Response of Bumble Bees to Postfire Shrub Removal Treatments on Eldorado National Forest

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Top: Bombus melanopygus on *Trifolium hirtum; lower left: B. vosnesenskii on Helenium bigelovii;* lower right*: B. vosnesenskii on Vicia spp.* Photos by A.Schrage

INTRODUCTION

Bumble bees (*Bombus* spp.) provide vital ecosystem services as pollinators of both native plant species and agricultural crops (Kearns and Inouye 1997). However, many bumble bee species are declining across the northern hemisphere due to causes that are often inter-related and include habitat loss and fragmentation (Goulson et al. 2008, Koh et al. 2016), agricultural practices (Carvell 2002, Williams and Osborne 2009, Wu-Smart and Spivak 2018), altered fire regimes (Taylor and Catling 2012), and the fungal pathogen *Nosemi bombi*, which is believed to have been transmitted from domesticated bumble bees (Cameron et al. 2011, Koch and Strange 2012). Climate change is another cause of decline (Potts et al. 2010), leading to shifts in the ranges of bumble bees (Kerr et al. 2015) and temporal mismatches between bumble bee life-cycle phenology and the floral resources they require (Miller-Struttmann et al. 2015). Unless widespread declines in bumble bees and other pollinators (Koh et al. 2015) are better understood and addressed (LeBuhn et al. 2013), the functional integrity of natural ecosystems may be compromised (Ollerton et al. 2011) and agricultural crop production could be greatly reduced (Klein et al. 2007). With widespread declines of bumble bees attributed in part to habitat loss (Goulson et al. 2008, Koh et al. 2016), it is essential to understand how habitat characteristics influence bumble bee abundance and diversity, and to use that understanding to guide land management efforts towards improving habitat for bumble bees and other pollinators (Goulson et al. 2011).

In the Sierra Nevada, bumble bees are often found at highest densities in montane meadows (Hatfield and LeBuhn 2007) and other riparian areas (Cole et al. 2019, 2020), but burned or otherwise disturbed upland forested areas also provide habitat when abundant flowering plants and suitable nesting burrows exist (Grundel et al. 2010). We conducted systematic bumble bee (*Bombus* spp.) surveys throughout the area burned by the 2004 Power and 2004 Fred's fires from 2015-2017. We used those data to describe patterns of bumble bee species richness and abundance across the two burned area, and to identify the plant species that were most frequently used by foraging bumble bees (Loffland et al. 2017, 2018). We found that plots dominated by herbaceous vegetation had greater bumble bee abundance and species richness, and that one chaparral shrub species, bear clover (*Chamaebatia foliolosa*), was foraged on preferentially over all other shrub species and over all but 1 forb taxon, and was associated with increased occupancy probability in the Vosnesensky bumble bee (*Bombus vosnesenskii*), the most abundant bumble bee species on our study plots. A complex of closely related herbaceous species in the genus *Phacelia*, commonly associated with upland chaparral in our study area, was the plant taxon most frequently used by bumble bees, and appeared to be particularly important during midsummer after bear clover flowers became scarce. More generally, we found that Bumble bee abundance and species richness were substantially greater in riparian plots than in upland, chaparral-dominated plots, but given the much greater extent of upland habitat on the landscape, chaparral-dominated habitats were clearly important to bumble bees, and accounted for the majority of the bumble bees we caught.

Here we report on analyses based on our previous data from the Power and Fred's fires, plus two additional years (2018 and 2019) of data collection at the Power fire. With these additional data, we sought to build on our understanding of which post-fire vegetation communities and specific areas within the fire footprints provide the most important habitat for bumble bee species, and to use bumble bee survey data collected before and after shrub reduction treatments within our study areas to assess how the treatments affected the occurrence of individual bumble bee species. In Sierra Nevada forests, montane chaparral that develops in forest openings created by fire or timber harvest is often cleared in preparation for planting conifer seedlings, and in subsequent years may be treated again to reduce competition with naturally occurring or planted conifer seedlings and saplings (McDonald and Everest 1996, McDonald et al. 2004) in areas where reforestation is a management priority. In areas where montane chaparral is dense, it may also be treated within a fuels reduction effort in places with high wildfire risk. However relatively little is known about impacts of treatment of montane chaparral on wildlife in general, and almost nothing is known about how these activities impact insect pollinators like bumble bees.

During our study, post-fire shrub treatments included prescribed fire, mechanical thinning, and chemical treatment (Figure 1), each of which was applied at a unique subset of our study plots during various years between 2016 and 2019. The treatments were not implemented within the framework of a designed study, and we had no control and limited foreknowledge of where and when they would be implemented, but we nevertheless sought to assess and compare their effects on bumble bee occurrence over several years.

Figure 1. Example of untreated bear clover in foreground and chemically treated bear clover in background.

METHODS

Site Selection

We surveyed bumble bees within 20-m radius plots located throughout the areas burned by the Power fire (Fig. 2) and Fred's fire (Fig. 3) on Eldorado National Forest. For efficiency during surveys, most of the plots were clustered in groups of five, with a central plot and 4 additional plots centered 100 m from the mid-point of the central point in each cardinal direction. We determined locations for the 5-plot clusters using a random design stratified by 3 elevation bands (<1372 m, 1373 m – 1676 m, and >1676 m) and 2 treatment categories (inside and outside treatment units that included herbicide application, grubbing, or mastication), with the centers of plot clusters located a minimum of 275 m apart. Whether a plot was initially projected to be inside or outside of a treatment area was based on planning maps provided by the Amador ranger district in 2015. Final group membership within a treated or untreated group was based on post-treatment data summarized from the FACTS GIS data layers, and consultation with Forest Service staff. In addition, we deliberately placed additional plots in riparian plant communities which were relatively rare within out study areas and not well represented in our random sample, but which we believed might host distinct floral resources and possibly distinct assemblages of bumble bees. In 2018 additional plots were placed 100m apart in two planned meadow restoration project areas on the Amador ranger district to provide baseline conditions for future monitoring of restoration effects. In all instances, plot coordinates were selected based on existing geospatial land cover information using ArcMap 10.3 (Environmental Systems Research Institute, Redlands, CA), and then navigated to in the field.

Crew Training and Certification

All data were collected by full-time crew members working or volunteering for The Institute for Bird Populations. At the beginning of the field season, crew members underwent an intensive 1-week bumble bee survey training session to ensure surveyors were fully competent and qualified to collect reliable data on bumble bees and vegetation. At the end of the training session all crew members passed a rigorous bumble bee identification exam that tested the skills necessary to survey and identify bumble bees in the field.

