Point Blue Report

Vegetation and Avian Response to Aspen Restoration on the Almanor Ranger District

Final Report

April 10, 2020

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Conservation science for a healthy planet

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SUMMARY

Treatments designed to restore aspen in the Lassen National Forest were effective at reducing conifer cover and increasing recruitment of aspen stems whose terminal leaders were out of reach of browsing by cattle and deer. In 2018 (4-13 years post-treatment) conifer cover and total basal area remained lower, while shrub and herbaceous cover had increased in the years following treatment. Locations with high aspen canopy cover had higher numbers of aspen stem recruits, and upland sites also had higher stem counts than riparian or lithic (lava flow) locations. Fencing also appeared to be effective at promoting recruitment, but was only evident for larger size classes (5 feet tall and larger), suggesting treatment results in an initial flush of aspen, and even with fencing new recruitment in the years following restoration is relatively small. If continued recruitment of aspen into larger size classes can be maintained there is potential for these stands to meet the objective of increasing mature aspen stem density. In the long-term, assuming continued fire suppression, active management to mimic natural disturbance will be required to keep these stands from transitioning back to conifer dominated. Total bird abundance and aspen focal species increased at treated stands in comparison to reference stands, and most of this changes was manifest in the initial post-treatment period. Focal and overall bird abundance increased at treated stations in the initial post-treatment, and few species showed a declined as a result of treatment. Continued management of aspen stands to remove encroaching conifers and remove browsing pressure on small aspen stems has the potential to save this ecologically important habitat, and treatments appear to benefit bird species associated with aspen while not negatively affecting overall bird abundance.

INTRODUCTION

Quaking aspen (*Populus tremuloides*) is a disturbance-dependent species in western North American forests. It has disproportionately high ecological values relative to its spatial extent, especially for the maintenance of biodiversity (Flack 1976, Griffis-Kyle & Beier 2003, Kuhn et al. 2011). In the face of nearly a century of fire suppression and herbivory, aspen habitat throughout the Sierra Nevada has been degraded or lost (Sheperd et al. 2006, Rogers et al. 2007). Restoration to reverse aspen decline and increase recruitment by mechanically removing encroaching conifers has become a management priority in the Sierra Nevada ecosystem (Shepperd et al. 2006). Reducing conifer encroachment in established aspen stands, as well as reducing heavy herbivory on regenerating aspen, is necessary to lower the risk of losing the remaining aspen stands (Tate et al. 2005). The removal of conifers has been shown to effectively increase aspen recruitment in the region (Jones et al. 2005a), though the effects of wildlife exclusion fences on aspen recruitment are not well studied in the Sierra and southern Cascades. However, they have been found to effectively increase aspen recruitment in the Rocky Mountains (Kota & Bartos 2010).

To evaluate the ecological effects of mechanical aspen restoration in the Sierra Nevada, we monitored birds and vegetation in treated and untreated aspen stands in the Lassen National Forest (LNF). As part of the aspen restoration program on the ARD, multiple monitoring efforts were implemented to measure success. Point Blue collected data on birds and vegetation responses from 2004 – 2012 (Campos and Burnett 2014). However, the data for that assessment was primarily from restoration on the Eagle Lake Ranger District (ELRD), as most of the treatments on the Almanor Ranger District (ARD) were not yet implemented, or were in the initial post-restoration period (less than 5 years). The ARD staff also collected substantial data on aspen vegetation response, data that has previously not been reported. As the landscape setting, soils, and climate on the ARD are quite different than much of the ELRD, the responses from ARD treatments may be more analogous to expected responses to aspen restoration elsewhere on the ARD, including within the Storrie Fire area (especially those stands unaffected by the fire). In 2018 we re-surveyed all ARD treated aspen stands, and use new data to further evaluate the effects of restoring aspen vegetation and bird communities over 10 years following treatments. Secondarily, we sought to establish the effects of grazing exclosures on vegetation and bird abundance, and to develop site-specific recommendations to guide future restoration prescriptions in aspen habitat within the Storrie Fire area. We also report on conditions within Storrie Fire aspen stands using initial surveys of birds and vegetation collected in 2018.

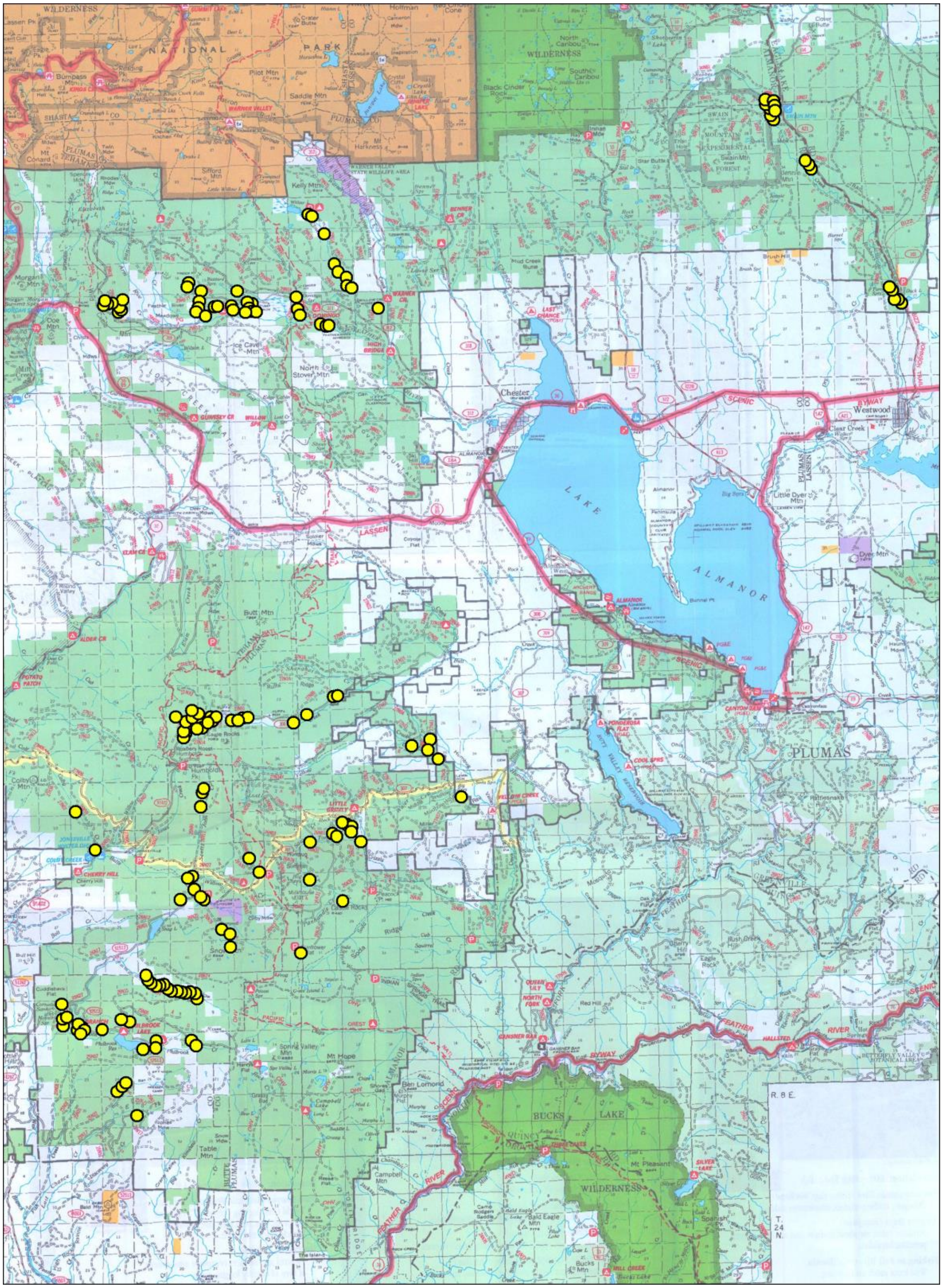
METHODS

Sampling Design and Field Methods

We compiled bird and vegetation survey data from three separate monitoring projects in aspen stands in the LNF. These monitoring efforts include bird and vegetation surveys in aspen enhancement project areas conducted by Point Blue, vegetation survey data in many of the same enhancement project areas conducted by LNF staff, and bird and vegetation survey data in priority aspen stands within the Storrie Fire footprint (Figure 1).

In 2006, 94 stations on the ARD were established by Point Blue within proposed aspen enhancement projects. Bird point count stations >220-m apart were laid out on transects within aspen stands, ranging from as small as a single aspen stem to hundreds of acres. The number of point count stations in a transect (4-16) varied as a function of the size of aspen stands in selected areas. At each Point Blue survey station we conducted a standardized bird point count survey (Ralph et al. 1995), where a single observer estimated the distance to the location of

Figure 1. Location of Point Blue avian and vegetation monitoring stations on the Almanor Ranger District of the Lassen National Forest. Yellow dots in northern section are where treated stands exist. Those in the southern portion represent the Storrie Fire sample.



each individual bird detected within a five minute time span from a fixed location. All observers underwent an intensive training period focused on bird identification and distance estimation prior to conducting surveys. Counts began after local sunrise, were completed within four hours, and did not occur in inclement weather. Laser rangefinders were used to assist in distance estimation.

