Interim Monitoring Report For Peaks To People Water Fund Demonstration Sites

Big Thompson Watershed Demonstration Site: Ramsay Shockey

Cache la Poudre Watershed Demonstration Site: Ben Delatour Scout Ranch

Prepared by Peaks to People Science Team

June 13th, 2018

Contributing Authors:
Colorado Forest Restoration Institute
Brett Wolk, Kat Morici, Jeff Cannon, Ben Gannon.
The Nature Conservancy
Rob Addington.

EXECUTIVE SUMMARY

Central to the Peaks to People Water Fund is the establishment of on-the-ground projects that can be used to demonstrate the benefits of forest management in moderating wildfire behavior and protecting water resources from negative impacts associated with postfire soil erosion and sedimentation. Peaks to People selected one site in each of its focus watersheds, Ramsay Shockey in the Big Thompson watershed, and the Ben Delatour Scout Ranch (Scout Ranch) in the Cache la Poudre watershed, to demonstrate concepts of forest restoration and watershed protection. Forest restoration, consisting of mechanical tree harvesting, commenced during summer 2016 and nearly 100 acres of tree cutting was completed in spring 2017. In the fall of 2017, a broadcast prescribed burn was accomplished across 150 acres at the Scout Ranch to reintroduce fire to the landscape and further reduce risk of high intensity wildfires.

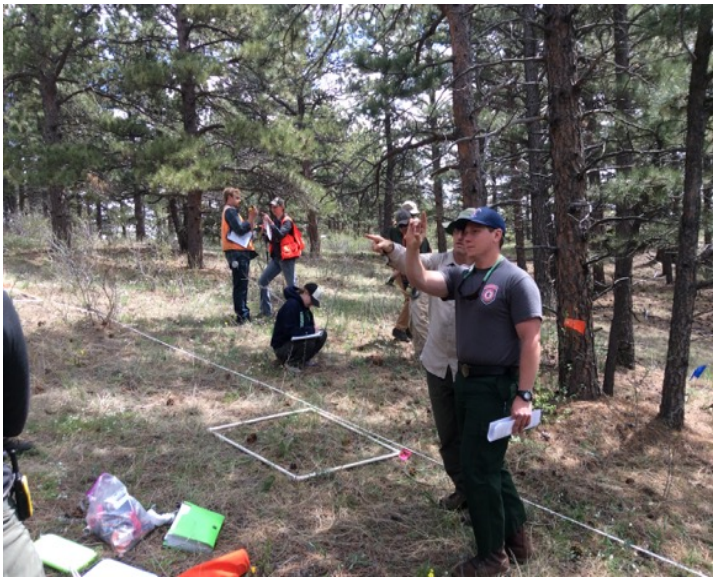
Throughout the process, the Colorado Forest Restoration Institute at Colorado State University, working closely with the Colorado Chapter of The Nature Conservancy and other partners led an effectiveness monitoring program to assess to what degree the projects achieved the project-level desired conditions and the Peaks to People program management goals. High elevation conifer forests in Colorado naturally burn intensely with high severity effects, but lower elevation ponderosa pine forests were historically more resilient to low and mixed severity fires. Forest restoration goals aim to re-create and maintain long-term low-density forest structural conditions that support characteristic low to mixed-severity fire, and create and maintain conditions that support resilience and resistance to wildfire, insect and disease, and changing climate by managing for openings and complex forest structure. Peaks to People aims to improve outcomes when a fire does occur so that not all trees are killed, soils are protected, post fire erosion is minimized, and the ecosystem services we value from our forests are not degraded.

Before and after photos from Ramsay Shockey Unit B.

Project monitoring and evaluation of wildfire and forest health incorporates a wholistic, multi scale approach, including on-the-ground plot-based measures of forest structure and fuel loading before and after management, remote sensing techniques to quantify changes in forest cover and distribution at a project scale, and a model-based approach using the Watershed Investment Tool to measure cumulative benefits towards reducing high severity fire and improving source water security across the landscape. Importantly, peer to peer learning and collaboration are explicit goals of the monitoring program to enhance learning and deliver information to the forestry and fire managers who can use it on a daily basis to improve project outcomes.

Fire behavior modeling results using plot-based data suggest that mechanical forest management moved both sites closer to the desired conditions and is likely to enhance forest resilience to wildfire within the management units. The likelihood of high severity crown fire at Ramsay Shockey was relatively high before forest treatments, with roughly half of the area susceptible to crown fire under severe weather conditions. While tree density remains higher than desired in some areas, restoration treatments substantially reduced fire hazard across the site to a more characteristic low to mixed severity fire regime dominated by surface fire with some passive crown fire, even under severe fire weather conditions. The Scout Ranch showed only a slight potential for high severity crown fire before mechanical treatment, and the forest restoration activities further reduced tree density and modeled fire behavior to be more aligned with resilient forest structures found in historical reference conditions. At Ramsay Shockey, we found that the forest restoration treatment decreased tree canopy cover (44% to 35%) and increased coverage of large gaps from 23% to 37%. Gap size distributions show that Ramsay Shockey restoration treatments generally shifted gap cover from being primarily dominated by many small gaps (≤ 2.2 acres) to larger gaps (> 2.2 ac). Restoration treatments decreased overall tree density, and increased the size, size variability, and aggregation of gaps towards the more complex desired forest structure. Canopy cover and gap analysis, as well as fire effects monitoring on the prescribed broadcast burn, is ongoing for the Scout Ranch.

Peaks to People stakeholders participated in plot-based data collection as part of the monitoring process and provided invaluable insights into the application of monitoring data. In turn, fire and forestry professionals learned measurement techniques that helped them improve outcomes on other projects, expanding the impact of the demonstration sites. Participants from over 10 agencies collaborated and assisted Colorado Forest Restoration Institute in the data collection, including several local and state firefighting agencies, the Colorado State Forest Service, Larimer County Open Space, The Nature Conservancy, Coalition for the Poudre River Watershed, and student interns from Redlands College and the Colorado Natural Heritage Program.



Colorado Forest Restoration Institute Assistant Director Brett Wolk assists a Colorado Division of Fire Prevention and Control firefighter with monitoring measurements at Ramsay Shockey.

Overall, the modeled fire behavior suggests forest management changed conditions to a more characteristic low to mixed severity fire regime at both demonstration sites, enhancing forest resilience to wildfire within the management areas. While tree density remained high in some areas of the Ramsay Shockey site, decreased forest cover and increased frequency of larger gaps in the tree canopy are indicators of improved forest health and resilience to disturbances towards the desired conditions beyond fuels reduction.

INTRODUCTION

The Peaks to People Water Fund is working to improve watershed health and protect water resources on the northern Front Range through well-designed forest management targeting areas of highest wildfire risk and impact to water resources. Forest management activities under Peaks to People are focused on changing forest structure and fuel loads in ways that reduce the potential for active crown fire and high-severity fire effects over broad scales. Where possible, additional ecological and social values will be incorporated, such as protection of infrastructure within the wildland urban interface and habitat enhancement for wildlife.

