as material (especially coarse woody debris) is redistributed to the forest floor. Following mechanical treatments with surface fuels treatments such as prescribed fire is extremely important. While opportunities for the use of prescribed fire are limited in the Front Range, the Landscape Restoration team should continue to promote it as a necessary tool for achieving a wider range of treatment benefits and should consider incorporating the use of fire more explicitly as a desired condition. Restoration of a more characteristic fire regime (i.e. low to mixed-severity) is a primary goal of the Front Range CFLRP, yet will be difficult to achieve without the use of prescribed fire.

While the Common Stand Exam is a suitable technique for demonstrating treatment effects on basic stand structural and fire hazard metrics, the approach was not originally intended to address other components of the monitoring program such as wildlife monitoring, spatial heterogeneity monitoring, and understory vegetation monitoring (Clement and Brown 2011). Several important advances have been made recently in developing and implementing these additional components of the monitoring program. For example, the LR team's wildlife group completed their recommendations for wildlife monitoring during spring 2014 and carried out sampling during summer 2014. The spatial heterogeneity subteam also developed and implemented protocols for assessing stand- and landscape-scale spatial patterns during 2014 (see Pelz and Dickinson 2014 and Dickinson and Giles 2014). The understory subteam made valuable progress as well in designing a sampling approach in spring 2014, which will likely be implemented in 2015. As these components of the monitoring program continue to mature and produce data, some effort should be made to integrate results with the Common Stand Exam. While stand-alone reports may be produced by each of these efforts, the LR team envisions a summary report that highlights the main outcomes from the various monitoring components so that results are integrated and enable the LR team and Roundtable to determine if desired conditions are being achieved for the full suite of metrics identified in the monitoring plan. Some discussion among the LR team about the level of funding for each of the monitoring components would be valuable as well to balance the range of monitoring methods being used and to maximize the utility of the data being generated. As the CSE continues to demonstrate changes in basic stand structure (e.g. density) as a result of treatments, the LR team may wish to shift emphasis to other aspects of the monitoring program not well represented by the CSE. For example, changes have been made to treatment prescriptions over the life of the CFLRP to encourage more stand-scale heterogeneity, yet this evolution in treatment approach is not well demonstrated in the data due to limitations of the CSE. Given the importance of restoring spatial heterogeneity, the LR team should evaluate whether increased funding for spatial heterogeneity monitoring proposed by Pelz and Dickinson (2014) at the expense of the CSE is justified, and if so, how best to balance this funding among other emerging components of the monitoring program such as wildlife and understory monitoring.

The LR team made significant strides in the last year as well in formalizing an approach to adaptive management (AM) for CFLRP projects (see Aplet et al. 2014). The AM diagram developed by Aplet et al. (2014) poses several direct questions that guide the collaborative in interpreting monitoring outcomes and using monitoring results to inform future treatment design and implementation: Are we treating the right areas? Are treatments contributing to desired conditions? Are we monitoring the right things? In April 2014, the LR team held its first monitoring review session whereby LR team members gathered to review Common Stand Exam data and ask the question of whether treatments are contributing to desired conditions. Results of that exercise are presented in Appendix E. The review session was an important step in implementing adaptive management and making a collective determination about whether treatments are contributing to desired conditions. Such a review session will be held annually to provide an opportunity for LR team members to evaluate data as well as to review the monitoring program itself.

Lastly, in addition to depicting change and informing adaptive management, monitoring may also highlight information gaps and point to uncertainties that can be addressed by research. Specific questions have arisen from the Front Range CFLRP monitoring program, especially concerning post-treatment tree regeneration and opening sizes. Will openings become quickly colonized by tree regeneration? How much regeneration is too much? What is the appropriate range of opening sizes based on site conditions? These unknowns may provide opportunities for more targeted monitoring, as well research opportunities that the LR team should consider exploring.

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APPENDICES

Appendix A. Table from the FR-CFLRP Monitoring Plan (Clement and Brown 2011) depicting ecological metrics and desired trends.

Table 2: Monitoring Protocols Table. Desired Conditions, restoration parameters, and monitoring details for the Colorado Front Range CLFRP. Note that several of the restoration parameters still need further details.

Desired Condition						
Restoration parameters	**Desired trends**	**Variables to measure**	**Methods**	**At what point measured**	**Scale of analysis**	**Notes**
Establish a complex mosaic of forest density, size and age (at stand and treatment scales)						
Tree Density	• Decreased basal areas	• Basal area	• Count all trees ≥2.5" diameter at breast height (DBH) in a variable radius prism plot (10 or 20 Basal Area Factor) and scale up to per acre basis • Count all seedlings and saplings (<2.5" DBH) in fixed radius 1/200 ac (8.3' radius) plot centered on prism plot and scale up to a per acre basis	• Before treatment • After treatment • 5 to 10 years after treatment	• Treatment Unit	• Example data: 40-80 ft^2 per acre (1" DBH and above); however, expert review suggested this is site dependent
	• Decreased trees per acres	• Trees per acre	• Count all trees ≥2.5" diameter at breast height (DBH) in a variable radius prism plot (10 or 20 Basal Area Factor) and scale up to per acre basis • Count all seedlings and saplings (<2.5" DBH) in fixed radius 1/200 ac (8.3' radius) plot centered on prism plot and scale up to a per acre basis	• Before treatment • After treatment • 5 to 10 years after treatment	• Treatment Unit	• Example data: 40-100 trees per acre (1" DBH and above); however, expert review suggested this is site dependent
Tree Sizes	• Increased Quadratic Mean Diameters	• Diameters at breast height for larger trees and root collar for seedlings and saplings	• Measure diameters at breast height (DBH) using diameter tapes on all variable radius plot "tally" trees and scale up to per acre basis • Count number of seedlings and saplings (<2.5" DBH) in fixed radius 1/200 ac (8.3' radius) plot (seedlings = below BH; saplings = BH to <2.5" DBH) and scale up to per acre basis	• Before treatment • After treatment • 5 to 10 years after treatment	• Treatment Unit	• Quadratic Mean Diameter (QMD) – Integration of stems per acre and diameters – representative of average tree size
Tree Ages	• Increased ratios of old trees (>200 yrs) to transitional trees (150-200 yrs) to younger trees (<150 years).	• Tree ages	• Use visual references and morphology of all variable radius plot tally trees (RMRS-GTR-109 and 110) to define old/transitional/young trees and scale to per acre basis • Obtain dendrochronologically crossdated (or ring-counted) ages from increment cores as available	• Before treatment • After treatment • 5 to 10 years after treatment	• Treatment Unit	