At all of the Point Blue stations, we also collected vegetation data across a 50-m radius plot at the station center. On these plots we made ocular estimates of the percent cover of understory (<5 m) aspen, shrubs, and herbaceous vegetation, and measured canopy cover using a GRS densitometer. We took densitometer readings along two 50 m transects at 3 meter intervals and identified hits to species for a total of 32 readings, then calculated % canopy cover of each species and all species in total from these readings. Transects were oriented south and east from the plot center unless barriers were encountered in those directions, in which case we chose the opposite direction (west or north). Using these same transects we counted the total number of aspen stems within 1 meter of the transect line and categorized them into four height/diameter classes: 0- 0.46 m (0 – 18”), 0.46 – 1.52 m (18” – 4.5’), 1.53 m (4.5’) tall to 2.5 cm (1”) diameter (DBH), and over 2.54 cm (1”) DBH. Point Blue survey study design and field methods are described in more detail in Campos and Burnett (2012).

The LNF compiled vegetation data from a separate set of 72 stations near the Point Blue survey stations. These stations were surveyed by USFS staff multiple times from 2006 through 2018 using a similar line transect design as was used at Point Blue stations to count aspen and conifer stems in the same four size classes (0-18”, 18”-5’, 5’ to 1 inch diameter (DBH), and over 1” DBH). USFS study design and field methods are described in more detail in Jones et al. (2005b).

Finally, in 2018 we established and visited 54 bird and vegetation survey stations in aspen stands identified by the LNF as priorities for restoration within the Storrie Fire perimeter. We used USFS generated GIS inventory and management layers to place survey stations within these stands. All points established were within 500m of roads, separated by at least 230 meters, and in locations that are accessible for treatment. We report the vegetation conditions at Storrie Fire survey stations as a comparison to conditions outside of the fire footprint in order to evaluate management recommendations for aspen stands within the fire.

Analyses

We show vegetation results from Point Blue surveys grouped into treatment categories (described below) to visualize the progression of vegetation change that occurs after treatment. In addition, we show untreated (control/reference) vegetation survey results as a comparison to the treated stations using roughly the same time periods. The reference sample consists of 40 stations sampled during both the treatment period (primarily 2006, with a few surveys from

2007 and 2012) and 2018. The pre-treatment sample consists of 42 stations surveyed primarily in 2006 and 2007, with a few surveys from 2011 and 2012. The initial post-treatment sample consists of all the stations surveyed between 1 and 4 years after treatment, consisting of 36 of the 42 treated stations surveyed in 2011 or 2012 (n=16), or 2018 (n=20). The remaining 22 of the 42 treated stations that were surveyed in 2018 were between 5 and 10 years after treatment, and thus were grouped into a separate 5+ years post-treatment category to evaluate any differences that may manifest after the initial post-treatment period. We include vegetation data from the 54 Storrie Fire stations as a comparison to these four other treatment categories. At a small portion of the sample, multiple vegetation surveys (visits during more than one year) within the same treatment period were available. In those cases we averaged the measurements. We chose the data groupings listed above to balance the sample as much as possible across each category because the stations were not consistently sampled across years within representative ranges of time since treatment.

The USFS vegetation survey sample consists of 72 stations surveyed prior to treatments, with most resurveyed multiple times post-treatment and no untreated reference sample. We split the post-treatment category into two levels depending on time since the treatment occurred; 1-3 years and 4-7 years after treatment. We chose this cutoff for the LNF data to create better balance in the sample sizes for each category and because a previous study in the region had found that four years post-restoration was sufficient to detect a significant response to restoration (Jones et al. 2005a). These data are shown separately from the Point Blue data.

All data are grouped at the station scale and then plotted with boxplots showing the median value in a bold horizontal line, the upper and lower bounds of the box showing the 75th and 25th quartile, respectively, and the upper and lower error bars showing the maximum and minimum, respectively. We also overlaid each data point on the boxplot for complete visualization of the data. Each dot is a single survey station average value (where multiple yearly surveys are available) of that particular variable. In the results we show boxplots for a variety of canopy, shrub layer, ground, and aspen stem count variables from both the Point Blue and USFS vegetation datasets grouped by treatment category, as well as time since fencing construction.

To establish statistical significance to the data plots we calculated an ANOVA using the “aov” function in R, and then used “TukeyHSD” to establish which treatment category groups were different from each other and labeled them accordingly on each plot. We labeled each plot with ANOVA results including F-value and statistical significance (p-value) of difference between group means.

To explore factors that may be driving aspen recruitment we also calculated a linear regression of log-transformed aspen stem counts recorded during 2018 Point Blue vegetation surveys with a set of covariates including: site condition (three categories: upland mixed conifer, riparian/meadow fringe, lithic lava outflow), time since treatment (# years), fencing presence/absence, slope, shrub cover, herbaceous cover, basal area (all species), conifer canopy cover, and aspen canopy cover. We then proceeded through stepwise variable removal selecting a single covariate with the lowest significance (highest p-value) for removal, and proceeded in this stepwise process until AIC did not improve.

We estimated bird abundance at each Point Blue survey station to explore the response of birds to aspen restoration treatments. We considered all species combined as well as a subset of aspen focal species and 6 conifer associates to treatments (Table 1). Focal species were referenced from Campos and Burnett (2014) but excluded two of those species– Tree Swallow and Mountain Bluebird -as there were insufficient detections to fit a reasonable model. We used a “stacked years” format where each site/year combination is treated as an independent sampling unit and all years are simultaneously fit using the function “distsamp” in the R package Unmarked (Fiske and Chandler 2011). Abundance and detection covariates were included to improve model fit (MacKenzie et al. 2006) and give more accurate abundance estimates for each species at the selected pre and post-treatment time periods. All models included a set of covariates on occupancy including treatment category (pre-treatment, initial post-treatment, and 2018 at both treated and reference/control stations – this variable serves as a proxy for time in the model), transect grouping, site condition (meadow, stream, upland dry, or upland spring/fen), aspen canopy cover, conifer canopy cover, shrub cover (tree species removed), and aspen stem counts. All continuous covariates were verified to be non-collinear by calculating the variance inflation factor of each variable in the dataset and all were <3.0 (Heiberger 2017). We fit models for a set of 39 species with more than 30 individuals detected in the dataset, but removed results from 7 species with poor model fit. We use these models to predict overall bird abudance at treated and untreated stands over time.

To allow birds to recover following treatments we did not include any data from 1 year post-treatment in our bird abundance models. Treatments generally occurred in the fall and birds returning the following spring may have not had sufficient time to make decisions to abandon unsuitable habitat or occupy newly created habitat, thus the first year following treatment is a transitional period and we feel it is appropriate to remove these data prior to fitting models. We show the average predicted abundance for each species within the treatment categories described above and plot those data with standard errors for each focal species, all focal species combined, as well as all 32 species combined.

Table 1. Aspen and Conifer Focal species considered in this report.

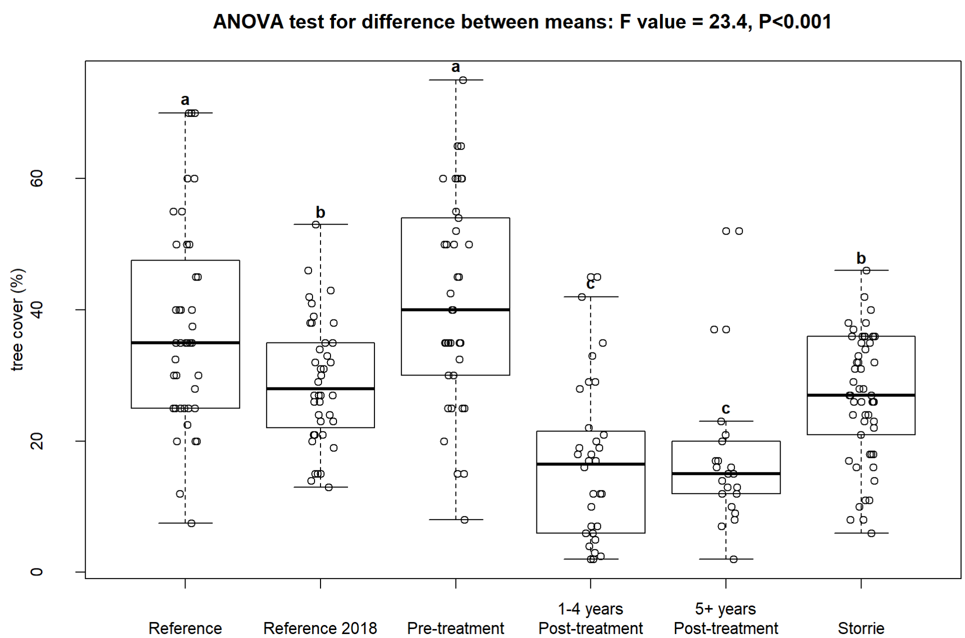
Species	4-letter Code
Aspen Focal Species	
Dusky Flycatcher	DUFL
MacGillivray's Warbler	MGWA
Chipping Sparrow	CHSP
Red-breasted Sapsucker	RBSA
Hairy Woodpecker	HAWO
Western Wood-Pewee	WEWP
Warbling Vireo	WAVI
Mountain Chickadee	MOCH
Tree Swallow	TRES
Mountain Bluebird	MOBL
Conifer Focal Species	
Golden-crowned Kinglet	GCKI
Red-breasted Nuthatch	RBNU
Brown Creeper	BRCR
Western Tanager	WETA
Dark-eyed Junco	DEJU
Olive-sided Flycatcher	OSFL