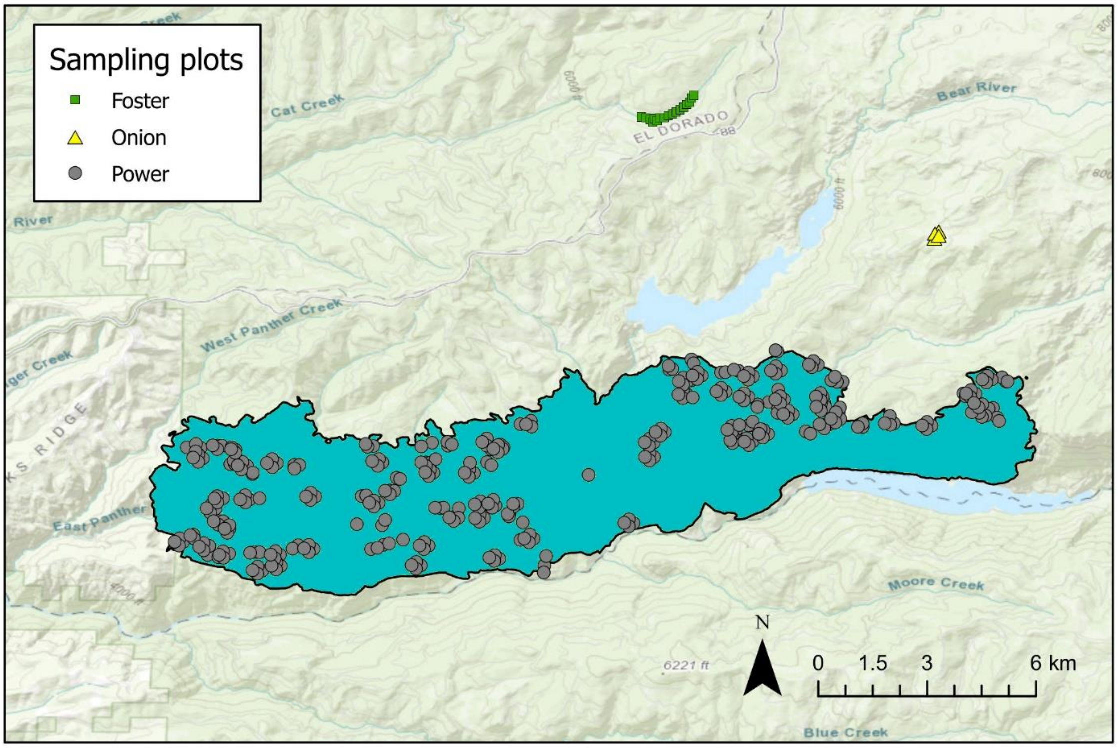

Figure 2. Bumble bee plots that were surveyed annually from 2015 to 2019 within the Power fire (gray circles within turquoise filled polygon) and meadow restoration projects in Foster Meadow (green squares) and Onion Valley (yellow triangles) on Eldorado National Fo

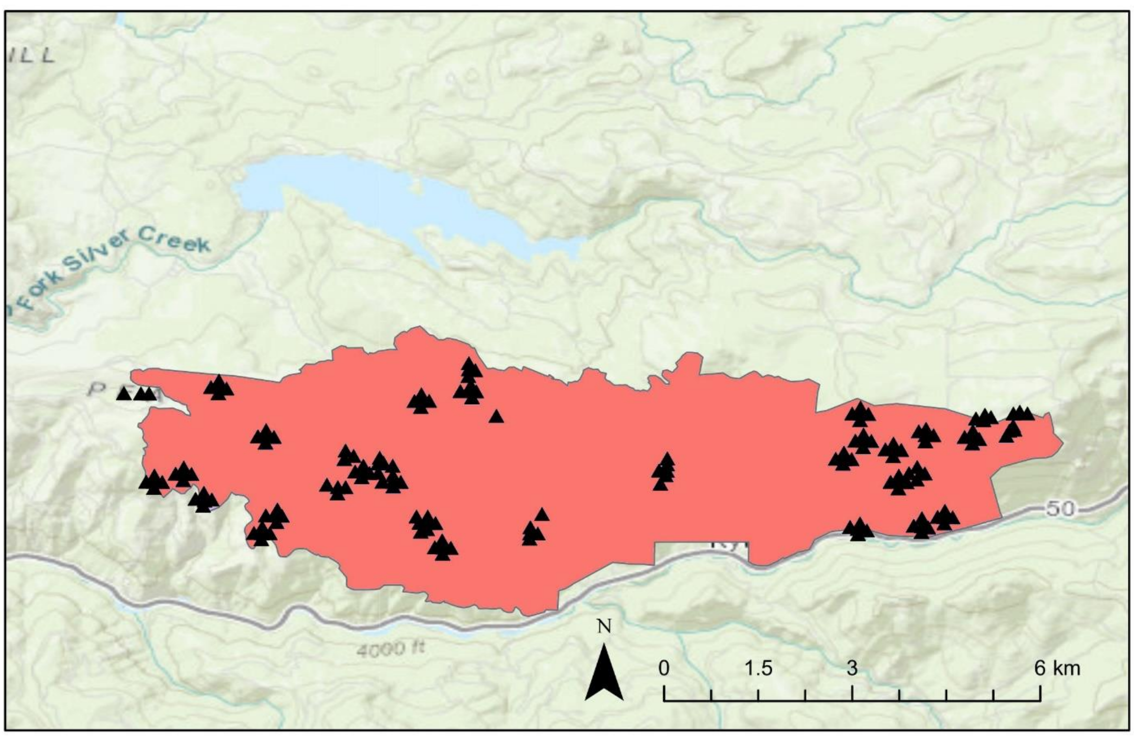

Figure 3. Bumble bee plots (black filled triangles) that were surveyed annually from 2015 to 2017 within the Fred's fire (red filled polygon) on Eldorado National Forest.

Data Collection

Bumble Bee Surveys

Bumble bee surveys were conducted within 20-m radius plots centered at predetermined survey locations. When survey plots spanned roads, terrain that was too steep to survey, or areas that were inaccessible for other reasons, they were relocated up to 20 m from the intended plot location. Each plot was surveyed for bumble bees during a 16-min survey period between 0830 and 1900 hrs. During that period a single observer would visually scan and walk throughout the plot. When a bumble bee was encountered within the 20-m radius plot, the surveyor would capture the bee and suspend the survey until the bumble bee was transferred to a numbered vial and placed in a cooler to chill. The surveyor also recorded the plant species on which the bumble bee was caught (or noted if the bumble bee was caught in flight). Once the bee was in the cooler, the survey was resumed and the search time continued until another bee was caught. At the end of the 16-min survey period, or the passing of 1 hour of searching and capturing of bumble bees combined, the survey was ended. Chilled bumble bees were photographed from various angles and characteristics used to identify the bumble bee to species (i.e. cheek length, face color, terga color, number of terga, corbicula presence) and caste (queen, worker, drone) were recorded. After a few minutes outside the cooler to warm, the bumble bees were released.

Plots were typically surveyed three times during the field season according to a random survey order within the 3 elevation bands, such that plots in the lower elevation band were visited earlier in the season than plots in the higher elevation bands to account for earlier bloom and bumble bee emergence cycles at lower elevations. Plots were surveyed between May 4 and August 28. The timing of the surveys was based on information about the timing of emergence of the bumble bee species expected to be found in the survey region (Koch et al. 2012).