Desired Condition						
Restoration parameters	**Desired trends**	**Variables to measure**	**Methods**	**At what point measured**	**Scale of analysis**	**Notes**
Within-stand spatial heterogeneity and structural stage diversity	• Increased tree clumps and spatial heterogeneity in stands • Increased number of openings (>.25 acre)	• Variation in structural stages at sub-stand level • Number of openings	• Exact method(s) to be determined • Test plot/transect method at Manitou Experimental Forest or with other spatial data sets • Test use of spatial stats derived from orthophotos	• Before treatment • After treatment	• Treatment Unit	• Needs further discussion. • A sub-group will determine specific details over the course of the next 6 months
Establish a more favorable species composition						
Tree Species	• Increased ratio of ponderosa pine to other conifers where appropriate	• Tree species	• Identify species of all variable radius plot "tally" trees and scale up to per acre basis • Count seedlings and saplings in fixed plot by species and scale up to per acre basis	• Before treatment • After treatment • 5 to 10 years after treatment	• Treatment Unit	
Establish a more characteristic fire regime						
Surface fuels	• Decreased litter and duff depths • Decreased or similar coarse woody debris	• Surface fuel conditions for development of surface fuel models	• Two Brown's transects (that measure log amounts and sizes, and litter and duff depths) running 50 ft from plot centers, alternating E/W, N/S in plots	• Before treatment • After treatment	• Treatment Unit	
Fire behavior	• Mixed-severity that trends toward surface fire • Reduced crown fire potential at 90% weather as modeled in fire behavior models	• Tree heights, canopy base heights (CBH), canopy bulk densities (CBD), surface fuel models	• Canopy base height (CBH), canopy cover measured using Common Stand Exam methods • CBH, canopy bulk density (CBD), surface fuel models, and fire behavior afterwards modeled with plot and Brown's transect data, aggregated across landscape	• Before treatment • After treatment	• Treatment Unit • Landscape	• Example data: decrease in crowning and torching indices in pre- and post-treatment model runs

Increase coverage of understory plant communities (See Appendix A, page 37)						
Grass, forbs and shrubs.	• Increased cover by grass, forbs and shrubs • Decreased deep needle layers and bare ground.	• Ground cover by grass/forb/shrub functional groups • Presence and cover of key indicator species	• Average cover by functional groups (grass, forb, shrub, litter, rock, bare ground) measured on 3 50' point-intersect transects extending from plot centers • Average cover by individual or key indicator species as available (e.g., when botanist is available)	• Before treatment • After treatment • 5 years after treatment	• Treatment Unit	• See Appendix A for a list of possible Tier 2 indicator species for monitoring
Noxious or invasive plant species	• Similar (or decreased) occurrence and cover of noxious or invasive plant species	• Presence and cover of invasive species	• Average cover by individual or indicator species measured on 3 50' point-intersect transects extending from plot centers	• Before treatment • After treatment • 5 years after treatment	• Treatment Unit	• See Appendix A for a list of invasive species of concern
Occurrence of wildlife species that would be expected in a restored landscape (See Appendix B, page 39)						
Raptors (canopy nesters, accipiters)	• Increased use of restored areas • More nests, additional alternate nests • Increased number of plucking posts	• Goshawk (Cooper's and sharpshinned hawks also likely to respond to goshawk broadcast surveys)	• Identify active and inactive nests (GPS & photograph) • Search for evidence of raptor activity (pellets, whitewash,feathers, plucking posts). • Count, GPS, & photograph.	• Before treatment • After treatment	• Treatment Unit	
Carabid beetles (ground beetles)	• Increased species richness and Shannon diversity measurements	• Species diversity and abundance.	• Pitfall traps: plastic cups/coffee cans buried in the ground; one trap per plot • Photographs for later id.	• Before treatment • After treatment	• Treatment Unit	• Shannon index, is one of several diversity indices used to measure diversity in categorical data.
Snags	•	•	• Counted and diameter/height measured in variable radius plots	• Before treatment • After treatment	• Treatment Unit	Ken Morgan will give input