RESULTS

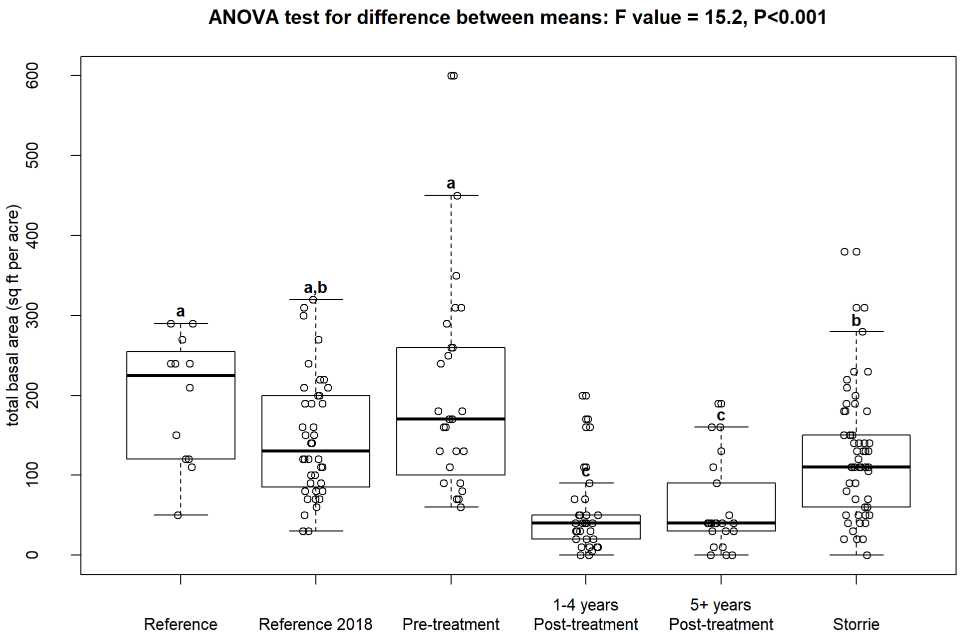
Aspen treatments resulted in substantial changes to the forest structure (Figure 2). Tree cover was reduced from 30-55% (lower and upper quartiles) pre-treatment to 8-21% post-treatment (Figure 2a). Similarly, tree basal area was reduced from 100-250 square feet per acre, to 20-50 post-treatment (Figure 2b). After 5 years had passed, basal area and tree cover had remained largely unchanged. The changes in total tree cover and basal area from pre to post-treatment were due largely to removal of fir and pine (Figures 2c-e). Storrie Fire stations had similar basal area, aspen cover, and conifer cover in comparison to pre-treatment and reference stations outside of the fire. Aspen canopy cover, as would expected in the first decade post-treatment, did not change appreciably in our dataset (Figure 2f).

Figure 2: Basal area and Canopy cover measurements at treated and untreated aspen stands on the Almanor Ranger District from Point Blue data. Dark lines are median, boxes represent 25th – 75th quartile, whiskers represent extent of all data, and dots are individual data points. Plots with a shared letter above the top whisker are not statistically different from each other.