Central to the Peaks to People Water Fund is the establishment of on-the-ground projects that can be used to demonstrate the benefits of forest management in moderating wildfire behavior and protecting water resources from negative impacts associated with postfire soil erosion and sedimentation. During winter 2016, Peaks to People carried out a site selection process (Peaks to People 2016a) which resulted in the development and implementation of forest management actions at demonstration sites in the two Peaks to People focus watersheds:

- Big Thompson Watershed: Ramsay Shockey
- Cache la Poudre Watershed: Ben Delatour Scout Ranch

Mechanical forest management at each demonstration site then commenced during summer 2016 and was completed at both sites in spring 2017. Throughout the process, the Colorado Forest Restoration Institute (CFRI) at Colorado State University (CSU), working closely with the Colorado Chapter of The Nature Conservancy (TNC) and other partners has led an effectiveness monitoring program to assess to what degree the projects achieved the management goals and stated desired conditions. Importantly, the monitoring program aims not to pass judgment on good vs bad, but rather provides information to support adaptive management so forestry practices can be improved through peer learning by providing metrics that communicate outcomes of forest management beyond counting acres treated.

Management Goals and Desired Conditions

Following selection of the demonstration sites, forest management plans and prescriptions were developed to describe management goals, desired conditions, and guidelines for implementation (Peaks to People Water Fund 2016b, 2016c). Forest management goals for Ramsay Shockey and Ben Delatour Scout Ranch (hereafter Scout Ranch) were to create open, low-density ponderosa pine stands characteristic of historical conditions, that are not at risk of high-severity wildfire, and are resilient to future disturbance. Specific management goals for Ramsay Shockey and Scout Ranch projects included:

· *Wildfire* – create and maintain long-term forest structural conditions that support characteristic low to mixed-severity fire;
· *Forest Health* – create and maintain conditions that support resilience and resistance to insect and disease by managing for openings and complex forest structure;

Both the Scout Ranch and Ramsay Shockey projects aimed to achieve diverse management goals in addition to wildfire and forest health, including improved conditions for hydrologic function, wildlife habitat, aesthetics and recreational opportunities, supporting forest products industry, and value for Peaks to People demonstration and outreach

activities. While monitoring has so far focused on wildfire and forest health, it's important to note these broader project goals informed the site selection and influenced forest management prescriptions.

Demonstration Project Descriptions

Ramsay Shockey

The project is located in the Big Thompson Watershed on the Ramsay-Shockey Open Space and adjacent State Land Board land off CR 18E approximately 18 miles west of Loveland, Colorado. Both properties are located upslope of Pinewood Reservoir, an important water resource managed by Northern Water as part of the Colorado-Big Thompson Project.

The project area covers approximately 70 acres across both the Open Space and State Land Board properties and is divided into three management units (Figure 1). Unit A is located on the Ramsay-Shockey Open Space and comprises 11 acres. Unit B (22 acres) and Unit C (35 acres) are located on State Land Board property. The project area was divided into these three units based primarily on the difference in ownership, as well as residual woody biomass management plans for handling branches, small trees, and other woody material not being removed from the site otherwise known as "slash". Units A and B are designated for piling and burning of slash, whereas slash was lopped and scattered throughout Unit C. The forest management was implemented by Larimer County Emergency Services by hand falling trees using chainsaws, and manually distributing slash according to the management plan for each unit. Beyond slash management, the treatment methods and objectives for overstory structure and composition were the same across units as described in the management goals above. More detailed information is available in Peaks to People (2016c).

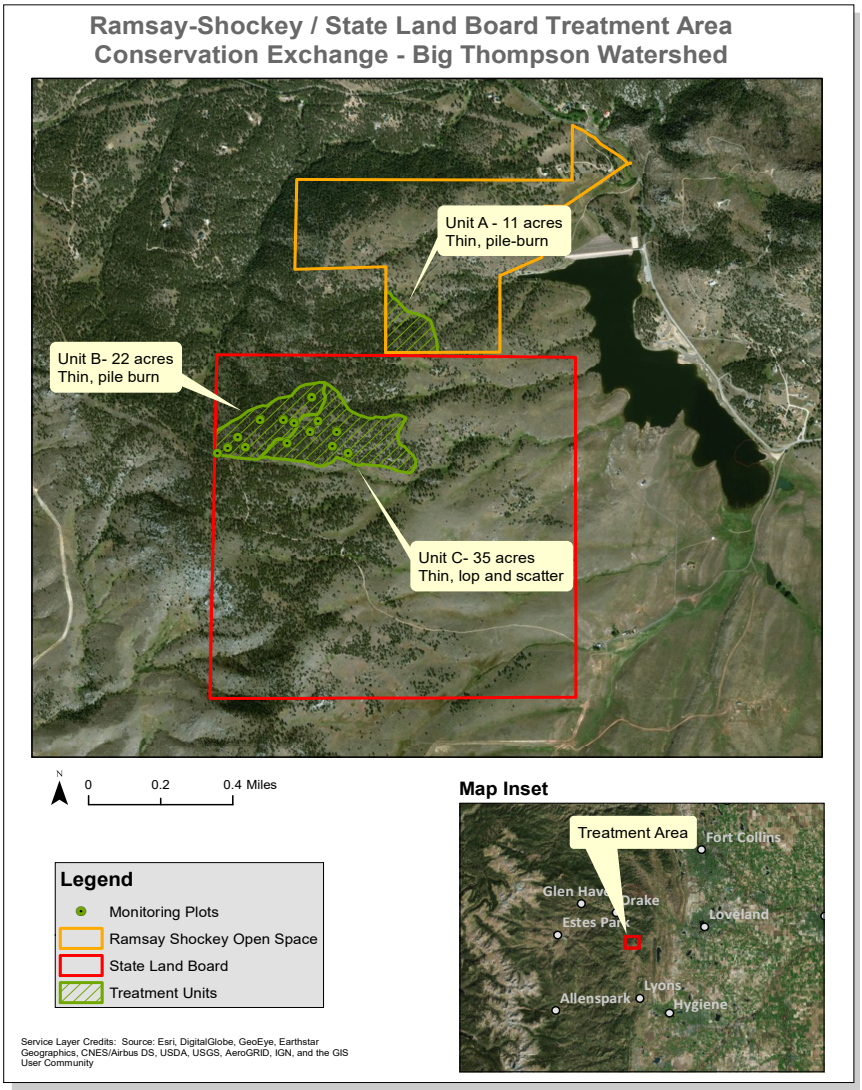


Figure1. Location of Ramsay Shockey and monitoring plots.

Scout Ranch

The Scout Ranch is located within the Elkhorn Creek sub-watershed of the Cache la Poudre Watershed off Red Feather Lakes Rd and Rd 68C approximately 40 miles west of Fort Collins, Colorado. The Scout Ranch represents a significant private land holding (~3200 acres) within a landscape otherwise consisting mostly of public land managed by the U.S. Forest Service. The property sits on Elkhorn Creek, an important tributary to the main stem of the Cache la Poudre River.