Floral Resource and Habitat Assessment

Before beginning each bumble bee survey the surveyors collected data on weather conditions (i.e., temperature, cloud cover). They identified and recorded all blooming plants in the plot and estimated the number of inflorescences blooming at the time of the visit on a logarithmic scale. Surveyors also completed a habitat assessment after the initial bumble bee survey at a plot. Within the 20 m-radius survey plot, surveyors recorded overstory and mid-layer cover estimates for conifers, hardwoods, and shrubs (by species), relative cover of understory vegetation by type and the relative cover of abiotic ground cover components.

Data Analysis

Bumble Bee Abundance

We summarized changes in bumble bee abundance by species between years as both a simple sum of bee captures and as a metric of captures relative to sampling effort. To account for uneven sampling between years we divided annual number of captures of each bumble bee species by the annual number of plot surveys completed. For example, if *Bombus vosnesenskii* was captured 40 times in 2016 and there were 100 plot visits in that year the adjusted abundance estimate would be 0.4 bees per plot visit. When plotting trends in abundance we standardized the adjusted abundance numbers to have a mean of 0 and a standard deviation of 1, so years with abundance metrics greater than the mean have values >0 and years lower than the mean have values <0. Standardization allows us to plot changes in abundances from all species using the same scale.

Foraging Use of Blooming Plant Species

We report bumble bee use of flowering plant species by summing total bumble bee captures per species and year within each study area (including the Foster Meadow and Onion Valley restoration projects). In order to compare changes in plant usage across years we plotted the top 10 most used plants in a grid for each study area, enabling one to determine if a plant species was within the top 10 list over multiple years. For difficult to identify species we grouped plants into taxonomic "complexes" Appendix Table A1)

Bumble Bee Response to Plot Treatments – Between-year Changes

We assessed the effects of three categories of plot treatments by comparing the proportion of occupied non-treated plots to the proportion of occupied treated plots by a given bumble bee species each year. Plot treatments to reduce shrubs were grouped into the categories of prescribed burning, mechanical thinning, and chemical application (Appendix Table A2). We initially attempted to use occupancy modeling to estimate the effect of treatments on occupancy state of plots while accounting for imperfect detection, but the limited number of treated units and strong interannual variation in bumble bee occurrence patterns hindered model fitting. We instead compared uncorrected detection rates of bumble bee species, as if any bee species present at plots were detected without error. The assumption of error-free detection is likely invalid, but it nonetheless allows estimation of change in response to plot treatments. However, we note that those estimates could be biased if treatments effect detection probability (i.e., probability of detecting species that are present is either improved or degraded after treatment application).

For each species, we calculated the difference in the proportions of treated and untreated plots that were occupied each year (treated plot proportion minus non-treated plot proportion). For instance, if *B. mixtus* occupied 0.75 of non-treated plots in 2016 and 0.25 of treated plots in 2016, then the occupancy proportion difference for 2016 would be -0.50. The negative sign indicates a preference for non-treated plots in that year. We use the proportion differences for the years prior to treatment to determine the variation in occupancy and compared it to occupancy proportion in the post-treatment year. We calculated the mean and standard error of the proportion difference for the pre-treatment years and used this to assess whether the proportion difference changed significantly in the post-treatment year.

We present the estimate of change in occupancy proportion as percentage change in proportion difference pre-treatment to post-treatment along with variation around the mean (1.96 * SE). For example, if the mean pre-treatment proportion difference was 0.5 (± 0.25) and the post-treatment proportion difference was 0.1, then the mean change in occupancy proportion would be -0.4 (± 0.25). Because the lower and upper bounds of change in this example were, respectively, -0.65 to -0.15, and did not include 0, we would consider the treatment effect significant. We caution again that our measure of significance does not account for imperfect detection and may be confounded by changes in detectability of a species due to treatment of vegetation (e.g., less vegetation may make a bee more visible to a surveyor and make it appear as though a species is occupying more plots).

Bumble Bee Response and Exposure to Chemical Treatment – Within-year Changes

We evaluated the effect of chemical treatment (in this case the application of one of many herbicide mixtures) on the persistence of bumble bee species on plots by identifying plots that had been chemically treated between the first and second plot visit in a given year. This method allowed us to compare pre-treatment presence to post-treatment presence, in the same year. Of the plots we surveyed, 53 met this criterion. We report persistence for two species, *B. vosnesenskii* and *B. vandykei*, because these were the only species detected at >1 of the 53 treatment plots. We also report the proportion of plots where bumble bees occurred after chemical treatment and we assume may have been exposed to some level of herbicide.

Change in Flowering Plant Richness in Response to Plot Treatments

In addition to looking directly at bumble bee occurrence, we evaluated the effect of prescribed burning, mechanical thinning, and chemical application treatments on flowering plant richness, by which we mean the number of plant species that were flowering at the time of the survey. However, for this analysis we wanted to determine the pre-treatment and post-treatment plant richness at plots *within the same year*, so we only considered plots that received a treatment after plot visit 1 and prior to plot visit 2. This more restrictive criterion resulted in a slightly different sample size than the bumble bee occupancy comparison. For a site to be considered a control it must have had no plot treatments for the duration of the sampling years (if any treatment polygon crossed into the plot that to any extent, that plot was considered a treatment plot rather than a control plot). We calculated a ratio of flowering plant richness by dividing the mean flowering plant richness at treatment plots by mean richness at control plots in each year. This value could be near 1, greater than 1, or <1, which indicated equal plant richness in control and treatment, higher richness at treatment plots, or lower richness in treatment plots relative to control plots, respectively. We then subtracted the post-treatment ratio from the pre-treatment ratio to get an index of change in difference in plant richness due to plot treatment. For example, if the post-treatment ratio was 1.5 and the pre-treatment ratio was 2.0, then the change index would be 0.5 and would indicate that the treatment had a negative effect on plant richness at treatment plots.

RESULTS

Bumble Bee Abundance

We captured and identified 1,205 bumble bees of 12 species during sampling spanning 2015 to 2017 at the Fred's fire and 3,171 bumble bees of 10 species spanning 2015 to 2019 at the Power fire (Table 1). *Bombus vosnesenskii* and *B. vandykei* were by far the most frequently captured species. The least frequently encountered species were *B. appositus, B. sylvicola, B. rufocinctus,* and *B. fernaldae* at both the Fred's and Power fires (Table 1).

Table 1. Bumble bee captures and percent of captures of all species at each of the two fire areas. Total captures are summed across 2015 to 2017 for the Fred's fire and 2015 to 2019 for the Power fire.