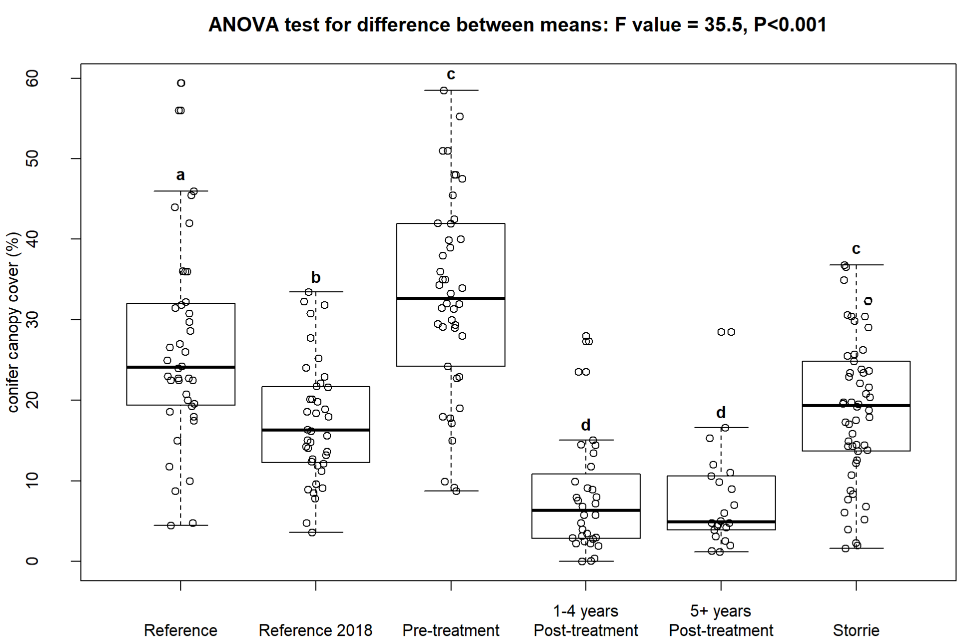
a) Total tree cover



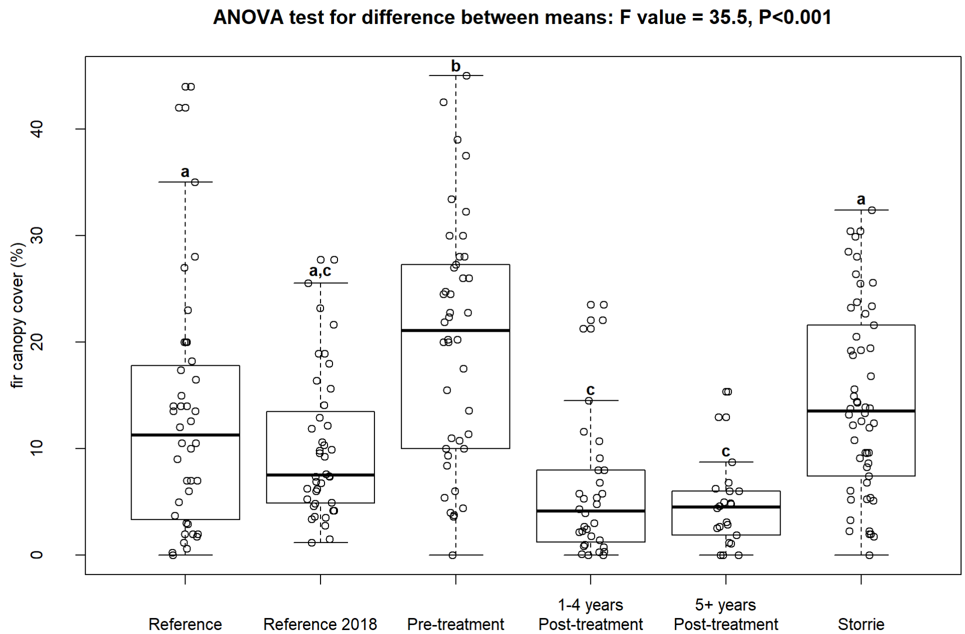
b) Total basal area



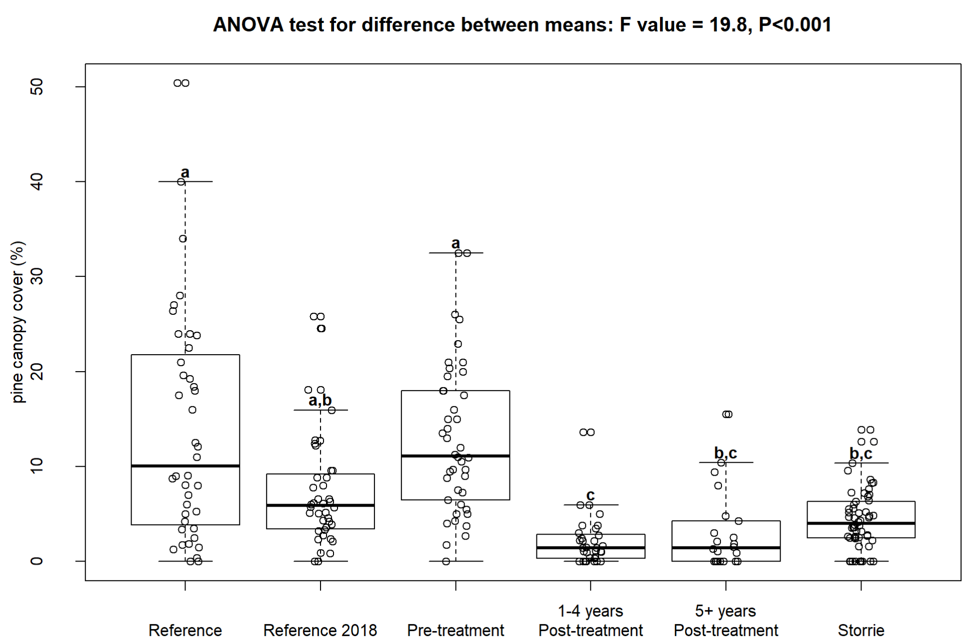
c) Conifer canopy cover



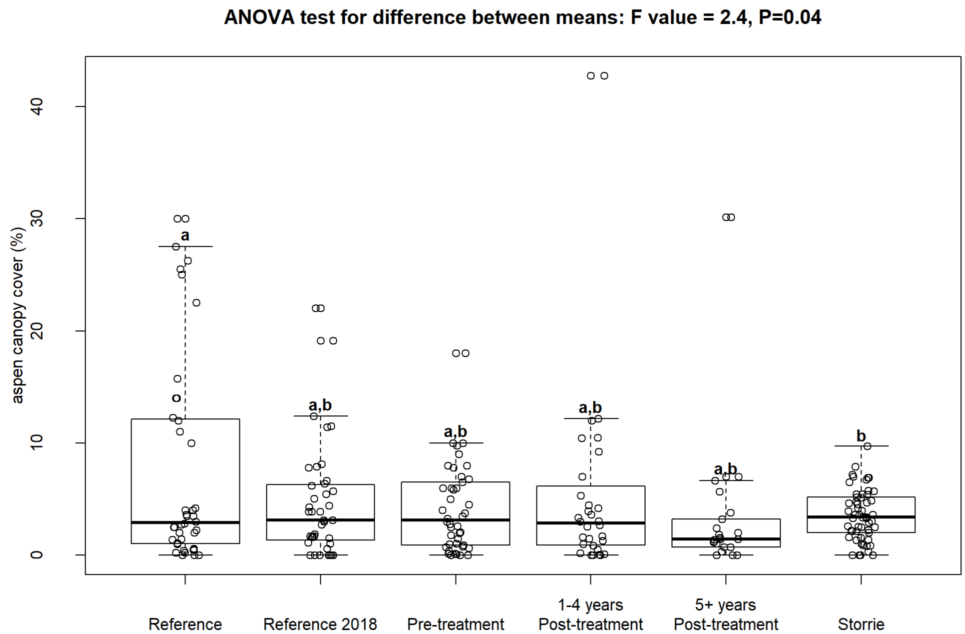
d) Fir canopy cover



e) Pine canopy cover



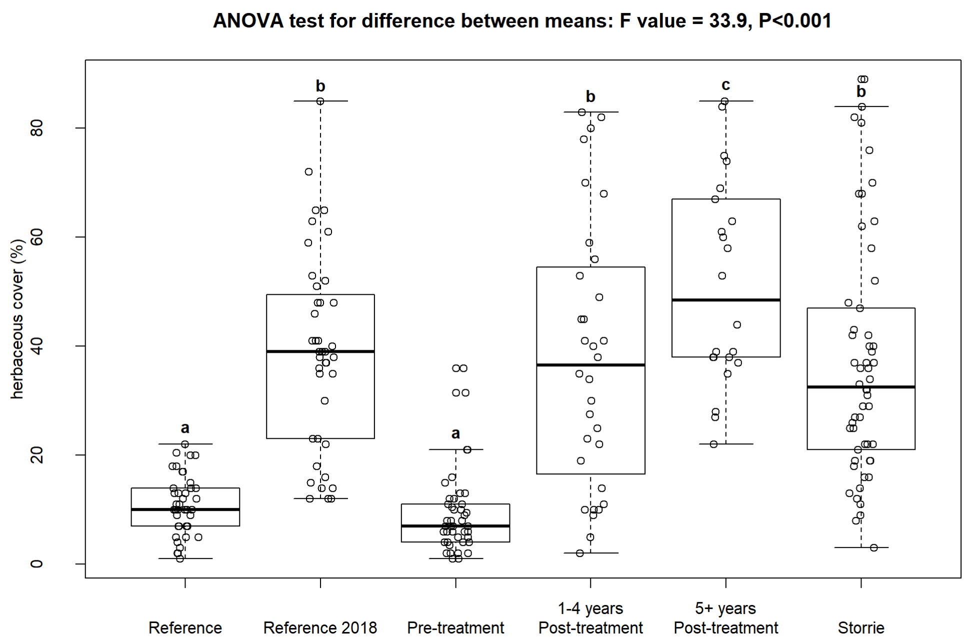
f) Aspen canopy cover



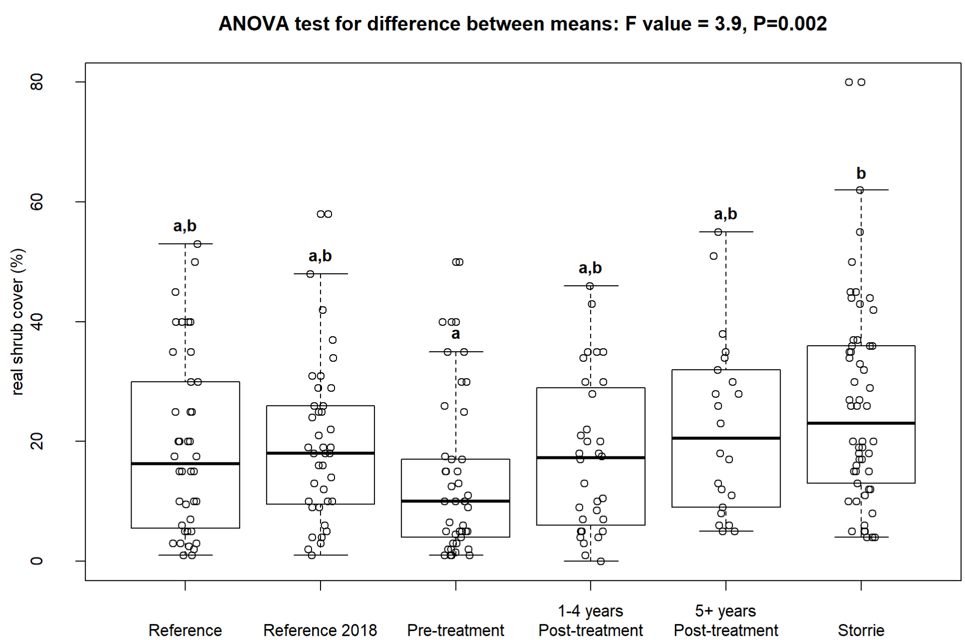
Some understory vegetation conditions changed strongly following treatments as well (Figure 3). Herbaceous plant cover increased in the immediate post-treatment period and was even higher in the late post-treatment period, experiencing a five-fold increase from pre-treatment to late post-treatment (Figure 3a). Herbaceous cover also increased substantially at the reference sites in 2018 suggesting that factors other than treatment may affect herbaceous cover (e.g. annual precipitation). There was little evidence that treatment resulted in changes in shrub cover (Figure 3b). Sub-canopy aspen and fir cover changed very little at either the reference or treated stations (Figure 3c-d). Storrie Fire survey stations were similar to the pre-treatment and initial reference sample but had slightly higher fir and lower aspen subcanopy cover on average in comparison to the 2018 reference sample.

Figure 3: Understory vegetation measurements are listed in panels a-e. All data from Point Blue.