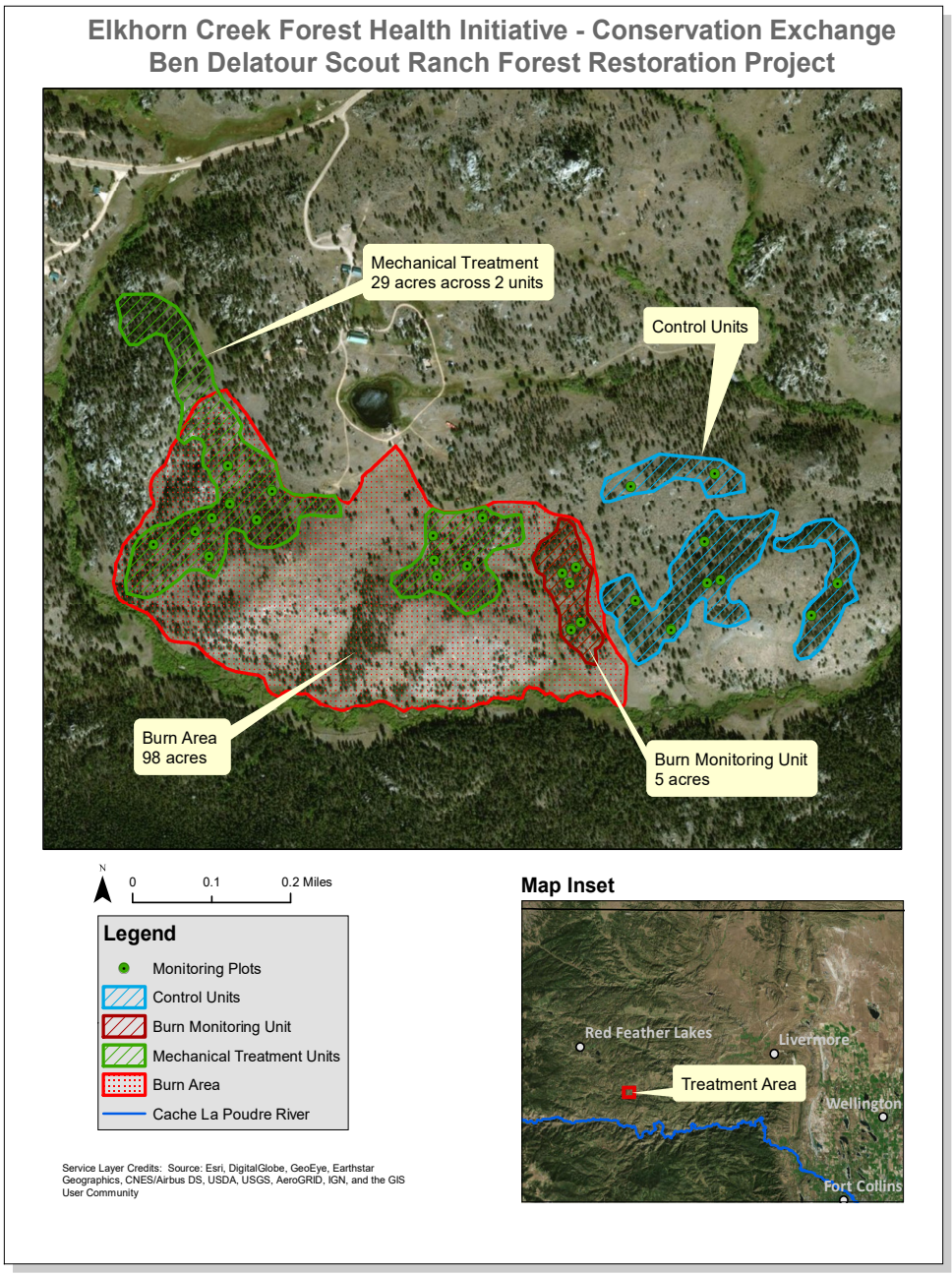


Figure 2. Location of the Scout Ranch site and monitoring plots.

The project area covers approximately 185 acres on the southern end of the property and is adjacent to an existing 85 acre treatment area. Mechanical forest management occurred on approximately 29 acres in areas where forest density and hazardous fuels are highest within the larger project area (Figure 2). The subsequent prescribed broadcast burn was completed across a larger area of 98 acres that encompassed the mechanically harvested forest areas. The mechanical forest management activities were implemented by Morgan Timber Products using heavy machinery including feller bunchers and processers. All material was skidded to landings, where biomass was process and sorted. Slash was piled by machines at the landings for later

burning. The approach for achieving forest structure and composition goals was similar to Ramsay Shockey as described in the management goals above.

Monitoring and Evaluation

Projects funded by the Peaks to People Water Fund follow a process of planning, implementation, and project evaluation as outlined in the Peaks to People Operations Plan (Section 2 Participation in the Water Fund). Following the development of project goals and desired conditions, the project evaluation phase applies monitoring criteria that can be used to assess project performance and whether management goals and objectives were met. Project evaluation of wildfire and forest health attributes incorporates a wholistic, multi scale approach, including three methods:

1. On-the-ground, plot-based measures of forest structure, species composition, and fuel loading.
2. Remote sensing techniques to quantify forest cover and distribution at a project scale.
3. A model-based approach using the Watershed Investment Tool to measure cumulative benefits towards reducing high severity fire and improving source water security across the landscape.

MONITORING METHODS

Plot-Based Approach

For the plot-based monitoring approach, fuel loading and forest structure and composition were measured before and after forest management using standardized monitoring protocols developed by CFRI to evaluate changes in fire behavior and forest dynamics. Measurements included tree density and species composition, forest canopy cover, tree height and canopy base height, shrub and herbaceous vegetation cover and species composition, and surface fuel loads. CFRI applied two complimentary sampling protocols at the Peaks to People demonstration sites, the Simple Plot and Mothership Plot methods. Simple Plot methods are intended to quantify fuel loading, forest structure and composition, describe the dominant shrub and herbaceous vegetation at the site, and require minimal botanical knowledge to complete. Mothership Plot methods are designed to capture comparable metrics of fuel loading and forest structure and composition, with more robust measures of vegetation cover, species composition, and plant diversity where more intensive monitoring is desired. More details on specific measurement protocols are available on the CFRI website (Wolk et al 2018a, 2018b).

At the Ramsay Shockey site, 17 plots were measured using the Simple Plot sampling protocol once pre-treatment in late May to early July 2016, and once post mechanical treatment during the last week in August through early September 2017. Plots were randomly located within Units B and C, and no plots were measured in Unit A. At the Scout Ranch, the more intensive CFRI Mothership Plot sampling protocol was used for the majority of plots established, in addition to 5 plots measured using the Simple Plot methods to augment sample intensity. To capture the range of treatment types applied, plots were installed across three treatment types and placed randomly within each unit. Management types measured included thinned units scheduled for prescribed broadcast burning (THIN BURN), forested areas not thinned but scheduled for broadcast burning (BURN ONLY), and adjacent unburned unthinned

control (CONTROL). Plots were measured in late July 2016 before mechanical fuel reduction activities began, and during late June and July 2017 post mechanical treatment. Following the prescribed broadcast burn implemented by The Nature Conservancy and partners on September 22, 2017, fire effects were measured on all plots from October 24th through November 6th, 2017, to quantify fire intensity and burn severity. Fire effects monitoring methods include measures of tree scorch and consumption, soil burn severity, and fine woody fuel loading. Additional monitoring is planned for summer 2018 at the Scout Ranch to quantify changes over time and the impacts of combined mechanical harvest and prescribed fire on fuel loading, forest structure, and plant species composition. Analysis of fire effects will be completed in the fall of 2018.