Tree squirrels (small mammals)	• Increased counts of squirrel sign	• Abert's squirrel	• Identify and GPS squirrel feed tree • Count at each plot and remove squirrel feeding sign (fungi digs, clippings, bones (twigs), cone cobs) • Indentify and count squirrel nests	• Before treatment • After treatment	• Treatment Unit	
Establish a complex mosaic of forest density, size and age (at landscape scale)						
Habitat Structure Stage at landscape scale ((6th or 7th level HUC) mosaic	• Increase larger, more open structure • Increased structural stages 4&5 • Slight increase of structural stage 1: grass, forbs • Decrease in closed, dense structure	• Change in ratio of structure stage	• Area of structure stage derived from existing veg layers (adjusted for change by treatments & other disturbances)	• Before treatment • 10 years after treatment	• Landscape	• A landscape is defined in this context as a 6th or 7th level watershed or a group of 6th and 7th level watersheds • Analysis should be of change in ratio of structural stages, differences and similarities between HUCs

Appendix B. Projects, stands, and associated sampling information for plots sampled in the Pike-San Isabel National Forest in 2013.

PROJECT DATA					CSE REP. STAND DATA						SAMPLE DATE	
PROJECT	**UNIT NO.**	**UNIT ACRES**	**TREE SELECT**	**TREAT-MENT**	**STAND ID**	**ACRES**	**PLOTS**	**MEAN ELEV.**	**MEAN ASPECT**	**COVER TYPE**	**PRE**	**POST**
PHANTOM CREEK 4 (contract award July, 2012)	2	118	DxP	MAST	US08050347	60.1	6	9028	SE	PP	07/11/11	08/18/13
	2	118	DxP	MAST	US08050351	33.1	5	8961	NE	PP	07/11/11	08/19/13
	3A/3B	83	DxP	MAN	US08050822	48.0	5	8683	WE	DMC	07/09/11	08/19/13
	3A	49	DxP	MAN	US08050837	41.2	4	8829	SO	DMC	07/09/13	08/18/13
	8	103	DxP	MAN	US08050466	28.0	4	8664	NE	DMC	07/08/11	08/19/13
	8	103	DxP	MAN	US08050471	44.6	4	8779	SE	PP	07/08/11	08/19/13
LONG JOHN (contract award August, 2012)	1/2	21	ITM - CT	MECH	US08020136	26.1	5	8140	WE	TPP	08/15/12	10/10/13
	2	91	ITM - CT	MECH	US08031003	19.7	4	8081	NE	DMC	08/15/12	10/11/13
	2	91	ITM - CT	MECH	US08031007	26.1	5	8146	NO	TPP	08/16/12	10/11/13
	4	80	ITM - CT	MECH	US08020141	18.0	4	8164	WE	TPP	08/16/12	10/13/13
	4	80	ITM - CT	MECH	US08031010	35.1	7	8261	NW	TPP	08/16/12	10/12/13
	5	31	ITM - LT	MECH	US08031014	20.5	4	8276	NO	DMC	08/17/12	10/13/13
	6	64	ITM - LT	MECH	US08031018	37.9	6	8269	NO	DMC	08/17/12	10/12/13
CATAMOUNT 1 (contract award July, 2012)	1	26	DxP/ITM	MECH	FC01010049	22.2	3	9243	NW	DMC	5/31/09	8/20/13
	1	26	DxP/ITM	MECH	FC01010050	13.6	3	9304	SE	PP	5/31/09	8/20/13
	2	26	DxP/ITM	MECH	FC01010053	9.4	3	9321	SE	DMC	6/2/09	8/20/13
	2	26	DxP/ITM	MECH	FC01010054	8.9	3	9300	NW	WMC	6/2/09	8/20/13
	3	28	DxP/ITM	MECH	FC01010127	7.9	3	9317	NW	PP	9/20/11	8/20/13
	3	28	DxP/ITM	MECH	FC01010129	6.3	3	9336	NW	DMC	9/20/11	8/21/13
	3	28	DxP/ITM	MECH	FC01010136	19.1	4	9332	SO	PP	9/21/11	8/21/13
	4	55	DxP/ITM	MECH	FC01010186	10.1	3	9355	SE	DMC	9/19/11	8/21/13

	6	57	DxP/ITM	MECH	FC01010194	12.2	3	9475	SO	AS	9/22/11	8/22/13
	6	57	DxP/ITM	MECH	FC01010213	6.4	3	9433	EA	PP	9/23/11	8/20/13
	6	57	DxP/ITM	MECH	FC01010214	14.8	3	9388	WE	AS	9/23/11	8/20/13
	6	57	DxP/ITM	MECH	FC01010218	10.1	3	9305	WE	DMC	9/23/11	8/20/13
	15	33	DxP	MAN	FC01010193	8.3	3	9470	SO	AS	9/22/11	8/22/13
	15	33	DxP	MAN	FC01010195	39.5	7	9381	SW	PP	9/22/11	8/21/13
	20	38	DxP	MAN	FC01010048	16.6	3	9252	SO	PP	5/31/09	8/19/13
MESSENGER GULCH 2 (contract award January, 2013)	1/8	24	DxP	MAN	SH04010410	66.2	12	8742	NE	PP	n/a	8/17/13
	9	12	DxP	MAN	SH04010225	14.6	3	8980	EA	PP	n/a	8/18/13
	11	34	DxP	MAN	SH04010232	35.1	7	8707	NE	PP	n/a	8/16/13
	2	23	ITM - LT	MECH	SH04010430	43.4	9	8638	NE	PP	n/a	8/16/13
	7	95	ITM - LT	MECH	SH04010472	95.2	12	8588	NE	PP	n/a	8/17/13

Appendix C. Plot-level summary data (basal areas and trees per acre, >2.5 inches DBH) for projects in the Pike-San Isabel forest in 2013.