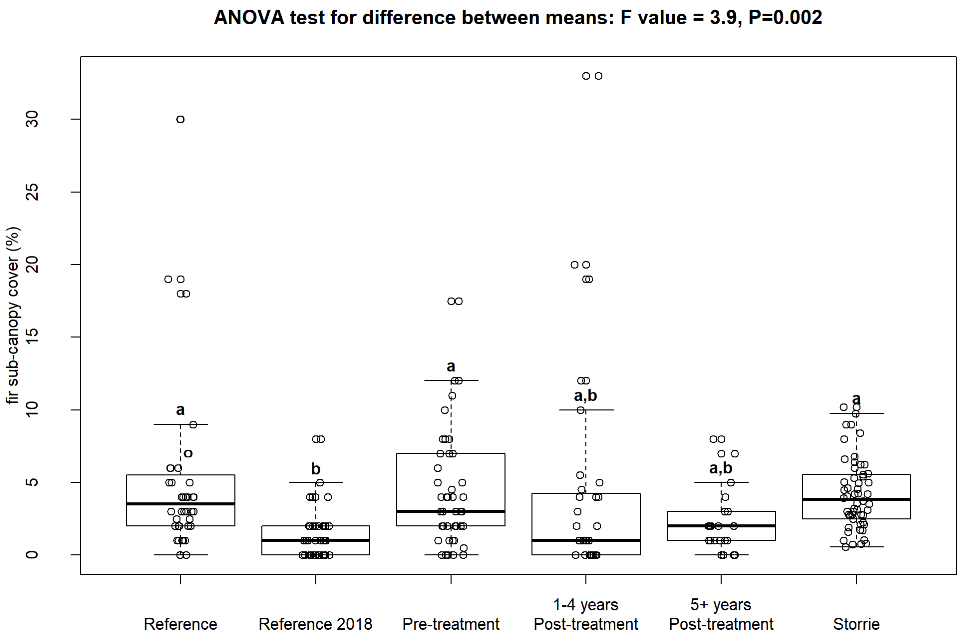
a) Herbaceous vegetation cover



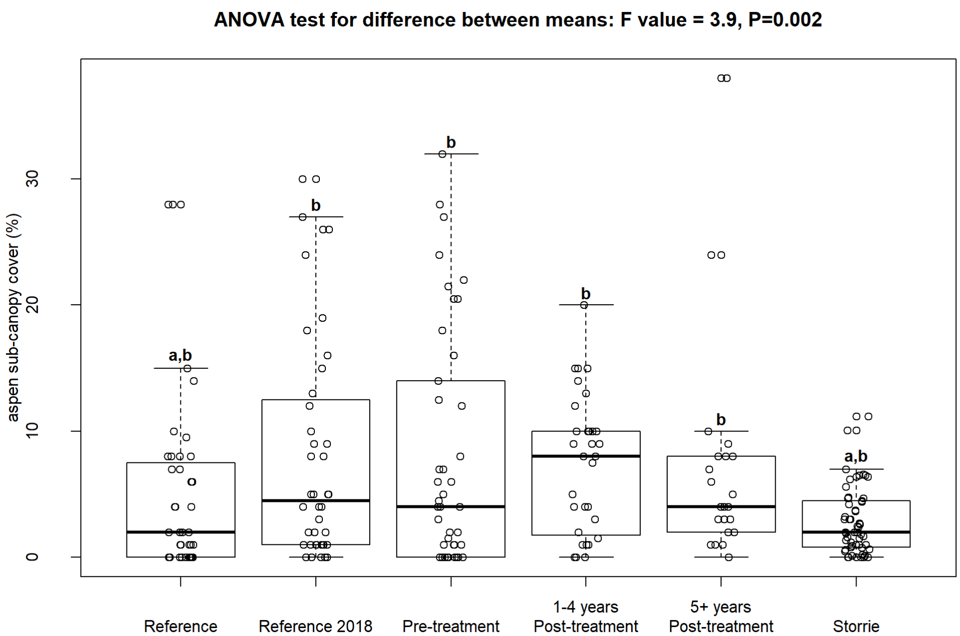
b) Shrub cover



c) Fir understory cover



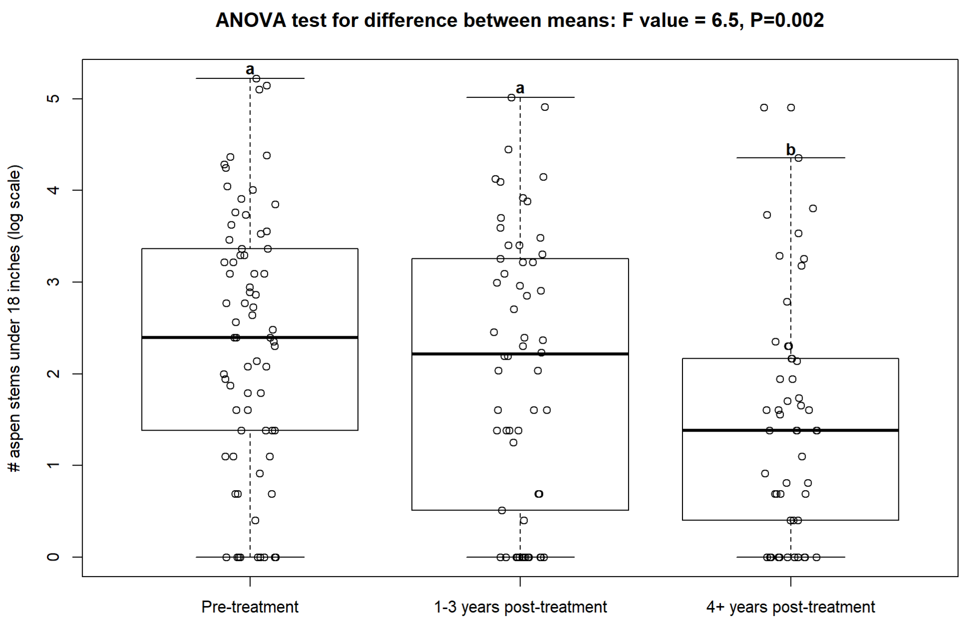
d) Aspen understory cover (<5 m tall)



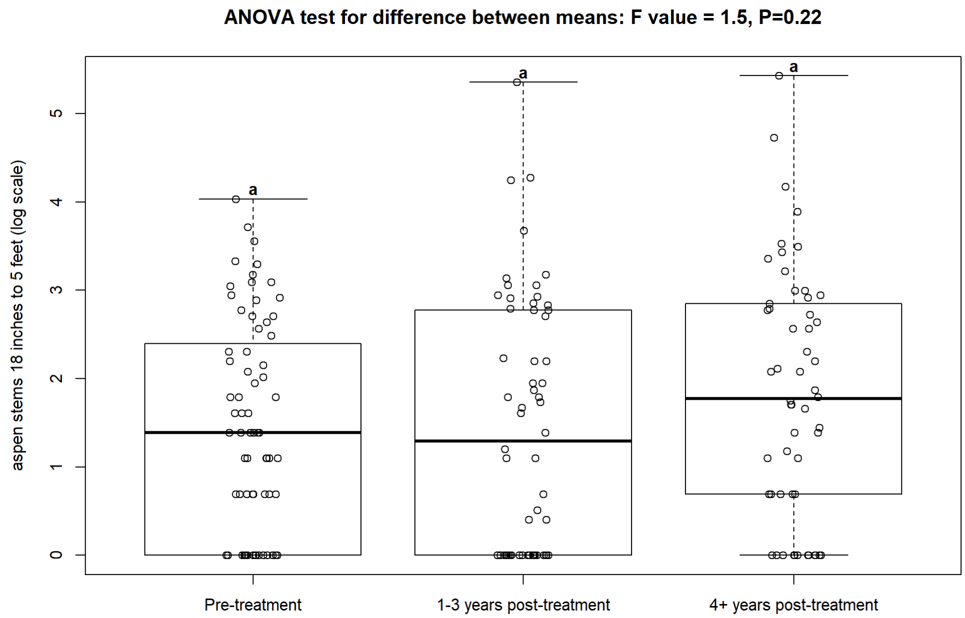
From the USFS vegetation surveys there is evidence of recruitment of aspen stems of larger size classes (over 5' tall) but not the smaller sized stems (Figure 4). Stems less than 18" declined slightly in both the 1-3 years post-treatment time period and also in the surveys over 4 years since treatment (Figure 4a). Stems 18" up to 5' tall did not appear to change (Figure 4b), but a small increase in stem counts in small trees from 5' tall to 1" DBH (Figure 4c), and 1" DBH or larger trees (Figure 4d) is apparent.

Figure 4: Counts of aspen stem hits from transect surveys are listed in panels a-d. Data populating these figure are from USFS field surveys.

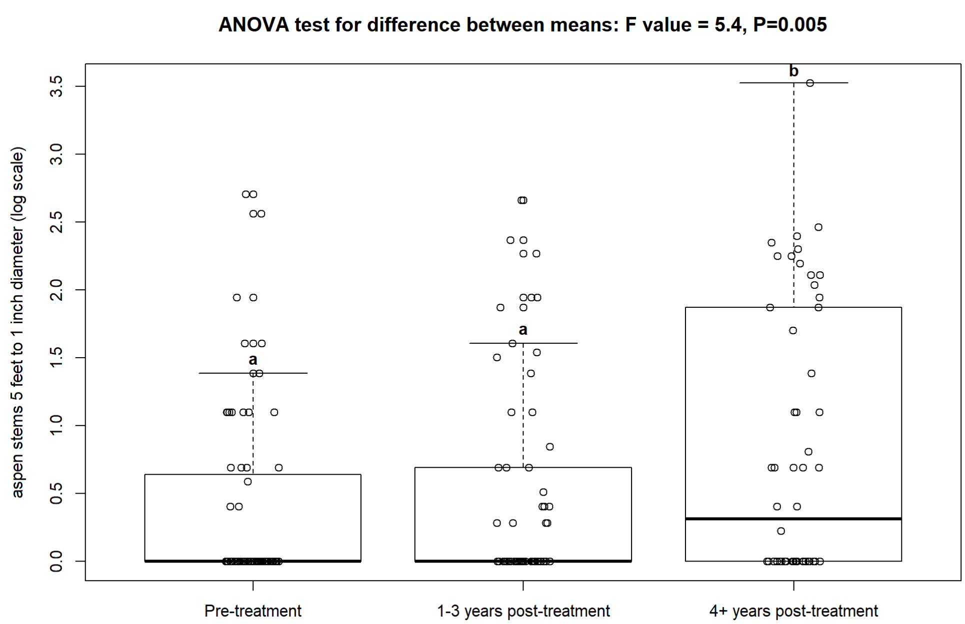
a) Counts of aspen stems less than 18 inches tall



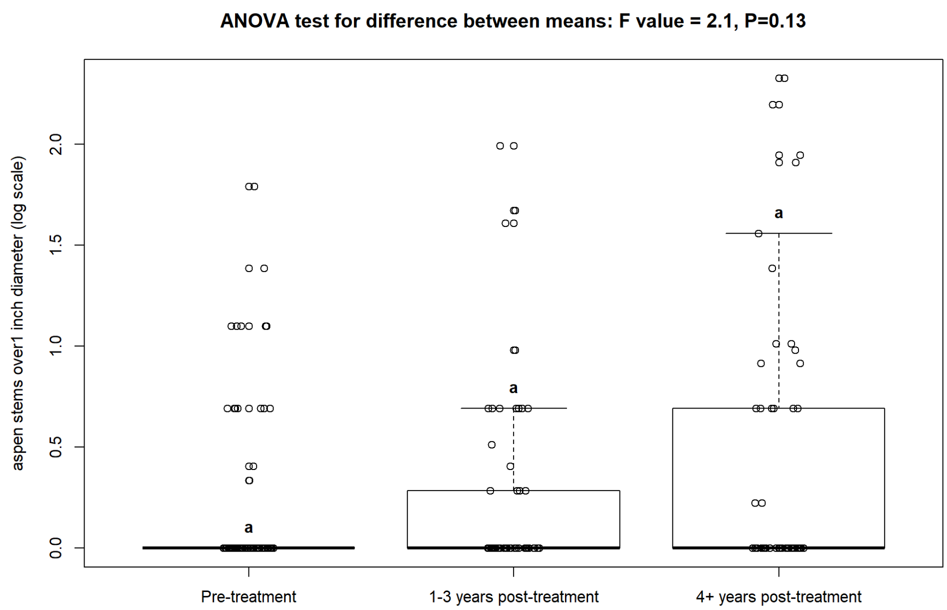
b) Counts of aspen stems 18 inches to 5 feet tall



c) Counts of aspen stems 5 feet tall to 1 inch diameter



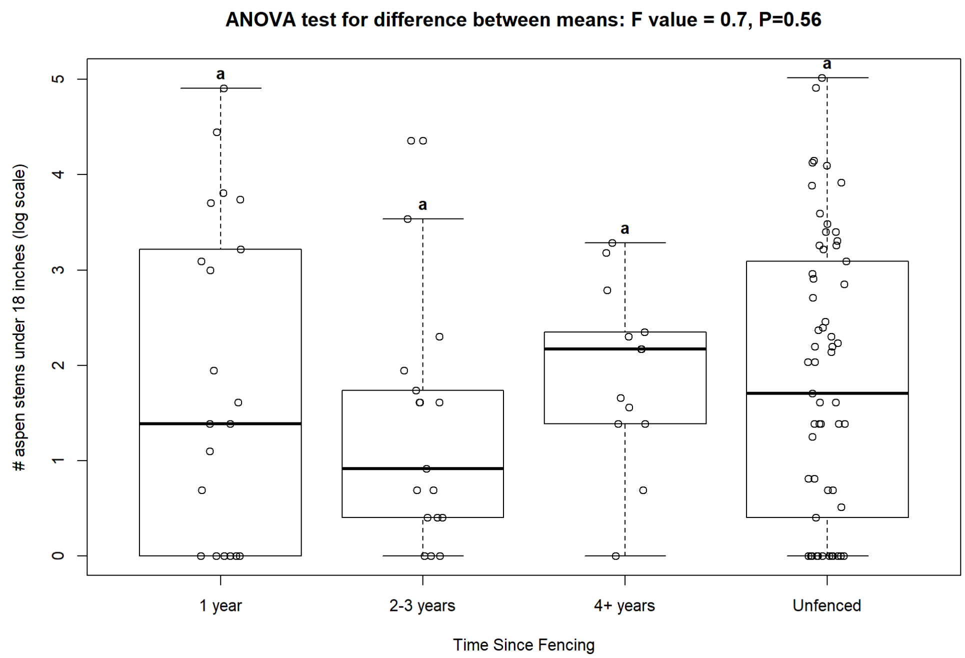
d) Counts of aspen stems of over 1 inch diameter