Fire Behavior Analysis

Plot-based data were used to examine fuel treatment effectiveness through fire simulations in pre-treatment and post-treatment stands using the Fuels and Fire Extension (FFE) of the Forest Vegetation Simulator (FVS) (Reinhardt and Crookston 2003). Tree basal area and trees per acre were calculated in FVS and included all trees taller than 4.5 feet. Plot-based measures of fuel loading and arrangement for trees and dead woody fuels were processed by FVS to select up to two of the standard 53 fire behavior fuel models (Anderson 1982; Scott and Burgan 2005) for each plot, which were used to model potential fire behavior. Fire simulations were run under both moderate and severe fire conditions, with severe fire weather and fuel moisture settings being similar to red flag warning extreme fire conditions (e.g. 97th percentile) across forested lands in Colorado (Table 1). Outputs include simulated fire behavior and fire effects, such as fire type, surface flame length, total flame length, and tree mortality. Model results for pre-treatment and post-treatment plots were compared to estimate changes in fire hazard for a stand.

Table 1. Weather and fuel moisture values used for fire behavior analysis with FVS-FFE.

Fire Conditions	WIND (MPH)	TEMP (F)	Fuel Moisture Conditions (%)						
			0-0.25"	0.25-1"	1-3"	3"+	DUFF	LIVE WOODY	LIVE HERB
SEVERE	20	70	4	4	5	10	15	70	3
MODERATE	6	70	8	10	12	16	125	120	120

Forest Cover and Distribution

To quantify management goals of creating large gaps and increasing forest complexity to enhance forest health, we measured changes in canopy cover and gap structure through supervised classification of pre- and post-treatment imagery into tree canopy and openings using protocols in Cannon et al. (2018). We acquired leaf-on, snow-free pre- and post-treatment satellite imagery for the Ramsay Shockey site from WorldView-02 satellite on September 2015 and April 2017, respectively (Figure 3A). Imagery adequate for classification from the Scout Ranch is not currently available, thus only the Ramsay Shockey site was analyzed. We resampled satellite imagery to a 3 meter resolution for consistency across monitoring projects,

and we derived additional metrics to aid in classification including the normalized difference vegetation index (NDVI), simple ratio, and red to green ratio (Lillesand et al., 2015). To classify imagery, an analyst stratified approximately 100 training areas in each image and used supervised maximum likelihood classification to classify the image into canopy, openings, and shadows. Next, NDVI values of regions classified as shadows were re-classified into canopy and openings using a grey-level threshold estimated as the local minimum frequency NDVI-value among shadow areas (Figure 3B). To test the accuracy of the maximum likelihood classification, we used 5-fold cross verification of imagery using training areas as inputs (Congalton and Green 2009). We delineated "large gaps" as all continuous regions with <5% canopy cover over an area of 0.11 ac (40 ft radius; Figure 3C). Although "large gaps" can be defined variously depending on the ecological process of interest, this scale was chosen because resource abundance and growth of regenerating seedlings are predictable in neighborhoods of approximately 40 ft radius in size (Boyden et al 2012). From the resulting canopy, opening, and large gap data, we estimated pre- and post-treatment averages for canopy cover and cover of large gaps. Using individually identified gaps, we also calculated gap size distributions, and assessed gap size variability using the coefficient of variation (standard deviation/mean) of gap size. Finally, we calculated gap decay coefficient (adapted from stand-replacing decay coefficient Collins et al. 2017), which is related to proportion of area concentrated within gap interiors. Since implementation only differed in slash disposal and the forest structure management goals were the same across all areas at Ramsay Shockey, forest cover and distribution analysis was measured across all three management areas (Units A, B, C) and not broken out into individual treatment units. By performing forest cover and distribution analysis across larger areas, we are able to make a more representative assessment of large gaps and average forest cover across the entire area.

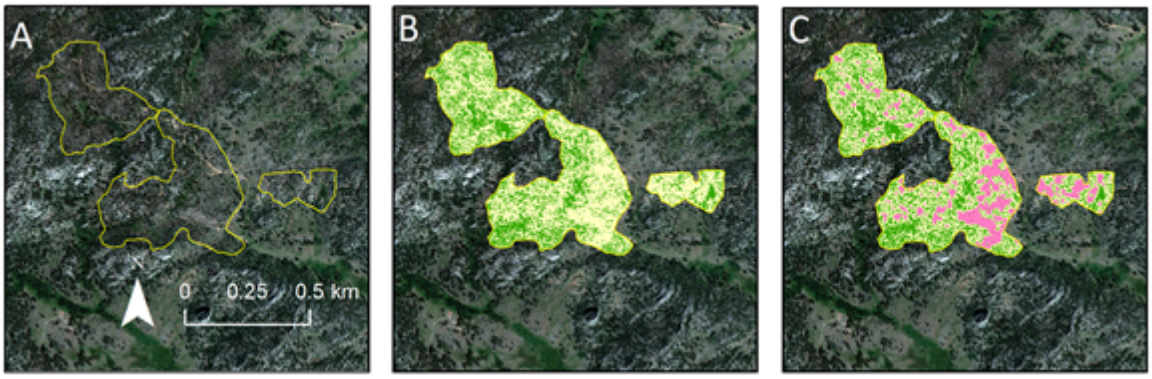


Figure 3. Example restoration treatment in the Arapaho Roosevelt National Forest illustrating satellite imagery classification process. (A) Example satellite imagery. (B) Classified imagery indicating canopy (green) and openings (yellow). (C) Demonstration of gap delineation (magenta) overlaid onto classified imagery indicating portions of imagery with <5% canopy cover over a 0.11 ac area (40 ft. radius).

RESULTS AND DISCUSSION

Tree Density and Potential Fire Behavior

Tree density was reduced across all management units as measured by trees per acre (Table 2). Ramsay Shockey Unit B and Scout Ranch tree basal area was reduced by approximately half, and trees per acre was reduced by greater than 50% at all sites because

many smaller trees were removed as prescribed in the treatment plans. Ramsay Shockey Unit C, however, remained well above the management goal with high residual basal area and tree density following the restoration treatment. Compared to historical reference conditions that were cited as desired resilient forest structures, and which informed treatment prescription development, Ramsay Shockey Unit B is within the historical range of variation, while Unit C remains outside of the management goals and at the high end of the historical range of variation for basal area and forest densities at similar sites for the northern Colorado Front Range. This could be the result of removing only small trees, or not removing enough trees within the stand to achieve the desired conditions. Additionally, some tree harvesting had already begun in the eastern portion of Unit C when monitoring was initiated, resulting in monitoring plots being concentrated in the western two thirds of the unit. Remote sensing canopy cover analysis across the entire unit indicates several large gaps and lower tree cover in the eastern portion of Unit C, and we suspect that the actual basal area and tree density across the entire unit is slightly lower than measured with our field plots. However, plot-based data is generally well distributed across much of the unit and indicates residual tree density remains high across Unit C following restoration treatments.

The Scout Ranch started with the lowest basal area and tree density of any of the management units, and it exhibited low potential for high severity fire before treatment. Forest management further reduced tree density and modeled fire severity to the desired conditions for the site within the targeted historical reference conditions. An important principle of restoring front range montane forests is to reduce tree density while maintaining a range of forest densities across the landscape (Addington et al 2018), and it appears both treatment areas achieved this goal as indicated by the high standard deviation in mean basal area and trees per acre post treatment in each stand.