	Fred's fire		Power fire	
Species	No. of captures	Percent of captures	No. of captures	Percent of captures
B. appositus	2	0.2	0	0.0
B. bifarius	5	0.4	73	2.3
B. californicus	22	1.8	121	3.8
B. fernaldae	4	0.3	10	0.3
B. flavifrons	34	2.8	29	0.9
B. insularis	8	0.7	73	2.3
B. melanopygus	67	5.6	291	9.2
B. mixtus	9	0.7	118	3.7
B. rufocinctus	4	0.3	2	0.1
B. sylvicola	2	0.2	0	0.0
B. vandykei	136	11.3	571	18.0
B. vosnesenskii	912	75.7	1,883	59.4
Total	1,205		3,171	

Numbers of captures of individual bumble bee species varied greatly between years; at each fire the number of captures of a given species in the year it was most abundant was frequently more than double the number of captures in the year it was least abundant (Fig. 4, Table 2). In some years captures of the majority of species trended in the same direction; for instance, in 2016 captures of 8 of 12 species increased relative to 2015 levels and this pattern held true in both the Fred's and Power fire study areas (Fig. 4, Table 2). Even when bee captures were corrected for sampling effort the interannual patterns were apparent across species (Table 3). However, overall the trajectories of the various species appeared to operate quite independently of one another, with no particular year being associated with uniformly high or low numbers for all species.

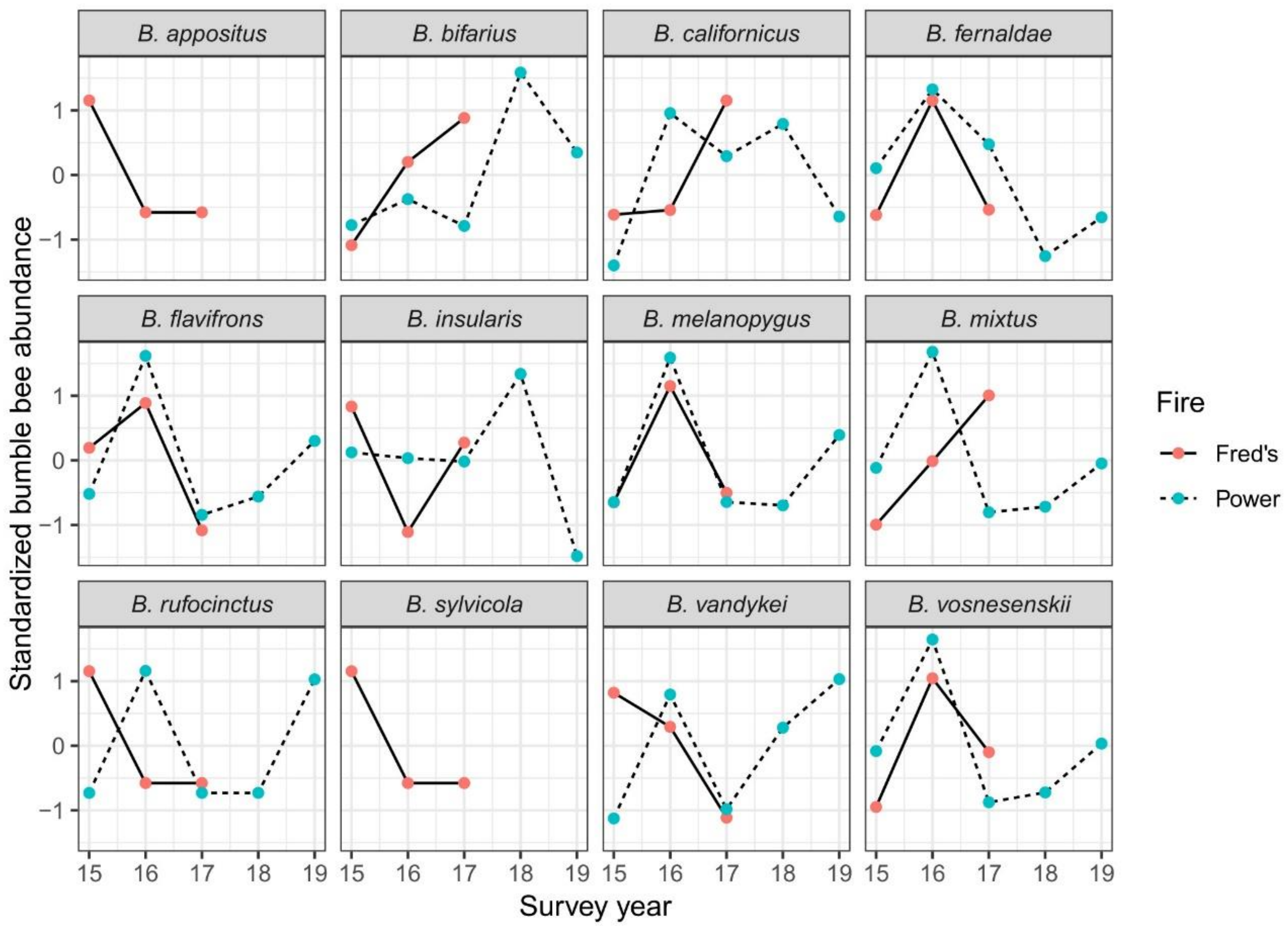

Figure 4. Interannual change in standardized bumble bee captures per species for both the Fred's and Power Fire study areas. Values on x-axis represent standard deviations away from the mean abundance across all years. For example a value of -1 represents an abundance 1 SD below the mean, and 1 indicates an abundance 1 SD above the mean.

Table 2. Total bumble bee captures aggregated by species, study area (Fred's or Power fire), and sampling year. Cell fill color corresponds to either increase (green), decrease (light blue), or no change (white) in bumble bee captures relative to the previous year.

	Fred's fire			Power fire				
Species	2015	2016	2017	2015	2016	2017	2018	2019
B. appositus	2	0	0	0	0	0	0	0
B. bifarius	0	2	3	1	6	1	49	16
B. californicus	6	6	10	10	27	25	42	17
B. fernaldae	1	2	1	2	4	3	0	1
B. flavifrons	12	13	9	2	16	0	3	8
B. insularis	4	1	3	12	12	13	35	1
B. melanopygus	0	62	5	11	165	13	13	89
B. mixtus	0	3	6	19	56	7	13	23
B. rufocinctus	4	0	0	0	1	0	0	1
B. sylvicola	2	0	0	0	0	0	0	0
B. vandykei	70	53	13	39	137	54	181	160
B. vosnesenskii	166	462	284	313	792	132	258	388
Total	267	604	334	409	1216	248	594	704

Table 3. Total bumble bee captures divided by number of plot visits conducted at each fire area in each year. Cell fill color corresponds to either increase (green), decrease (light blue), or no change (white) in standardized captures relative to the previous year.