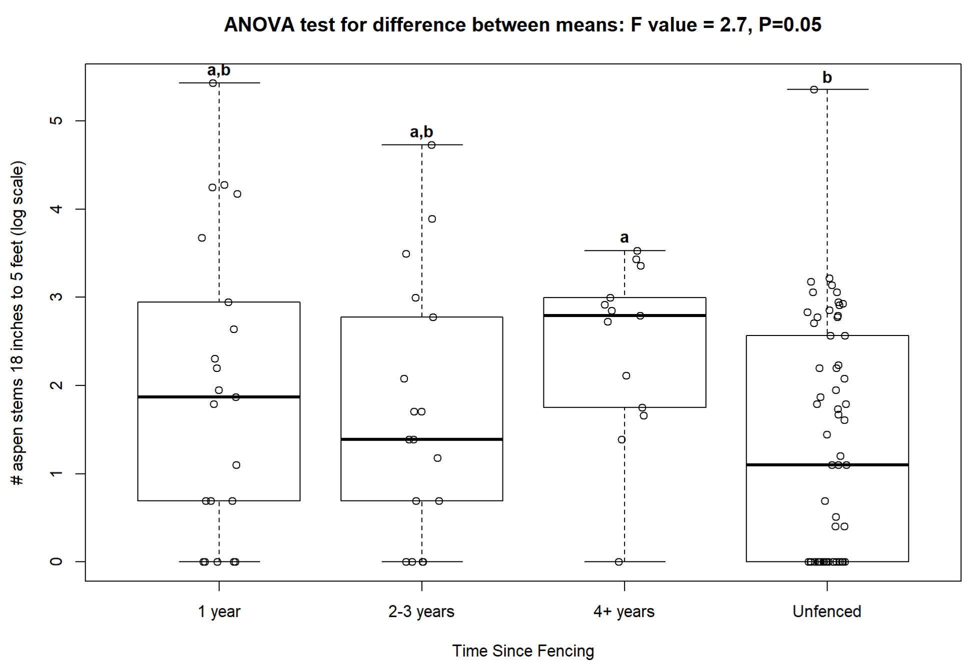
The positive effects of fencing are apparent on small aspen stem counts where the fencing has been in place for at least 4 years, implying that browsing is strongly influencing small aspen recruitment (Figure 5). Minimal increases are seen in the numbers of stems up to 18” tall (Figure 4a), but larger gains are apparent in 18” to 5’ tall trees (Figure 5b), as well as trees larger than 5’ (Figure 5c) and over 1” DBH (Figure 5d).

Figure 5: Counts of aspen stem hits from transect surveys at locations before and after fencing installation are listed in panels a-d. Data populating these figure panels are from USFS field surveys:

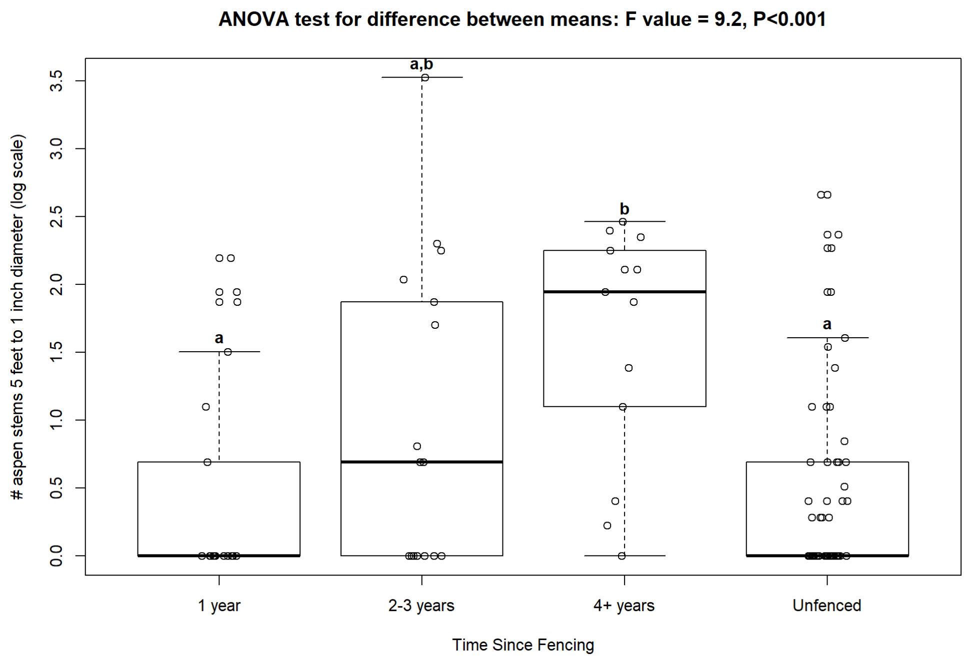
a) Counts of aspen stems less than 18 inches tall



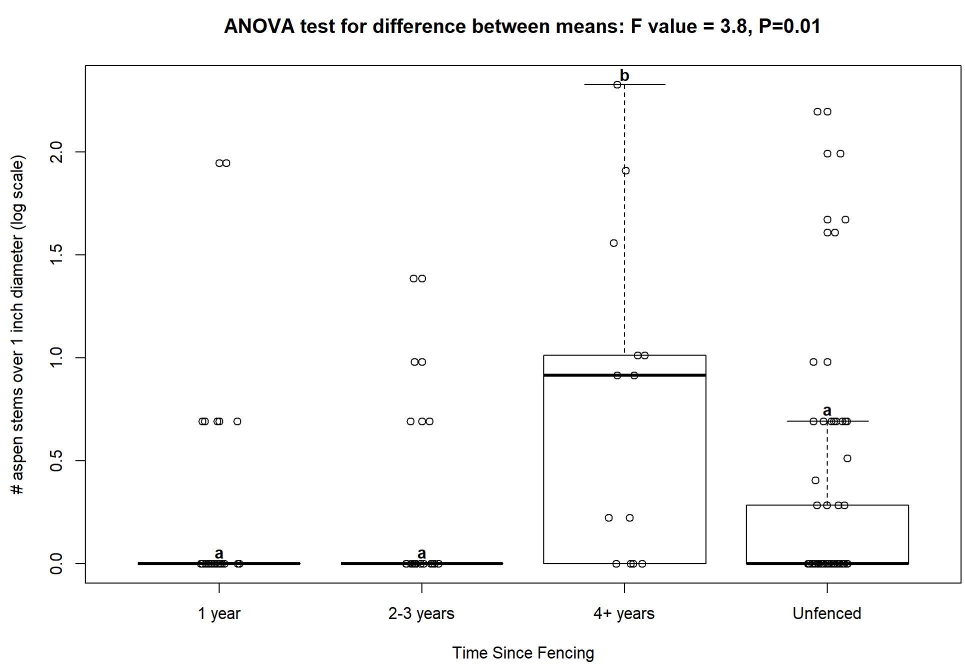
b) Counts of aspen stems 18 inches to 5 feet tall



c) Counts of aspen stems 5 feet tall to 1 inch diameter



d) Counts of aspen stems over 1 inch diameter



A linear regression of aspen stem counts (from Point Blue survey data) including only treated locations shows that high aspen canopy cover is associated with higher aspen stem counts (Table 2). Site condition also influences stem counts, with both riparian and lithic sites having lower stem counts, while time since treatment has a positive effect. Fencing presence did not have a clear association with aspen stem counts, but prior to removing that variable from the regression model the effect was positive (though not significant). The total variance explained by this regression is only 0.249, however, illustrating that the majority of factors influencing variation in aspen stem counts was not accounted for in our model.

Table 2. Multiple regression model evaluating factors influencing aspen stem counts (Point Blue survey data) in the Almanor Ranger District of the Lassen National Forest. Global model included the following additional covariates that were removed through model selection (listed in order of removal) – slope, basal area, conifer cover, shrub cover, fencing, herbaceous cover. AIC of global model = 136.7, AIC of final model = 123.3.