Table 2. Mean tree basal area and trees per acre (+/- one standard deviation) across the two demonstration sites. Management Goal is from the management plan desired condition at each site (Peaks to People 2016b, 2016c). Reference data were cited in the management plans as a means to inform management prescription development. Ramsay Shockey historical reference used Brown et al (2015), and the Lady Moon site (since published as part of Battaglia et al. 2018) and was used as a proxy for the Scout Ranch.

Site	Unit	Phase	Basal Area (ft^2/acre)	Trees per Acre
Ramsay Shockey	B	Pre	93 (+/-55)	235 (+/-154)
Ramsay Shockey	B	Post	47 (+/-39)	83 (+/-77)
Ramsay Shockey	C	Pre	123 (+/-33)	302 (+/-188)
Ramsay Shockey	C	Post	92 (+/-40)	148 (+/-73)
Ramsay Shockey	Management Goal		40 (Range 0-80)	None
Ramsay Shockey	Historical Reference		25 (Range 0-74.5)	39 (0-791)
Scout Ranch	2	Pre	71 (+/-33)	99 (+/-61)
Scout Ranch	2	Post	32 (+/-26)	41 (+/-45)
Scout Ranch	Management Goal		30 (Range 0-60)	None
Scout Ranch	Historical Reference		33 (Range 6-93)	53 (Range 24-69)

Before and after photos from plot 14 in Ramsay Shockey treatment unit C. While tree density was reduced, some areas remained more dense than desired throughout Unit C.

Before and after photos from plot 11 in Ramsay Shockey Unit B. Tree density was substantially reduced throughout Unit B.

Before and after photos from plot 2 at the Scout Ranch. Pre-treatment tree density was relatively low before treatment, and restoration further reduced tree density closer to target desired conditions.

Mechanical fuel reduction treatments had differing impacts on active crown fire potential and high severity fire effects at the two demonstration sites. Fire modeling results indicate the likelihood of high severity crown fire in management units B and C at Ramsay Shockey were both relatively high before treatment, with roughly half of the area predicted to burn as crown fire, and was substantially reduced across both units by mechanical fuel reduction actions to a more characteristic low to mixed severity fire regime dominated by surface fire with some passive crown fire, even under severe fire weather conditions (Figures 4 and 5).

Modeled fire behavior at the Scout Ranch showed only a slight potential for active crown fire before mechanical treatment, and the fuels reduction activities further reduced modeled fire behavior (Figure 6).

Fire behavior modeling results suggest that mechanical forest management moved both sites closer to the desired conditions and is likely to enhance forest resilience to wildfire within the management units. The shift in the proportion of plots expected to burn as active crown fire was similar to estimates modeled in the Watershed Investment Tool for the same project areas. Additional analysis is ongoing and will continue to investigate changes in predicted tree mortality during wildfire, forest structure, surface fuel loadings, and plant community response.

FVS and FFE are widely used to measure effectiveness of forest fuel reduction treatments on reducing potential fire behavior (e.g. Battaglia et al 2016, Mason et al 2008, Tinkham et al 2016). However, there are several limitations to consider when interpreting modelled fire behavior and effects. Fire simulations in FVS take place under constant weather conditions and do not include variation in fire activity due to topography. Additionally, the plot based data collected during monitoring is used to assign one or more pre-set fuel models per plot, which are limited in number and do not allow for a continuous spectrum of fire behavior governed directly by the input data. Thus, fine-scale differences in stand conditions may not lead to detectable differences in modeled fire behavior. Finally, modelled fire behavior in FVS does not account for spatial arrangement and complexity of forest conditions, or impacts of fire suppression actions, and is an imperfect representation of wildfire. While FVS may lack the ability to incorporate some fine scale detail in wildfire predictions, it is robust to large changes in forest conditions and is an effective tool for evaluating treatment effectiveness trends across a stand.

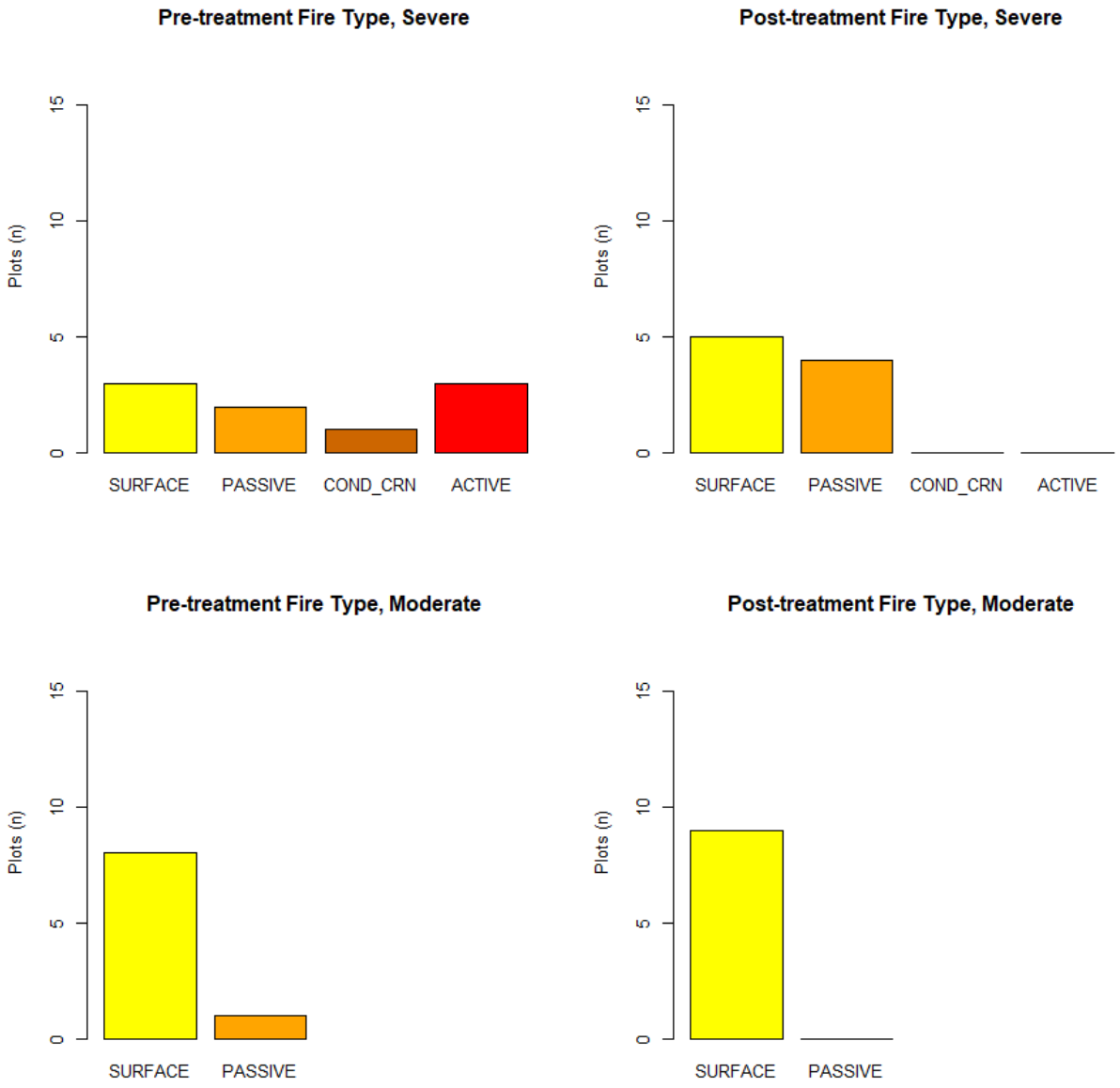


Figure 4. Ramsay Shockey Unit B, pre-treatment and post-treatment fire type modelled under severe and moderate fire conditions.