			Conifer TPA		Conifer BA		Aspen TPA		Aspen BA	
Project	**Stand**	**Plot**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Catamount 1	020809FC01010048	1	241.44	85.43	100.00	50.00	0.00	0.00	0.00	0.00
	020809FC01010048	2	49.12	24.13	80.00	40.00	0.00	0.00	0.00	0.00
	020809FC01010048	3	123.14	47.71	100.00	60.00	0.00	0.00	0.00	0.00
	020809FC01010049	2	75.24	66.51	75.00	60.00	0.00	38.51	0.00	10.00
	020809FC01010050	3	42.39	28.23	80.00	50.00	0.00	0.00	0.00	0.00
	020809FC01010053	1	29.02	19.33	60.00	40.00	0.00	0.00	0.00	0.00
	020809FC01010053	2	53.19	11.14	60.00	20.00	0.00	100.00	0.00	8.73
	020809FC01010053	3	90.51	15.28	120.00	40.00	0.00	0.00	0.00	0.00
	020809FC01010054	1	68.90	0.00	80.00	0.00	519.56	76.02	120.00	20.00
	020809FC01010054	2	369.48	54.86	160.00	30.00	0.00	0.00	0.00	0.00
	020809FC01010054	3	232.56	160.46	160.00	90.00	0.00	0.00	0.00	0.00
	020809FC01010127	1	105.52	131.45	75.00	70.00	93.55	0.00	25.00	0.00
	020809FC01010127	2	144.37	100.77	100.00	90.00	0.00	0.00	0.00	0.00
	020809FC01010127	3	325.27	14.31	112.27	30.00	0.00	0.00	0.00	0.00
	020809FC01010129	1	199.75	71.13	125.00	60.00	0.00	0.00	0.00	0.00
	020809FC01010129	2	146.27	94.00	100.00	70.00	0.00	0.00	0.00	0.00
	020809FC01010129	3	219.06	72.74	125.00	80.00	0.00	97.90	0.00	20.00
	020809FC01010136	2	123.37	107.16	125.00	18.73	0.00	0.00	0.00	0.00
	020809FC01010136	3	59.67	45.11	50.00	50.00	0.00	0.00	0.00	0.00
	020809FC01010136	4	37.50	47.49	75.00	70.00	0.00	0.00	0.00	0.00
	020809FC01010186	1	110.41	32.95	90.00	50.00	0.00	0.00	0.00	0.00
	020809FC01010186	2	86.56	35.60	90.00	40.00	0.00	0.00	0.00	0.00
	020809FC01010186	3	617.88	3.62	210.00	10.00	0.00	0.00	0.00	0.00

	020809FC01010193	1	38.98	0.00	15.00	0.00	685.70	639.92	102.27	121.88
	020809FC01010193	2	100.68	10.06	30.00	10.00	0.00	200.00	0.00	15.47
	020809FC01010193	3	4.66	3.11	15.00	10.00	0.00	200.00	0.00	11.92
	020809FC01010194	1	22.19	14.54	45.00	30.00	29.84	319.49	15.00	32.61
	020809FC01010194	2	135.47	41.84	75.00	40.00	0.00	100.00	0.00	10.56
	020809FC01010194	3	51.61	11.74	15.00	10.00	221.70	230.75	45.00	34.59
	020809FC01010195	1	185.45	36.79	150.00	40.00	0.00	0.00	0.00	0.00
	020809FC01010195	2	124.85	39.87	100.00	60.00	0.00	0.00	0.00	0.00
	020809FC01010195	3	207.70	15.75	75.00	40.00	433.35	306.26	38.96	36.30
	020809FC01010195	4	186.22	34.28	100.00	50.00	0.00	0.00	0.00	0.00
	020809FC01010195	5	153.00	48.26	75.00	40.00	176.23	65.27	25.00	10.00
	020809FC01010195	6	185.86	143.02	125.00	100.00	0.00	0.00	0.00	0.00
	020809FC01010195	7	122.01	86.66	75.00	90.00	250.00	100.00	12.27	4.28
	020809FC01010213	1	142.77	12.25	125.00	40.00	0.00	0.00	0.00	0.00
	020809FC01010213	2	58.12	33.78	75.00	50.00	0.00	0.00	0.00	0.00
	020809FC01010213	3	99.13	6.33	25.00	20.00	76.90	0.00	75.00	0.00
	020809FC01010214	1	431.22	73.26	100.00	40.00	127.33	49.28	25.00	10.00
	020809FC01010214	2	72.33	92.84	75.00	60.00	88.42	100.00	25.00	3.69
	020809FC01010214	3	63.55	3.75	100.00	10.00	250.00	0.00	14.85	0.00
	020809FC01010218	1	59.77	79.04	80.00	90.00	0.00	0.00	0.00	0.00
	020809FC01010218	2	102.07	280.48	80.00	140.00	0.00	0.00	0.00	0.00
	020809FC01010218	3	128.08	125.83	140.00	130.00	0.00	100.00	0.00	4.91
Long John	020809US08020136	1	63.07	68.44	100.00	90.00	0.00	0.00	0.00	0.00
	020809US08020136	2	72.90	38.38	80.00	40.00	0.00	0.00	0.00	0.00
	020809US08020136	3	276.60	63.80	144.91	80.00	0.00	0.00	0.00	0.00
	020809US08020136	4	64.50	24.87	80.00	40.00	0.00	0.00	0.00	0.00
	020809US08020136	5	197.28	32.97	100.00	60.00	0.00	0.00	0.00	0.00
	020809US08020141	1	151.82	43.17	100.00	60.00	0.00	0.00	0.00	0.00
	020809US08020141	2	131.63	69.84	80.00	60.00	0.00	0.00	0.00	0.00
	020809US08020141	3	43.48	32.21	40.00	40.00	36.67	0.00	20.00	0.00