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
Type: lithic	-1.06561	0.57464	-1.854	0.07126
Type: riparian	-0.85853	0.43332	-1.981	0.05464
Type: upland	-0.27557	0.50219	-0.549	0.58631
Years since treat.	0.12399	0.06901	1.797	0.08013
Aspen cover	0.40613	0.14448	2.811	0.00769

Residual standard error: 0.9101 on 39 degrees of freedom

Multiple R-squared: 0.249, Adjusted R-squared: 0.153

F-statistic: 2.584 on 5 and 39 DF, p-value: 0.0412

We found evidence that ARD aspen treatments resulted in increases in the abundance of the overall bird community (Figure 6 right panel), aspen focal species combined (Figure 6 left panel), and several species closely tied to aspen habitat (Figure 7). Combined conifer focal species abundance did not appear to change as a result of treatment. We found evidence that four of the eight aspen focal species we investigated increased in abundance as a result of treatment, and one, Dusky Flycatcher, declined (Figure 7). The species that appeared to increase in abundance after treatment, include: MacGillivray's Warbler (MGWA); Western-wood Pewee (WEWP); Hairy Woodpecker (HAWO); and Red-breasted Sapsucker (RBSA). Of the conifer focal species (Figure 8), Dark-eyed Junco (DEJU) and Olive-sided Flycatcher (OSFL) appeared to increase after 5+ years post-treatment, while Red-breasted Nuthatch and Golden-crowned Kinglet appeared to decrease. While aspen focal species combined increased during the initial post-treatment period at treated stations and remained at similar abundance 5+

years post-treatment, the conifer focal species were unchanged in the initial post-treatment period relative to pre-treatment and then increased in the later post-treatment period but did so equally at treatment and controls, suggesting no treatment effect. We found large variation in abundance of many species from the pre-treatment to post-treatment periods at both treated and control sites.

Figure 6. Bird community response to mechanical aspen treatments on the Almanor Ranger District. All species combined (n=32), aspen focal species (n=8), and conifer focal species (n=6). Abundance (y-axis) is calculated as the number of individuals per hectare.

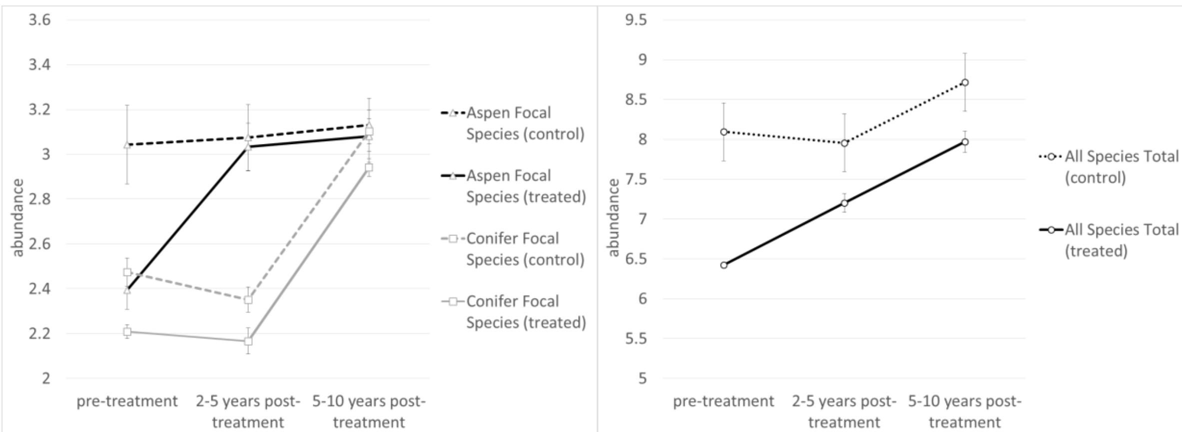
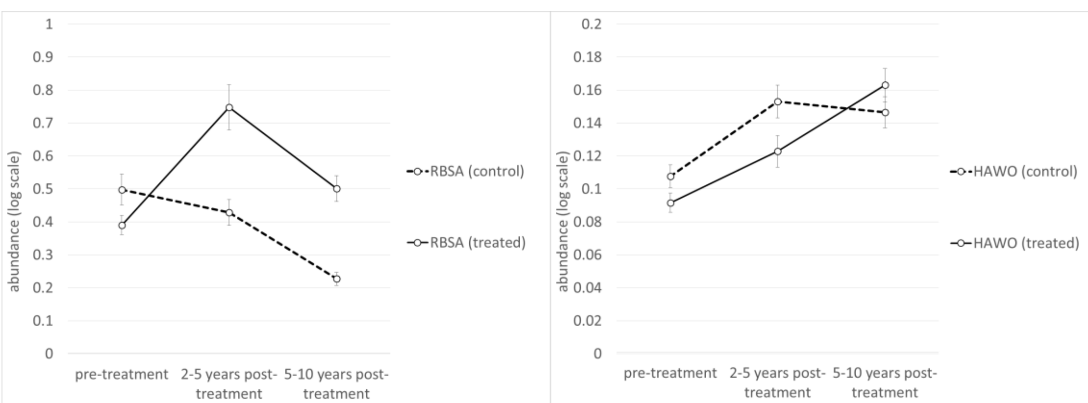
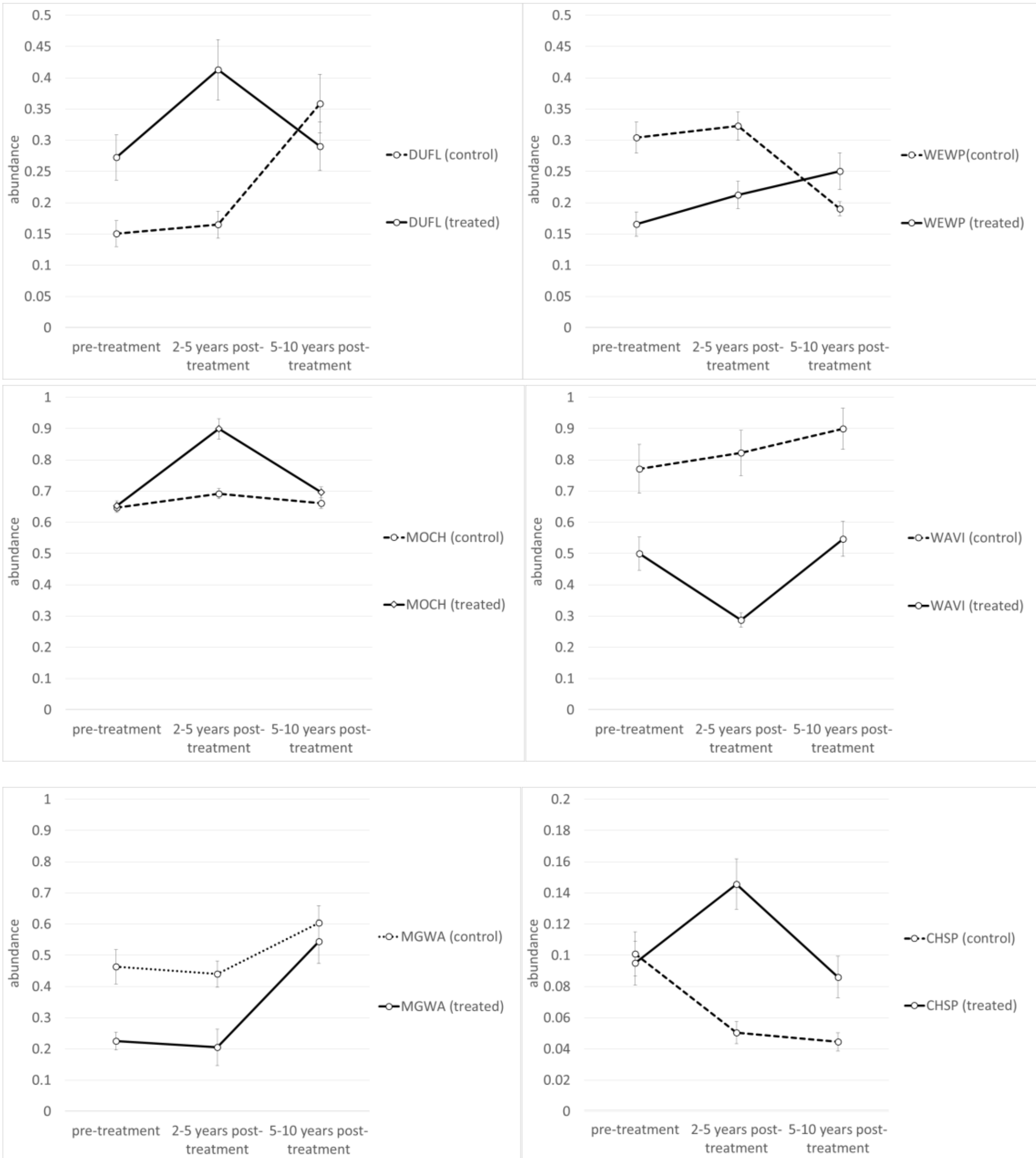