	Fred's fire			Power fire				
Species	2015	2016	2017	2015	2016	2017	2018	2019
B. appositus	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000
B. bifarius	0.000	0.006	0.009	0.002	0.009	0.001	0.046	0.023
B. californicus	0.018	0.018	0.031	0.016	0.041	0.034	0.039	0.024
B. fernaldae	0.003	0.006	0.003	0.003	0.006	0.004	0.000	0.001
B. flavifrons	0.035	0.039	0.028	0.003	0.024	0.000	0.003	0.011
B. insularis	0.012	0.003	0.009	0.019	0.018	0.018	0.033	0.001
B. melanopygus	0.000	0.187	0.015	0.018	0.251	0.018	0.012	0.126
B. mixtus	0.000	0.009	0.018	0.030	0.085	0.010	0.012	0.033
B. rufocinctus	0.012	0.000	0.000	0.000	0.002	0.000	0.000	0.001
B. sylvicola	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000
B. vandykei	0.205	0.160	0.040	0.063	0.209	0.073	0.169	0.227
B. vosnesenskii	0.485	1.392	0.871	0.502	1.205	0.180	0.242	0.550

Foraging Use of Blooming Plant Species

We captured bumble bees on 154 plant species or complexes when data were pooled from both study areas and all years (Appendix Table A3). The Phacelia complex had the greatest number of bumble bee captures of all plant taxa, and comprised 18.2% of all captures.

The Phacelia complex was also among the top 10 taxa most foraged on by bumble bees across all years at the Fred's fire (Fig. 5), where plants ranking in the top 10 varied between years and only three additional species (*Chamaebatia foliolosa*, *Hosackia crassifolia*, and *Solidago canadensis*) were present in the top 10 across all sampling years. The top 10 most used plants at the Power fire also varied across years and, similar to Fred's fire, only five species or complexes (*Chamaebatia foliolosa*, *Cirsium vulgare*, *Helenium bigelovii*, Phacelia complex, and Stickseed complex) maintained their top 10 ranking across all years (Fig. 6).

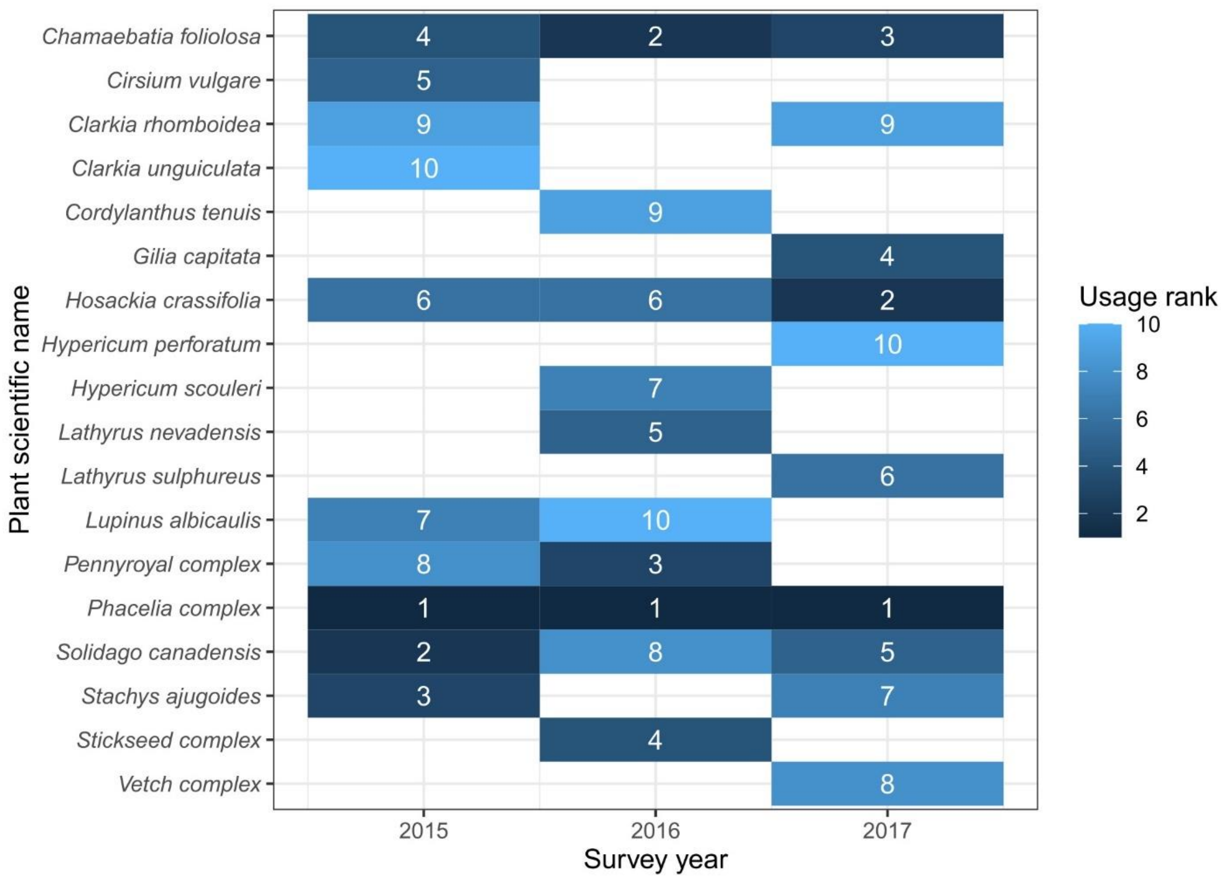

Figure 5. The top 10 plant species with the greatest number of bumble bee captures at the Fred's fire study area in each year. Shaded cells represent the ten plant species or complexes that yielded the most bumble bee captures, with cell fill color and the number within the cell representing rank within that group (smallest rank indicates greatest number of captures).