	020809US08020141	4	138.59	92.65	100.00	80.00	0.00	0.00	0.00	0.00
	020809US08031003	1	88.82	48.72	90.00	60.00	0.00	0.00	0.00	0.00
	020809US08031003	2	215.36	159.01	210.00	120.00	0.00	0.00	0.00	0.00
	020809US08031003	3	110.87	47.98	120.00	70.00	0.00	0.00	0.00	0.00
	020809US08031003	4	234.93	79.71	180.00	70.00	0.00	0.00	0.00	0.00
	020809US08031007	1	225.82	114.02	150.00	70.00	0.00	0.00	0.00	0.00
	020809US08031007	2	44.89	64.79	100.00	80.00	0.00	100.00	0.00	8.73
	020809US08031007	3	404.43	35.11	163.63	50.00	0.00	0.00	0.00	0.00
	020809US08031007	4	220.08	100.35	125.00	40.00	0.00	0.00	0.00	0.00
	020809US08031007	5	257.95	183.69	150.00	120.00	0.00	0.00	0.00	0.00
	020809US08031010	1	367.11	37.46	175.00	50.00	0.00	0.00	0.00	0.00
	020809US08031010	2	101.82	17.54	100.00	30.00	0.00	0.00	0.00	0.00
	020809US08031010	3	39.81	22.40	50.00	30.00	223.19	149.28	33.73	18.73
	020809US08031010	4	685.04	135.65	167.45	34.91	0.00	0.00	0.00	0.00
	020809US08031010	5	252.84	53.49	108.73	50.00	0.00	0.00	0.00	0.00
	020809US08031010	6	287.45	181.02	75.00	70.00	0.00	0.00	0.00	0.00
	020809US08031010	7	286.74	42.27	129.91	60.00	0.00	0.00	0.00	0.00
	020809US08031014	1	835.03	120.18	198.54	60.00	0.00	0.00	0.00	0.00
	020809US08031014	2	583.83	33.06	184.91	40.00	0.00	0.00	0.00	0.00
	020809US08031014	3	157.89	42.29	150.00	50.00	0.00	0.00	0.00	0.00
	020809US08031018	1	61.01	4.97	80.00	10.00	0.00	0.00	0.00	0.00
	020809US08031018	2	767.95	79.81	248.73	50.00	0.00	0.00	0.00	0.00
	020809US08031018	3	442.37	17.67	87.27	30.00	0.00	38.51	0.00	10.00
	020809US08031018	5	170.27	20.21	100.00	40.00	22.04	11.02	20.00	10.00
	020809US08031018	6	20.81	14.84	40.00	30.00	0.00	0.00	0.00	0.00
Phantom Creek 4	020809US08050347	1	159.66	63.18	140.00	80.00	0.00	0.00	0.00	0.00
	020809US08050347	2	32.24	63.01	60.00	50.00	0.00	0.00	0.00	0.00
	020809US08050347	3	127.26	140.82	100.00	100.00	0.00	0.00	0.00	0.00
	020809US08050347	4	46.74	44.28	40.00	50.00	385.62	230.55	44.05	28.73
	020809US08050347	5	124.02	79.27	80.00	50.00	0.00	0.00	0.00	0.00

	020809US08050347	6	106.72	68.12	80.00	80.00	0.00	0.00	0.00	0.00
	020809US08050351	1	125.76	44.18	20.00	50.00	98.55	112.15	20.00	20.00
	020809US08050351	2	61.61	46.34	60.00	60.00	70.74	35.37	20.00	10.00
	020809US08050351	3	390.97	46.40	99.69	50.00	0.00	0.00	0.00	0.00
	020809US08050351	5	70.56	91.12	100.00	80.00	0.00	0.00	0.00	0.00
	020809US08050466	1	376.77	72.21	120.00	80.00	0.00	0.00	0.00	0.00
	020809US08050466	2	154.05	79.64	80.00	50.00	0.00	0.00	0.00	0.00
	020809US08050466	4	337.78	70.08	120.00	50.00	0.00	0.00	0.00	0.00
	020809US08050471	1	112.66	86.43	120.00	90.00	0.00	0.00	0.00	0.00
	020809US08050471	2	49.43	55.64	60.00	40.00	66.97	137.46	20.00	23.69
	020809US08050471	3	29.62	25.74	60.00	50.00	0.00	0.00	0.00	0.00
	020809US08050471	4	93.70	66.07	80.00	60.00	0.00	0.00	0.00	0.00
	020809US08050822	2	158.74	92.46	100.00	70.00	0.00	0.00	0.00	0.00
	020809US08050822	3	566.95	45.66	90.69	40.00	0.00	0.00	0.00	0.00
	020809US08050822	4	410.72	83.31	93.96	50.00	0.00	0.00	0.00	0.00
	020809US08050822	5	153.44	92.75	100.00	70.00	140.99	65.27	20.00	10.00
	020809US08050837	2	265.28	114.47	160.00	90.00	0.00	0.00	0.00	0.00
	020809US08050837	3	166.44	142.35	140.00	120.00	0.00	0.00	0.00	0.00
	020809US08050837	4	284.68	112.58	180.00	90.00	0.00	0.00	0.00	0.00

Appendix D. Pre-treatment plot-level summary data (basal areas and trees per acre, >2.5 inches DBH) for projects in the Arapaho-Roosevelt forest in 2013.