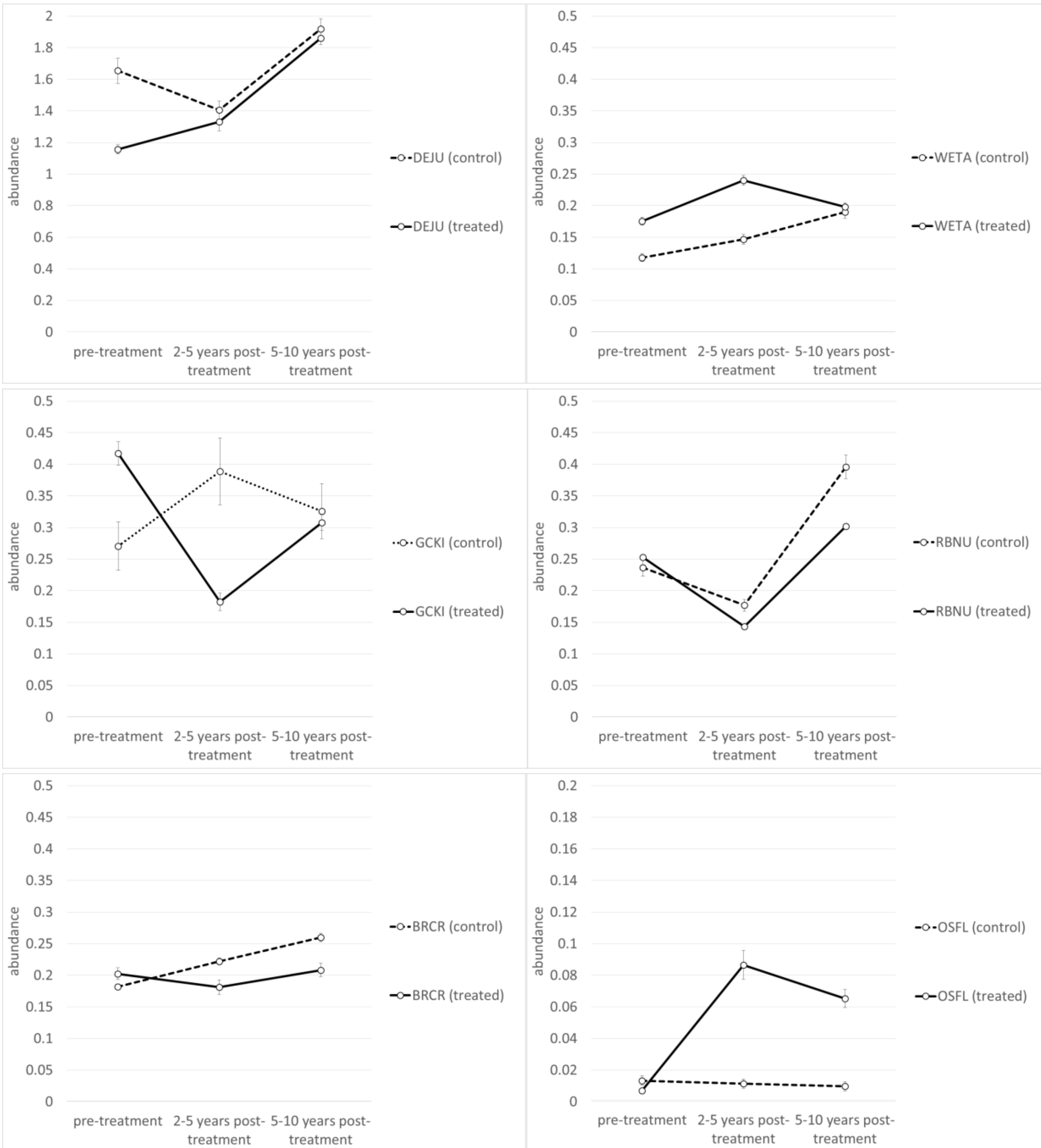
Figure 7. Aspen focal species response to mechanical treatment (4 letter bird codes defined in Table 1). Abundance (y-axis) is calculated as the number of individuals per hectare.





abundance
pre-treatment
2-5 years post-treatment
5-10 years post-treatment
DUFL (control)
DUFL (treated)
WEWP(control)
WEWP (treated)
MOCH (control)
MOCH (treated)
WAVI (control)
WAVI (treated)
MGWA (control)
MGWA (treated)
CHSP (control)
CHSP (treated)

Figure 8. Conifer focal species response at mechanical aspen treatments and untreated controls (4-letter bird codes defined in Table 1). Abundance (y-axis) is calculated as the number of individuals per hectare.



DISCUSSION

Treatments designed to restore aspen habitat at these locations had marked changes to the vegetation community but recruitment of new aspen stems was not as robust as we may have expected. Specifically, there was a large reduction in the cover of competing overstory conifers and large increase in herbaceous vegetation. There is also evidence that treatments resulted in an increase in recruitment of larger aspen stems over 5' tall and especially over 1" DBH. The lack of clear changes in aspen canopy or sub-canopy cover was expected as it will take more time to recruit new aspen stems into those size classes. However, the lack of an increase in small aspen stem recruits is contrary to results found on the Eagle Lake Ranger District (Jones et al. 2005a). The driver of these differences is not clear but we speculate on several potential causes here that may help guide restoration of Storrie Fire aspen stands. This muted recruitment may be due to heavy herbivory, primarily from deer in this study area. We found some evidence that fences increased aspen recruitment but delays in erecting fences may have reduced the effectiveness in these fences protecting the initial flush of aspen stems following treatment. Additionally, a number of the treated stands occur in dense lava rock, which may have a more limited capacity to expand than the stands studied by Jones et al. (2005a). We found lava based aspen had significantly lower recruitment of aspen stems than upland.

Finally, the influence of the historic drought in California that coincided with the early post-treatment period for many of these stands may have reduced recruitment. Drought has been shown to have large effects on aspen stand recruitment and overall biomass elsewhere in its range (Hogg et al. 2008 Huan & Anderegg 2012). If, recruitment of aspen stems is key to the success of these treatments, a better understanding of the factors driving recruitment and survival is critical. Low recruitment of smaller stems might be directionally related to the drought years. This in comparison to the understory response in a wet year may help explain the low recruitment. Especially since there was an obvious die off of aspen stems in those years we observed on many sites.

As for causal factors that drive aspen recruitment, it appears that locations where aspen canopy cover and herbaceous cover is high, and where shrub cover is low may lead to higher numbers of aspen suckers. It is not clear why herbaceous vegetation cover would influence aspen recruitment but it may be that herbaceous cover is an indicator of soil moisture and good growing conditions that favor both herbs and aspen. Shrubs are likely a direct competitor with new aspen recruits for water and sunlight.

Both the recruitment of new stems as well as their ability to survive to this release from herbivory are critical to achieving the goal of increased mature aspen stems in these degraded stands. Fencing appears to benefit the recruitment of aspen stems, and will likely aid those locations in completing the transition from sapling to stems freed from ground based herbivore pressure. Other work in this region has shown that aspen recruitment is highest when browse pressure on the terminal leader portion of the stem is minimized (Jones et al. 2009). We recommend fencing stands immediately following treatment as a best practice anywhere herbivory has the potential to impact recruitment and increasing recruitment is an objective.

Total bird abundance increased at both the reference and treated stations over the time span of this study, and it does appear that the aspen treatments benefitted aspen focal species. The Sierra Nevada bird community is highly resilient to disturbance and many species are adapted to a multitude of post-disturbance conditions (e.g. Campos and Burnett 2014, Stephens et al. 2014, Taillie et al. 2018, Roberts et al. 2019) so the finding that many species increase following removal of very high densities of conifers is not overly surprising. Aspen focal species abundance did increase in the initial post-treatment time period relative to the reference stations, largely due to three species that we have previously found to respond positively to aspen treatments in the short term; Hairy Woodpecker, Western Wood-pewee, and Red-breasted Sapsucker. Particularly interesting is that none of the conifer focal species were strongly negatively affected by treatments, though Golden-crowned Kinglet and Red-breasted Nuthatch both appear to decline in the initial post-treatment period. This result is also consistent with the only other study on bird response to aspen treatments in the Sierra-southern Cascade region (Campos and Burnett 2014). These results continue to reinforce the finding that aspen restoration treatments will have largely positive effects on aspen associated birds and few negative impacts on conifer associated species. One key caveat to this is that these treatments occurred in relatively small stands and retained some conifer cover. We would expect that complete removal of conifers over larger areas would likely result in more negative impacts to several of the conifer associates.

There were some limitations of study design and sample size that precluded our ability to implement more elaborate statistical methods. Several of the treated stations in the Point Blue sample could not be included in the post-treatment sample bird models because vegetation surveys were not completed within the initial post-treatment time period. In addition, some stations were fenced over a range of times following treatment, while others were not fenced. Crucially the survey stations were not selected or treated randomly, so some unknown bias was likely implemented on the reference and treated samples as a result. The reference sample included many stations of high quality aspen habitat where treatment was less necessary than in the treated sample, while the treated stations were largely at high risk of extinction due to conifer encroachment. Thus, the comparison of vegetation conditions at treated vs reference stations over time is likely biased by this effect. However, there is great value in monitoring real-world treatments to help guide adaptive management. In that spirit we provide the following recommendations for managing and restoring aspen on the ARD, including within the Storrie Fire footprint. These recommendations are based on the known literature, the results of this study, and expert opinion of the authors. They are intended as hypotheses that should be tested.

Storrie Fire Aspen Restoration Management Recommendations

Based on the findings of this study we suggest the following recommendations for treating Aspen within the Storrie Fire footprint.

- Treat aspen stands in the Storrie Fire area to increase focal bird abundance, aspen recruitment, and the herbaceous plant community.
- When appropriate the retention of some large pines could enhance structural complexity within stands for other edge associated species (e.g. Olive-sided Flycatcher)
- Identify herbivory issues prior to treatments and fence any stands where herbivory may impact post-treatment recruitment immediately following treatment (prior to the first growing season).
- While saving stands near extirpation is wise, the greatest response will likely occur in stands with a substantial remnant aspen component. Don't focus all resources on managing the stands with the highest risk of being lost in order to maximize benefits to wildlife in the short term.
- Consider the use of fire where a large aspen recruitment is desired and where loss of mature stems would be acceptable.
- Prioritize treatments in areas with greater soil moisture to minimize drought impacts to recruitment and increase potential resilience to climate change.
- Prioritize restoration in non-lithic stands if vigorous aspen regeneration is an objective.
- Minimize as much variation in treatment/fencing timing and develop a monitoring strategy that informs treatment timing and prescriptions to allow for a robust evaluation of treatment effects.

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