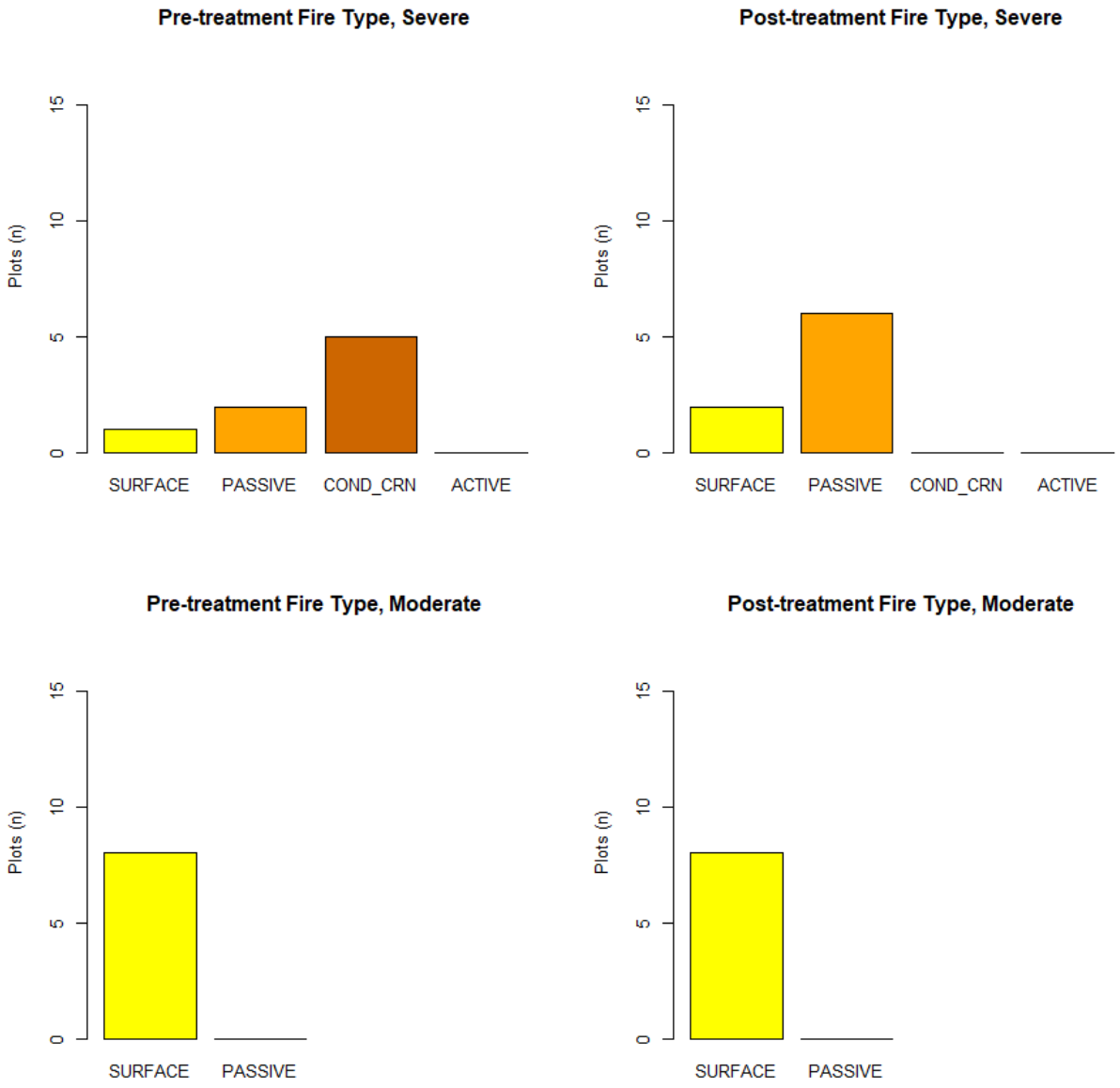


Figure 5. Ramsay Shockey Unit C, pre-treatment and post-treatment fire type modelled under severe and moderate fire conditions.

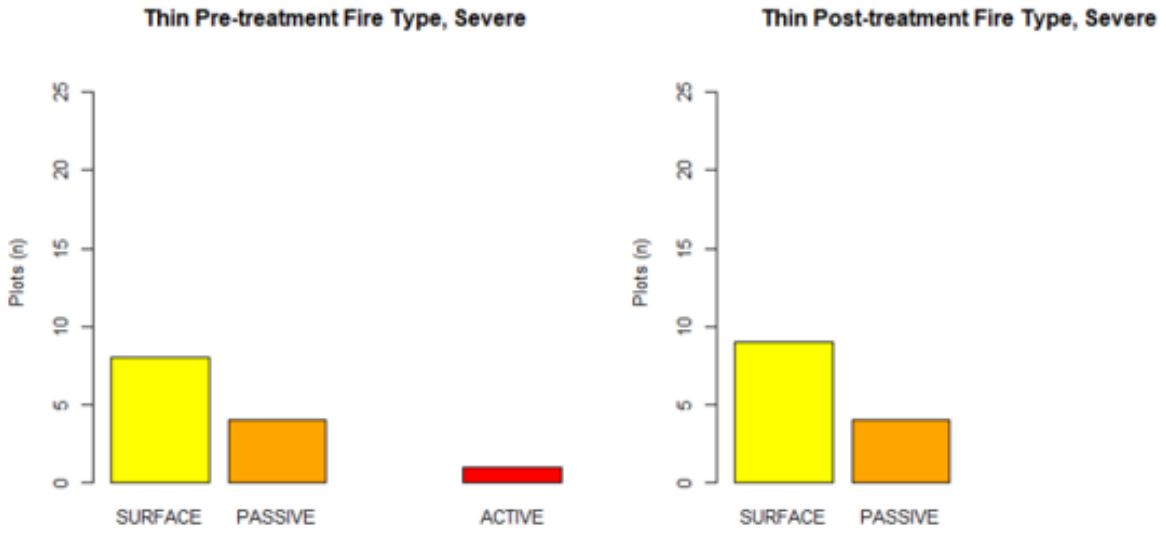


Figure 6. Scout Ranch, pre-treatment and post-treatment fire type modelled under severe fire conditions for thinned stands.