Project	Stand	Plot	Conifer TPA	Conifer BA	Aspen TPA	Aspen BA
Boulder Heights	021001SV06020156	4	86.80	160.00	0.00	0.00
	021001SV06020161	2	17.89	40.00	0.00	0.00
	021001SV06020161	3	33.57	80.00	0.00	0.00
	021001SV06020161	5	53.12	120.00	0.00	0.00
	021001SV06060127	2	5.79	20.00	0.00	0.00
	021001SV06060128	1	36.27	100.00	0.00	0.00
	021001SV06060133	1	78.68	140.00	0.00	0.00
	021001SV06060134	13	196.39	93.36	0.00	0.00
	021001SV06060134	14	227.57	87.47	0.00	0.00
	021001SV06060134	15	297.45	52.90	0.00	0.00
	021001SV06060134	16	72.42	60.00	18.34	20.00
	021001SV06060135	3	16.26	40.00	0.00	0.00
	021001SV06060135	4	18.25	40.00	0.00	0.00
	021001SV06060137	5	41.48	100.00	0.00	0.00
	021001SV06060137	6	34.54	100.00	0.00	0.00
	021001SV06060140	7	20.11	40.00	0.00	0.00
Forsythe	021001SV08040030	87	235.47	130.00	0.00	0.00
	021001SV08040030	91	248.50	110.00	50.93	10.00
	021001SV08040030	100	514.46	80.37	0.00	0.00
	021001SV08040032	70	340.64	120.00	0.00	0.00
	021001SV08040032	71	87.74	70.00	0.00	0.00
	021001SV08040032	83	145.05	60.00	0.00	0.00
	021001SV08040040	41	1328.62	212.94	0.00	0.00
	021001SV08040040	45	960.84	243.61	0.00	0.00
	021001SV08040040	48	225.60	100.00	0.00	0.00
	021001SV08040040	50	800.83	185.02	0.00	0.00
	021001SV08040040	61	638.25	176.68	53.28	20.00
	021001SV08040040	62	639.13	81.13	0.00	0.00
	021001SV08040041	44	114.65	60.00	0.00	0.00
	021001SV08040041	49	426.82	103.41	293.36	3.41
	021001SV08040041	57	36.01	30.00	0.00	0.00
	021001SV08040041	65	155.59	80.00	0.00	0.00
	021001SV08040041	67	212.19	100.00	0.00	0.00
	021001SV08040041	74	131.94	80.00	443.04	10.09
	021001SV08040041	75	692.45	113.03	0.00	0.00
	021001SV08040041	84	519.65	160.00	0.00	0.00
	021001SV08040041	89	276.67	78.38	0.00	0.00

	021001SV08040045	72	637.52	50.93	0.00	0.00
	021001SV08040045	73	317.56	33.41	646.76	79.49
	021001SV08040045	79	107.83	21.04	0.00	0.00
	021001SV08040045	88	716.24	51.13	443.04	53.86
	021001SV08040049	93	5.99	10.00	216.82	41.04
	021001SV08040050	60	383.91	24.68	443.04	27.13
	021001SV08040050	68	646.76	21.82	0.00	0.00
	021001SV08040051	53	371.34	54.15	0.00	0.00
	021001SV08040051	63	72.30	70.00	0.00	0.00
	021001SV08040051	66	149.99	90.00	533.58	21.13
	021001SV08040056	34	16.63	10.00	0.00	0.00
	021001SV08040056	42	65.75	20.00	293.36	6.82
	021001SV08040056	46	93.56	40.00	443.04	10.09
	021001SV08040056	54	409.69	83.41	293.36	6.82
	021001SV08040058	25	542.64	128.30	0.00	0.00
	021001SV08040058	26	352.94	120.00	0.00	0.00
	021001SV08040060	28	102.30	60.00	0.00	0.00
	021001SV08040065	27	397.85	73.41	0.00	0.00
	021001SV08040065	29	60.32	70.00	293.36	3.41
	021001SV08040065	35	24.81	20.00	0.00	0.00
	021001SV08080052	11	216.98	120.00	0.00	0.00
	021001SV08080052	12	611.54	143.41	0.00	0.00
	021001SV08080052	13	1032.36	197.06	0.00	0.00
	021001SV08080052	14	845.90	144.22	56.43	10.00
	021001SV08080060	1	112.20	31.04	0.00	0.00
	021001SV08080060	2	69.68	50.00	0.00	0.00
	021001SV08080060	3	401.50	93.41	0.00	0.00
	021001SV08080060	6	502.10	97.73	0.00	0.00
	021001SV08080060	8	369.55	116.68	443.04	16.91
	021001SV08080067	4	18.19	20.00	592.71	23.45
	021001SV08080067	5	5.66	10.00	0.00	0.00
	021001SV08080067	7	16.99	20.00	149.67	6.68
	021001SV10140035	101	305.84	90.00	0.00	0.00
	021001SV10140035	102	200.70	63.10	0.00	0.00
	021001SV10140035	104	402.62	110.56	383.91	14.45
	021001SV10140037	96	99.32	40.00	0.00	0.00
	021001SV10140037	97	760.74	122.76	0.00	0.00
	021001SV10140045	56	1208.06	152.18	0.00	0.00
	021001SV10140045	59	132.06	50.00	0.00	0.00
	021001SV10140045	64	112.40	40.00	0.00	0.00
	021001SV10140045	69	154.43	100.00	0.00	0.00