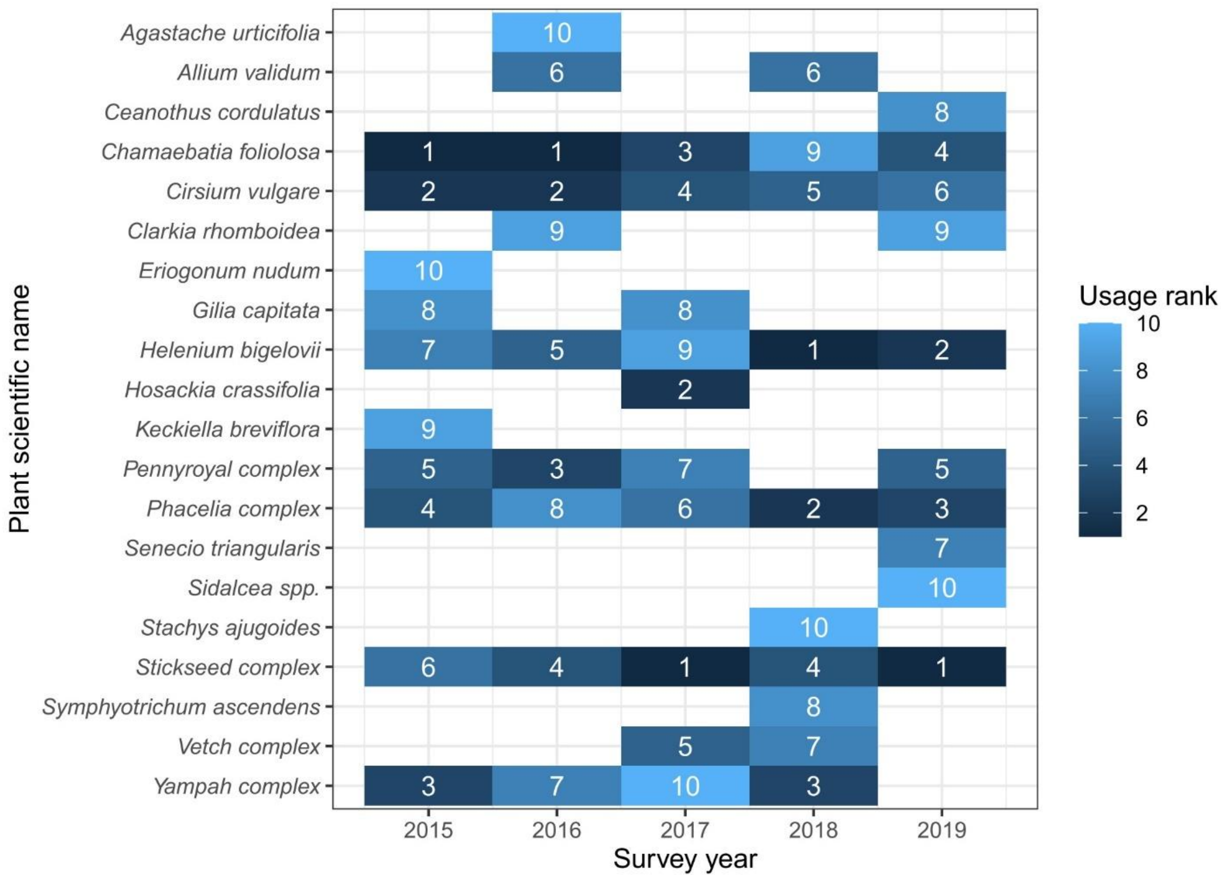

Figure 6. The top 10 plant species with the greatest number of bumble bee captures at the Power fire study area in each year. Shaded cells represent the ten plant species or complexes that yielded the most bumble bee captures, with cell fill color and the number within the cell representing rank within that group (smallest rank indicates greatest number of captures).

Bumble Bee Response to Shrub Treatments

Six bumble bee species were detected frequently enough to assess their response to postfire shrub treatments: *B. bifarius*, *B. californicus*, *B. flavifrons*, *B. mixtus*, *B. vandykei*, and *B. vosnesenskii*. Four treatment histories comprising unique sequences of the three treatment types (prescribed fire, mechanical thinning, and chemical treatment) were implemented at a sufficient number of treatment plots for comparison of change in bumble bee occurrence (Table 4). We created a fifth treatment history that included any plots that were treated by any method in 2019 and had no treatments prior to 2019 (see Table 4, Row 5), to accommodate small numbers of plots that otherwise would not have been analyzable.

Table 4. Treatment histories for five groupings of bumble bee survey plots. Treatment history column lists the annual treatment status of plots in each grouping. Codes for treatment history are as follows: YY-Pre (pretreatment year where neither designated control plots nor treatment plots received a treatment), YY-C (year when treatment plots received chemical treatment), YY-B (year when treatment plots received prescribed fire), and YY-Post (year after treatment plots received treatments).

Treatment history	Description	Treated plots (n)	Control plots (n)
15-Pre, 16-C, 17-Post	Plots treated with chemical solution between last 2015 survey and first 2016 survey	18	57
15-Pre, 16-Pre, 17-Pre, 18-B, 19-M	Plots treated with some form of prescribed fire between last 2017 and first 2018 survey and then mechanical shrub removal in between last 2018 and first 2019 survey	9	84
15-Pre, 16-Pre, 17-Pre, 18-Pre, 19-M	Plots treated with mechanical shrub removal between last 2018 survey and first 2019 survey	15	84
15-Pre, 16-Pre, 17-Pre, 18-Pre, 19-M & C	Plots treated with mechanical shrub removal and chemical treatement between last 2018 survey and first 2019 survey	14	84
15-Pre, 16-Pre, 17-Pre, 18-Pre, 19-B, C, or M	Plots received a mixture of either mechanical, chemical, or prescribed fire treatment between last 2018 survey and first 2019 survey	33	84

Between-year Bumble Bee Response to Plot Treatments

Chemical treatment of plots had a strong negative effect on occurrence in the first year after treatment for 3 of 6 bumble bee species (*B. flavifrons*, *B. vandykei*, *B. vosnesenskii*; Fig. 7). The ratio of occupied control plots to occupied treated plots was similar to the pre-treatment year (2015) two years after treatment (2017). The combination of prescribed fire in 2018 and mechanical thinning in 2019 had a discernable effect on 2 of 6 bumble bee species (Fig. 8). *B. vandykei* occupancy rates increased on treatment plots in 2018 and returned to near pre-treatment levels in 2019 (the year of mechanical thinning treatment). *B. vosnesenskii* occupancy proportion remained stable the year of prescribed fire treatment and then exceeded pre-treatment levels in 2019.