Remote Sensing Canopy Cover and Gap Delineation

The forest restoration treatment decreased canopy cover and increased coverage of large gaps at the Ramsay Shockey site, moving in the direction of the forest health desired conditions. Canopy cover was reduced from 44% to 35% following the restoration treatment. Correspondingly, gap cover increased from 23% to 37% in the post-treatment stand (Figure 7). Several metrics indicate that restoration treatments increased the size, size variability, and aggregation of gaps. Gap size distributions are shown in Figure 8. These figures show that restoration treatments generally shifted gap cover from being primarily dominated by many small gaps (≤ 2.2 acres) to larger gaps (> 2.2 ac). Gap decay coefficient, a metric of gap aggregation, decreased from 0.05 to 0.045. This metric indicates that following restoration treatments, gap areas shifted from being predominated scattered across many small gaps, to being consolidated into fewer, larger gaps. The overall size variability, measured as the coefficient of variation of gap size increased from 0.97 to 1.22, indicating that a larger variety of gap sizes was present following restoration treatments and horizontal forest structure complexity was increased.

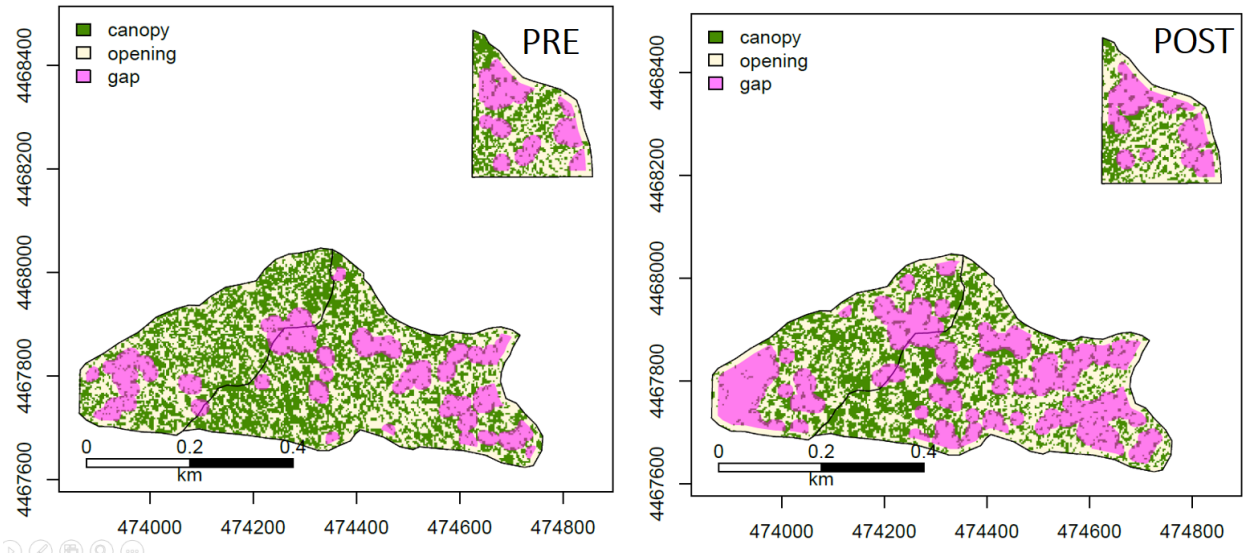


Figure 7. Tree cover of Ramsay Shockey restoration treatment for pre- (left, 45%) and post-treatment (right, 35%) stands, respectively, using analysis of aerial imagery. Canopy (green) and openings (yellow) are shown overlaid with large gaps (magenta, pre-treatment 23%, post-treatment 37%).

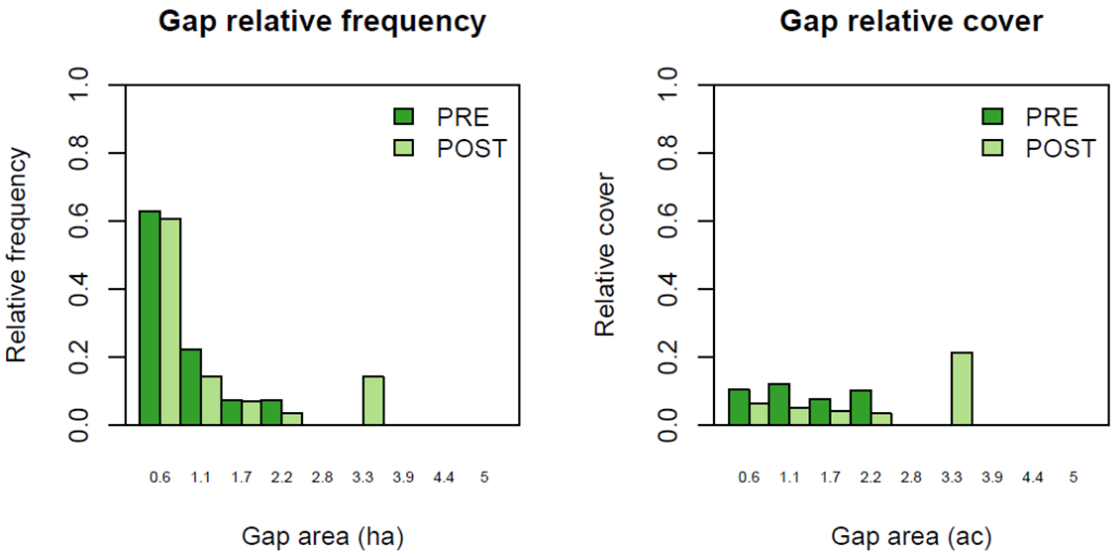


Figure 8. Gap distributions in Ramsay Shockey restoration treatment indicating shift in frequency and cover of gaps from primarily small gaps (≤ 2.2 acres) before treatments to increased dominance by larger gaps (> 2.2 acres).

Collaboration And Knowledge Sharing

An essential component of ecological monitoring is making data relevant to stakeholders and transferring knowledge from scientists to practitioners. To facilitate peer to peer learning, Peaks to People stakeholders were invited to participate in plot-based data collection throughout the monitoring process. Forestry and fire managers provided invaluable insights into the application of monitoring data, and also informed monitoring strategies based on information that would be useful for management decisions. In turn, fire and forestry

professionals learned measurement techniques that helped them improve outcomes on other projects, expanding the impact of the demonstration sites to improve forest management elsewhere. During the pre-treatment monitoring for Ramsay Shockey, CFRI hosted more than 15 visitors from over 10 agencies over a two day period to expose forestry and fire professionals to the monitoring process. The Nature Conservancy and Coalition for the Poudre River Watershed regularly contributed to monitoring efforts at the Scout Ranch. Agencies that assisted CFRI and participated in monitoring data collection included Colorado Division of Fire Prevention and Control, Bear Peak Wildland Fire module, Rocky Mountain Fire, the Colorado State Forest Service, Larimer County Open Space, The Nature Conservancy, Coalition for the Poudre River Watershed, and Redlands College and Colorado Natural Heritage Program student interns.