	021001SV10140045	77	246.79	110.00	0.00	0.00
	021001SV10140049	78	377.39	80.00	451.97	13.12
	021001SV10140049	81	205.31	100.00	0.00	0.00
	021001SV10140049	82	828.09	149.56	0.00	0.00
	021001SV10140051	86	343.23	52.05	0.00	0.00
	021001SV10140051	98	399.09	90.08	293.36	3.41
	021001SV10140051	99	870.74	125.77	0.00	0.00
	021001SV10140073	47	83.70	60.00	0.00	0.00
	021001SV10140073	52	36.77	20.00	0.00	0.00
	021001SV10140073	55	10.11	20.00	458.00	50.04
	021001SV10140074	51	836.47	42.81	293.36	17.04
	021001SV10140077	39	142.96	80.00	0.00	0.00
	021001SV10140078	36	324.93	100.00	0.00	0.00
	021001SV10140078	37	594.37	93.41	0.00	0.00
	021001SV10140078	40	122.18	50.00	0.00	0.00
	021001SV10140079	24	726.70	124.03	0.00	0.00
	021001SV10140079	30	487.76	42.13	0.00	0.00
	021001SV10140079	31	519.86	210.00	0.00	0.00
	021001SV10140079	33	1117.98	153.09	0.00	0.00
	021001SV10140079	38	125.20	60.00	293.36	3.41
	021001SV10140080	21	91.96	90.00	0.00	0.00
	021001SV10140080	22	222.84	67.88	0.00	0.00
	021001SV10140190	107	123.20	70.00	383.54	10.96
	021001SV10140190	119	592.71	23.45	0.00	0.00
	021001SV10140190	121	311.93	34.91	293.36	3.41
	021001SV10140190	122	439.96	96.31	0.00	0.00
	021001SV10140198	130	910.97	197.50	0.00	0.00
	021001SV10140198	131	793.15	153.41	0.00	0.00
	021001SV10140201	125	807.27	140.09	293.36	3.41
	021001SV10140201	128	1031.04	127.07	0.00	0.00
	021001SV10140202	123	130.48	50.00	0.00	0.00
	021001SV10140202	126	137.36	90.00	0.00	0.00
	021001SV10140204	129	350.08	23.41	0.00	0.00
	021001SV10140204	132	414.37	83.41	0.00	0.00
	021001SV10140204	133	1188.60	97.47	0.00	0.00
	021001SV10140319	176	245.58	70.00	0.00	0.00
	021001SV10140319	177	720.67	127.48	293.36	3.41
	021001SV10140356	148	269.14	42.59	0.00	0.00
	021001SV10140357	146	608.45	91.92	0.00	0.00
	021001SV10140357	152	698.39	71.70	0.00	0.00
	021001SV10140357	154	416.62	63.41	0.00	0.00

	021001SV10140363	135	4.54	10.00	0.00	0.00
	021001SV10140363	136	32.97	20.00	0.00	0.00
	021001SV10140363	142	115.41	60.00	0.00	0.00
	021001SV10140367	138	30.89	20.00	0.00	0.00
	021001SV10140367	139	16.95	10.00	0.00	0.00
	021001SV10140367	143	15.15	10.00	0.00	0.00
	021001SV10140368	140	473.41	94.45	0.00	0.00
	021001SV10140368	147	18.71	10.00	0.00	0.00
	021001SV10140369	144	218.02	4.59	0.00	0.00
	021001SV10140372	134	27.48	40.00	0.00	0.00
	021001SV10140372	137	335.84	33.41	0.00	0.00
	021001SV10140375	108	65.76	90.00	0.00	0.00
	021001SV10140375	109	11.46	20.00	0.00	0.00
	021001SV10140377	110	221.93	90.00	0.00	0.00
	021001SV10140377	113	144.74	60.00	544.87	10.79
	021001SV10140377	114	75.13	60.00	0.00	0.00
	021001SV10140377	115	455.11	61.27	0.00	0.00
	021001SV10140390	105	427.29	14.28	0.00	0.00
	021001SV10140390	106	201.96	63.36	0.00	0.00
	021001SV10140390	111	18.02	20.00	0.00	0.00
	021001SV10140390	112	16.32	10.00	611.40	22.71
	021001SV10140390	116	54.53	30.00	120.55	8.30
	021001SV10140390	117	247.49	14.28	70.49	10.00
	021001SV10140390	118	718.71	49.77	0.00	0.00
	021001SV10140390	120	771.89	48.91	0.00	0.00
	021001SV10140390	124	11.19	10.00	0.00	0.00
	021001SV10140390	127	40.29	20.00	0.00	0.00
	021001SV10140422	15	94.60	50.00	293.36	3.41
	021001SV10140422	16	67.09	40.00	0.00	0.00
	021001SV10140422	17	121.56	60.00	0.00	0.00
	021001SV10140422	18	368.84	43.41	0.00	0.00
	021001SV10140422	19	46.20	10.00	293.36	3.41
	021001SV10140422	20	1283.89	103.11	0.00	0.00
	021001SV10140423	9	268.99	89.17	43.40	10.00
	021001SV10140423	10	193.53	140.00	293.36	3.41
	021001SV10140449	141	122.49	90.00	0.00	0.00
	021001SV10140449	145	234.95	70.00	0.00	0.00
	021001SV10140458	155	405.40	96.68	0.00	0.00
	021001SV10140458	156	715.71	82.18	0.00	0.00
	021001SV10140458	157	897.06	64.68	0.00	0.00
	021001SV10140459	158	216.30	46.68	0.00	0.00