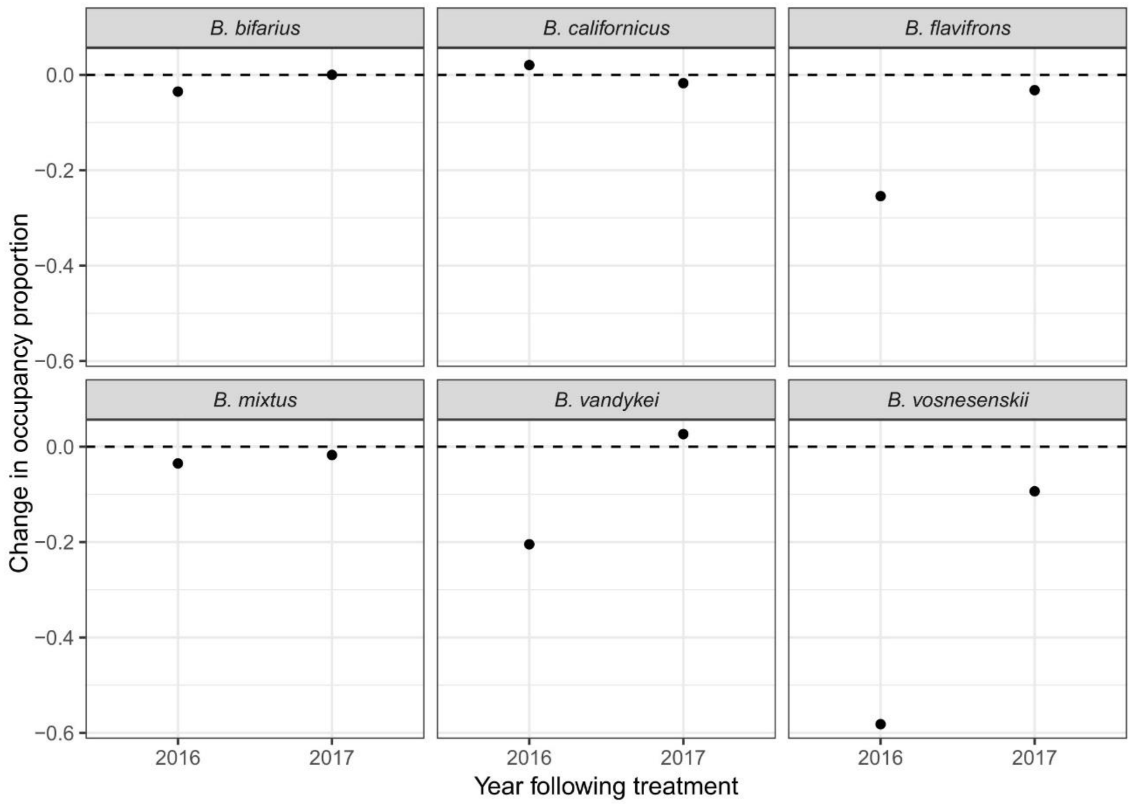

Figure 7. Change in the ratio of occupied chemical treatment plots to occupied control plots, from 2015 to 2016 (2016 label on x-axis) and from 2015 to 2017 (2017 label on x-axis) for each of six bumble bee species. Plots were treated chemically between the last survey of 2015 and prior to the first survey of 2016. Values below the dotted line correspond to a reduction in the number of occupied treatment plots (negative effect of treatment) and values above the dotted line correspond to an increase in occupied treatment plots (positive effect of treatment).

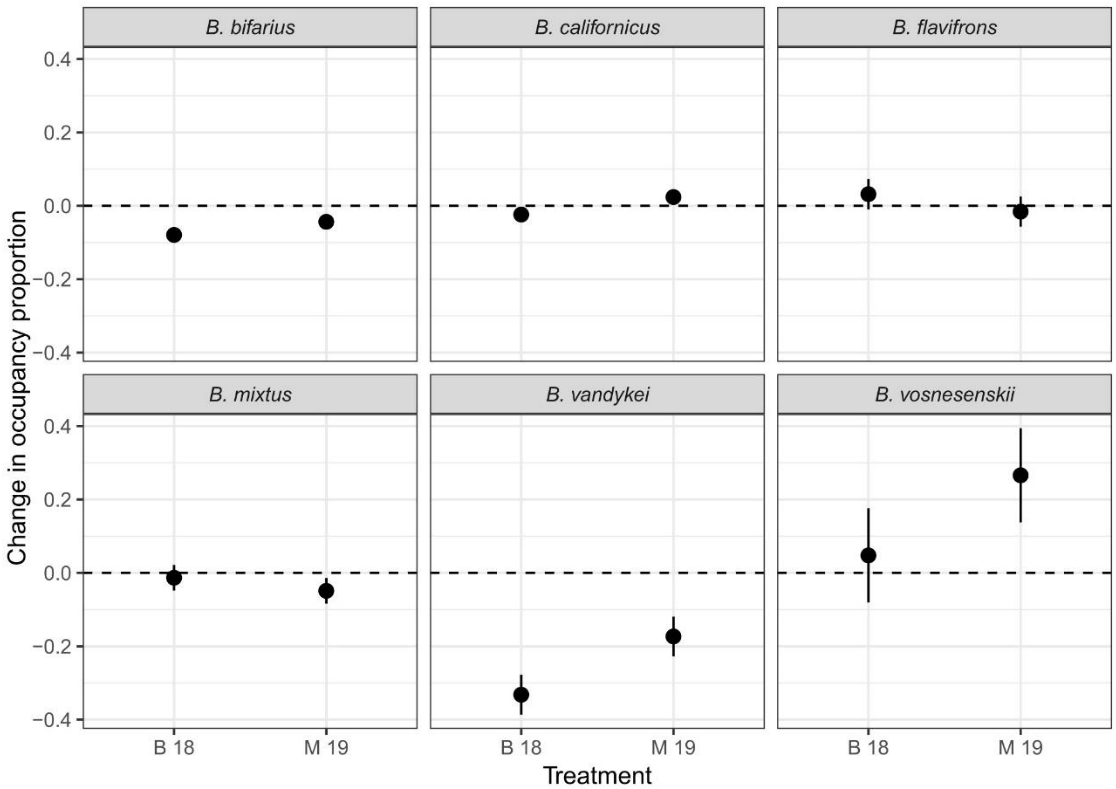

Figure 8. Change in the ratio of occupied prescribed fire and mechanical treatment plots to occupied control plots in 2015 through 2017, to 2018 (dot above B 18) and 2019 (dot above M 19) for each of six bumble bee species. Plots were treated with prescribed fire between the last survey in 2017 and first survey in 2018 (B 2018) and then treated by mechanical thinning in between the last survey in 2018 and first survey in 2019 (M 19). Dots indicate how much the occupancy proportion changed relative to the pre-treatment years (15-17). Lines extending from the dots represent 1.96*SE. Values below the dotted line correspond to a reduction in the number of occupied treatment plots (negative effect of treatment) and values above the dotted line correspond to an increase in occupied treatment plots (positive effect of treatment).

Two of six bumble bee species responded significantly to mechanical thinning treatment in 2019: *B. vandykei* responded positively and *B. vosnesenskii* responded negatively (Fig. 9). Three of six bumble bee species responded significantly to mechanical thinning and subsequent chemical treatment: *B. flavifrons and B. vosnesenskii* responded negatively and *B. californicus* responded positively. When all treatment types in 2019 were pooled, two bumble bee species (*B. flavifrons* and *B. vosnesenskii*) responded significantly negatively to any form of treatment (Fig. 10). All species except for *B. californicus* had a mean negative response to treatment, but the negative effect was significant only in *B. flavifrons* and *B. vosnesenskii*.