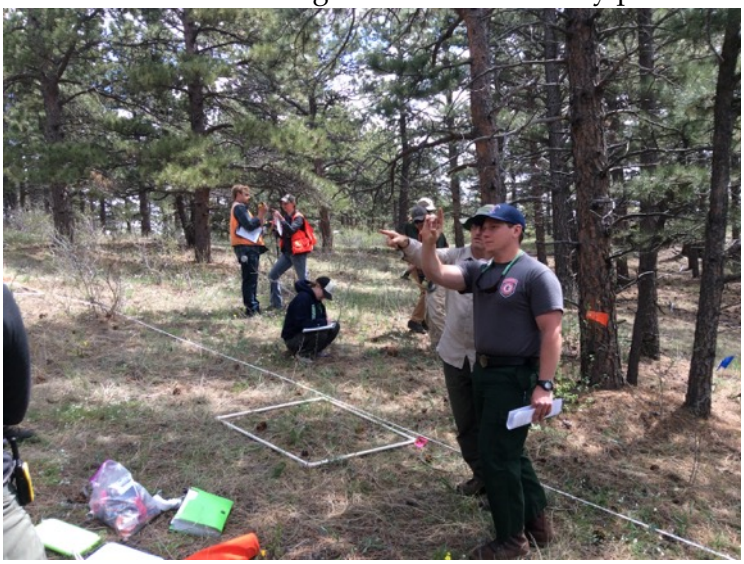


Figure 9. Colorado Forest Restoration Institute Assistant Director Brett Wolk assists a Colorado Division of Fire Prevention and Control firefighter with monitoring measurements at Ramsay Shockey.

Conclusion

Overall, the modeled fire behavior suggests forest management changed conditions to a more characteristic low to mixed severity fire regime at both demonstration sites, enhancing forest resilience to wildfire within the management areas. While tree density remained high in some areas of the Ramsay Shockey site, decreased forest cover and increased frequency of larger gaps in the tree canopy are indicators of improved forest health and resilience to disturbances beyond fuels reduction. Further evaluation and integration of project level monitoring with the Watershed Investment Tool is ongoing.

Figure 10. Nature Conservancy landscape ecologist Rob Addington discusses monitoring protocols and forest management with Peaks to People stakeholders during data collection at Ramsay Shockey.

Acknowledgements

Plot based data was collected with the help of CFRI field crews, particularly crew leaders Nate Teich and Kat Warnick. Wade Tinkham provided valuable insights for fire behavior modeling with FVS. Funding was provided by Peaks to People Water Fund, the Colorado Department of Natural Resources Wildfire Risk Reduction Grant Program, and the Colorado Forest Restoration Institute.

Literature Cited

Addington, R.N.; Aplet, G.H.; Battaglia, M.A.; Briggs, J.S.; Brown, P.M.; Cheng, A.S.; Dickinson, Y.; Feinstein, J.A.; Fornwalt, P.J.; Gannon, B.; Julian, C.W.; Pelz, K.A.; Regan, C.M.; Thinnes, J.; Truex, R.; Underhill, J.L.; Wolk, B. 2017. Principles and practices for the restoration of ponderosa pine and dry mixed-conifer forests of the Colorado Front Range. RMRS-GTR-373. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 121 p. (Available online: https://www.fs.usda.gov/treesearch/pubs/55638)

Anderson, H.E. 1982. Aids to determining fuel models for estimating fire behavior. USDA For. Serv. Gen. Tech. Rep. INT-122, 22p. lntermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Battaglia, M.A.; Smith, F.W.; Shepperd, W.D. Can prescribed fire be used to maintain fuel treatment effectiveness over time in Black Hills ponderosa pine forests? For. Econ. Manag. **2008**, 256, 2029–2038.

Battaglia, M.A. B. Gannon, P.M. Brown, P.J. Fornwalt, A.S. Cheng, L.S. Huckaby. 2018 Changes in forest structure since 1860 in ponderosa pine dominated forests in the Colorado and Wyoming Front Range, USA. For. Ecol. Manage., 3, pp. 1462-1473

Boyden, S., Montgomery, R., Reich, P.B., Palik, B., 2012. Seeing the forest for the heterogeneous trees: Stand-scale resource distributions emerge from tree-scale structure. Ecol. Appl. 22, 1578–1588. https://doi.org/10.1890/11-1469.1

Brown, P.M.; Battaglia, M.A.; Fornwalt, P.J.; Gannon, B.; Huckaby, L.S.; Julian, C.; Cheng, A.S. 2015. Historical (1860) forest structure in ponderosa pine forests of the northern Front Range, Colorado. Canadian Journal of Forest Research 45: 1462-1473.

Cannon, J.B., Barrett, K.J., Gannon, B.M., Addington, R.N., Battaglia, M.A., Fornwalt, P.J., Aplet, G.H., Cheng, A.S., Underhill, J.L., Briggs, J.S., Brown, P.M., 2018. Collaborative restoration treatments on forest structure in ponderosa pine forests of Colorado. For. Ecol. Manage. 424, 191–204.

Collins, B.M., Stevens, J.T., Miller, J.D., Stephens, S.L., Brown, P.M., North, M.P., 2017. Alternative characterization of forest fire regimes: incorporating spatial patterns. Landsc. Ecol. 32, 1543–1552. https://doi.org/10.1007/s10980-017-0528-5

Congalton, R.G., Green, K., 2009. Basic analysis techniques, in: Assessing the Accuracy of Remotely Sensed Data - Principles and Practices. CRC Press, Taylor Francis Group, Boca Raton, FL, pp. 105–120.

Lillesand, T.M., Kiefer, R.W., Chipman, J.W., 2015. Digital image analysis, in: Remote Sensing and Image Interpretation. Wiley, pp. 482–608.

Mason, G.J.; Baker, T.T.; Cram, D.S.; Boren, J.C.; Fernald, A.G.; VanLeeuwen, D.M., 2017. Mechanical fuel treatment effects on fuel loads and indices of crown fire potential in a south central New Mexico dry mixed conifer forest. For. Econ. Manag., 251, 195–204.

Peaks to People Water Fund. 2016a. Peaks to People Water Fund: Selection process for a demonstration sites in the Cache la Poudre and Big Thompson watersheds. 13 p.

Peaks to People Water Fund. 2016b. Cache la Poudre Watershed, Ben Delatour Boy Scout Ranch, Forest Restoration Project Treatment Plan. 10 p.

Peaks to People Water Fund. 2016c. Big Thompson Watershed, Ramsay Shockey Open Space / State Land Board, Forest Restoration Project Treatment Plan. 11 p.

Reinhardt, Elizabeth; Crookston, Nicholas L. (Technical Editors). 2003. The Fire and Fuels Extension to the Forest Vegetation Simulator. Gen. Tech. Rep. RMRS-GTR-116. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 209 p.

Scott, J.H. and R.E. Burgan. 2005. Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model. Gen. Tech. Rep. RMRS-GTR-153. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 72 p.

Tinkham, W.T., C.M. Hoffman, S.A. Ex, M.A. Battaglia, J.D. Saralecos, 2016. Ponderosa pine forest restoration treatment longevity: implications of regeneration on fire hazard Forests, 7, p. 137.

Wolk, B.H., Barrett, K.J., Cannon, J.B., Chambers, M.E., Hoffman, C., Morici, K., Warnick, K., and E.C. Williams. 2018a. Simple Plot Protocol: Field Data Collection Protocol for Evaluating Fire Mitigation Effectiveness. Colorado Forest Restoration Institute, Colorado State University. 12p.

Wolk, B.H., Barrett, K.J., Cannon, J.B., Chambers, M.E., Hoffman, C., Morici, K., Warnick, K., and E.C. Williams. 2018b. Mothership Field Data Collection Protocol For Evaluating Forest Restoration and Fire Mitigation Management Effectiveness. Colorado Forest Restoration Institute, Colorado State University.