	021001SV10140459	159	138.83	40.00	0.00	0.00
	021001SV10140459	160	10.06	10.00	0.00	0.00
	021001SV10140459	161	200.37	47.47	0.00	0.00
	021001SV10140459	162	38.19	30.00	0.00	0.00
	021001SV10140459	163	753.86	78.55	0.00	0.00
	021001SV10140459	164	197.13	76.68	0.00	0.00
	021001SV10140459	165	310.90	150.00	0.00	0.00
	021001SV10140459	166	599.70	86.82	0.00	0.00
	021001SV10140459	167	25.38	10.00	0.00	0.00
	021001SV10140670	76	96.90	60.00	0.00	0.00
	021001SV10140670	80	388.71	140.00	0.00	0.00
	021001SV10140670	85	374.20	200.00	0.00	0.00
	021001SV10140921	168	563.40	60.48	0.00	0.00
	021001SV10140921	170	349.55	137.47	0.00	0.00
	021001SV10140921	171	97.32	40.00	0.00	0.00
	021001SV10140932	172	555.57	116.29	0.00	0.00
	021001SV10140932	173	506.62	83.41	0.00	0.00
	021001SV10140933	174	765.96	133.41	0.00	0.00
	021001SV10140933	175	714.85	114.45	0.00	0.00
	021001SV10141013	169	652.77	146.31	0.00	0.00
Gold Hill	021001SV08060193	1	410.80	44.45	0.00	0.00
	021001SV08060193	2	399.81	146.31	293.36	3.41
	021001SV08060193	5	114.06	70.00	0.00	0.00
	021001SV08060209	8	104.03	70.00	0.00	0.00
	021001SV08060211	3	401.26	110.00	0.00	0.00
	021001SV08060211	4	254.07	70.00	0.00	0.00
	021001SV08060211	6	216.88	100.00	0.00	0.00
	021001SV08060211	7	445.14	85.41	0.00	0.00
	021001SV08060213	9	43.35	20.00	0.00	0.00
	021001SV08060213	10	57.66	30.00	0.00	0.00

Appendix E. Landscape Restoration team judgment regarding desired trends based on review of data during the monitoring review session, April 22, 2014.

Monitoring Metric	**Desired Trend – Question**	**LR Team Judgment**
Tree density	Are we decreasing basal area and trees per acre?	Yes
Tree sizes	Are we increasing quadratic mean tree diameters?	Yes
Tree ages	Are we increasing the ratio of old trees (>200 years old) to transitional and young trees?	Don't know – information not available
Stand-scale spatial heterogeneity	Are we increasing the number of tree clumps and openings?	Don't know – information not available across projects, though a means of assessment has been developed and recently implemented by the spatial heterogeneity subteam.
Tree species	Are we increasing the ratio of ponderosa pine to other conifers?	Inconclusive – difficult to measure directly because in some cases conifer species beyond ponderosa pine are not very abundant and thus ponderosa represents the majority of removals, with no measurable change in species ratios. This metric should be reevaluated and perhaps replaced with a different measure of species composition.
Surface fuels	Are we decreasing litter, duff, and coarse woody debris?	No. Overall surface fuels have increased as a result of treatments redistributing material from the canopy to the forest floor. Use of prescribed fire after mechanical treatments would help with surface fuel reductions.
Fire behavior	Are we reducing crown fire potential at 90% weather conditions?	Yes. Crowning indices have increased as a result of treatments, meaning that greater wind speeds are necessary to sustain an active crown fire after treatment.
Understory vegetation	Are we increasing grass, forb, and shrub cover?	Don't know – information not available, though a means of assessment is being developed by the understory monitoring subteam.
Wildlife	Are we increasing the occurrence of wildlife species expected in a restored landscape?	Don't know – information not available, though a means of assessment has been developed and implemented by the wildlife subteam during the 2014 field season.

Suggested citation:
Addington, R., Pelz, K., and T. Cheng. 2014. Colorado Front Range Collaborative Forest Landscape Restoration Project: Ecological Monitoring of Treatment Effects on Stand Structure and Fuels through 2013. Colorado Forest Restoration Institute, Colorado State University, Monitoring Report, CFRI-MR-1401. Fort Collins, CO. 32 p.

About the Colorado Forest Restoration Institute
The Colorado Forest Restoration Institute (CFRI) was established in 2005 as an application-oriented program of the Department of Forest & Rangeland Stewardship in the Warner College of Natural Resources at Colorado State University. CFRI's purpose is to develop, synthesize, and apply locally-relevant science-based knowledge to achieve forest restoration and wildfire hazard reduction goals in Colorado and the Interior West. We do this through collaborative partnerships involving researchers, forest land managers, interested and affected stakeholders, and communities. Authorized by Congress through the Southwest Forest Health and Wildfire Prevention Act of 2004, CFRI is one of three Institutes comprising the Southwest Ecological Restoration Institutes, along with centers at Northern Arizona University and New Mexico Highlands University.

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