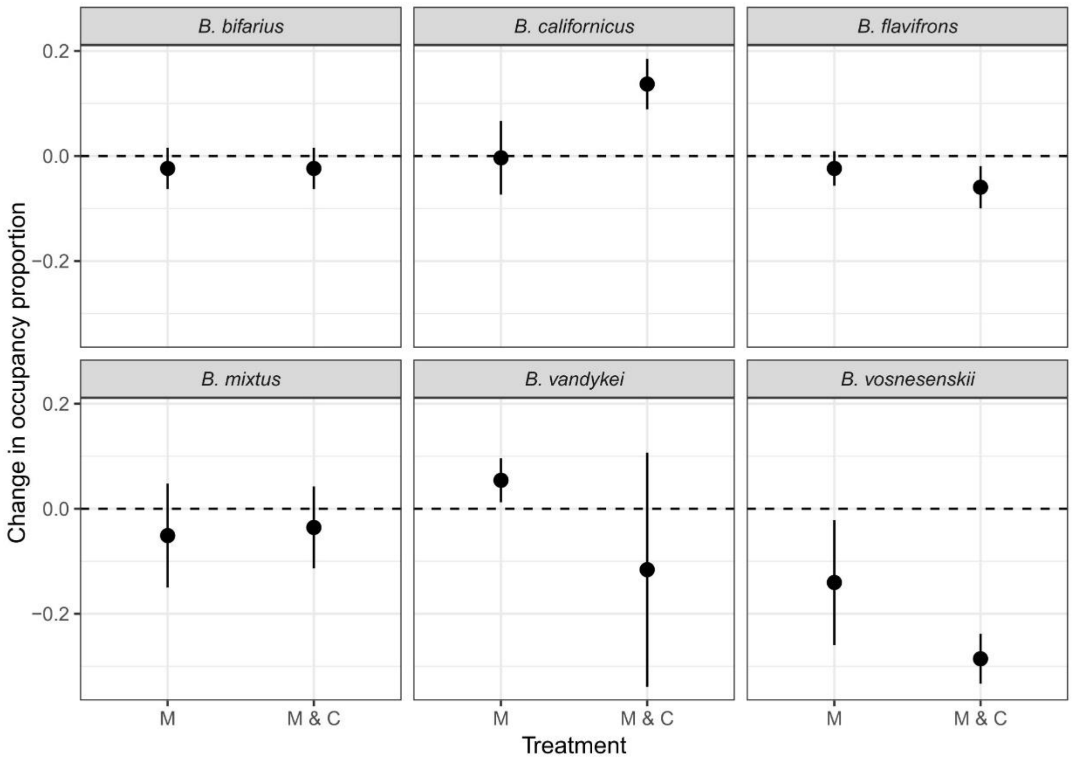

Figure 9. Change in the ratio of occupied mechanical and chemical treatment plots to occupied control plots in 2015-2018 to 2019 for two treatment histories for each of six bumble bee species. All treatment plots were treated in 2019 by mechanical thinning (M) or mechanical and chemical treatment combined (M & C). Dots indicate how much the occupancy proportion in the post-treatment year changed relative to the pre-treatment years (15-18). Lines extending from the dots represent 1.96*SE. Values below the dotted line correspond to a reduction in the number of occupied treatment plots (negative effect of treatment) and values above the dotted line correspond to an increase in occupied treatment plots (positive effect of treatment).

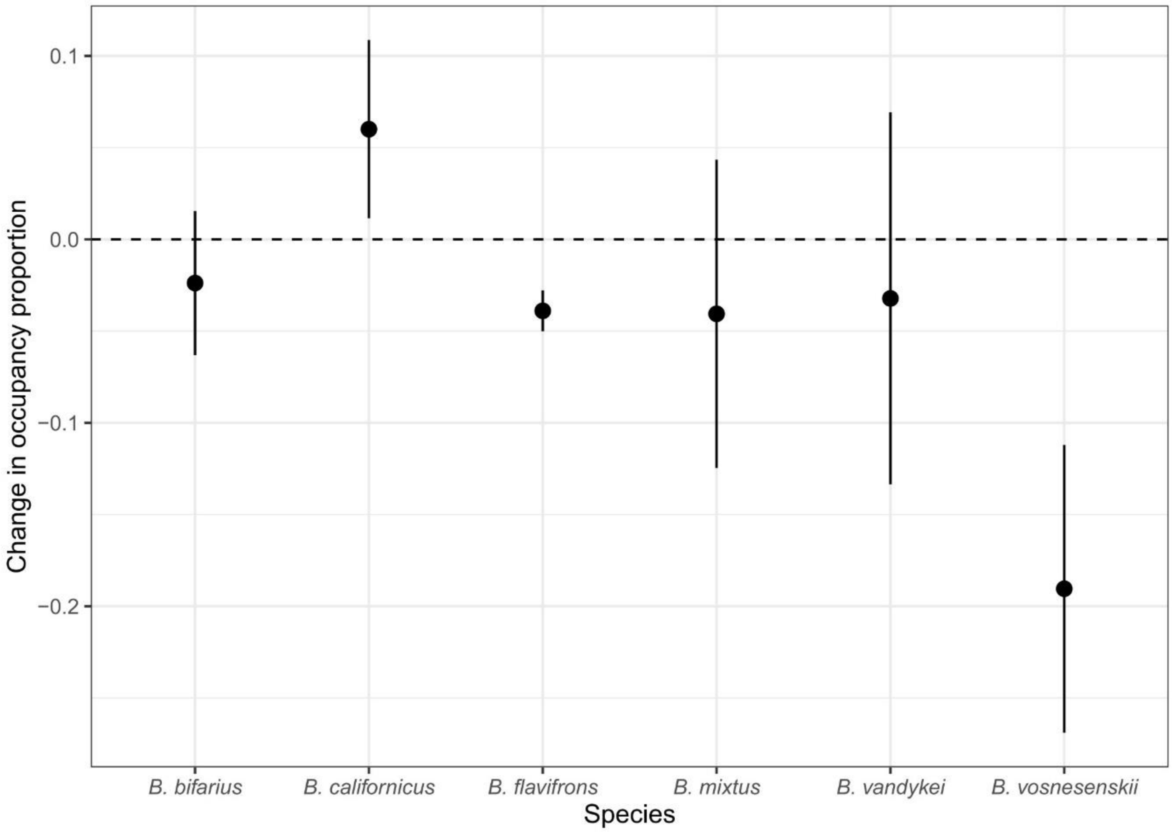

Figure 10. Change in the ratio of occupied treatment plots to occupied control plots in 2015-2018 to 2019 for two treatment histories. We pooled plots treated with any of the three treatment types in 2019. Dots indicate how much the occupancy proportion in the post-treatment year (2019) changed relative to the pre-treatment years. Lines extending from the dots represent 1.96*SE. Values below the dotted line correspond to a reduction in the number of occupied treatment plots (negative effect of treatment) and values above the dotted line correspond to an increase in occupied treatment plots (positive effect of treatment).

Within-year Bumble Bee Response and Exposure to Chemical Treatment

B. vosnesenskii went from present to absent directly following chemical treatment at 9 plots, absent to present at 4 plots, and underwent no change at 40 plots. *B. vandykei* went from present to absent directly after treatment at 3 plots, absent to present at 7 plots, and underwent no change at 43 plots. Only 13.2% of treated plots had either *B. vosnesenskii* or *B. vandykei* observed using the plot on the next visit after treatment (typically about 1 month). Of the 43 treated plots with two visits, 26 received a third visit and 7.7 % (2 of 26) of plots had both *B. vosnesenskii* and *B. vandykei* present during that visit.

Change in Flowering Plant Richness in Response to Treatment

We compared the effect of four treatment histories, comprising unique sequences of the three treatments (Table 5), on plant species richness. Only mechanical thinning in 2019, and mechanical and chemical treatment combined in 2019, had significant effects on flowering plant species richness. Flowering plant species richness increased on treatment plots the year of mechanical thinning, and decreased the year of mechanical thinning and chemical treatment combined (Fig. 11).

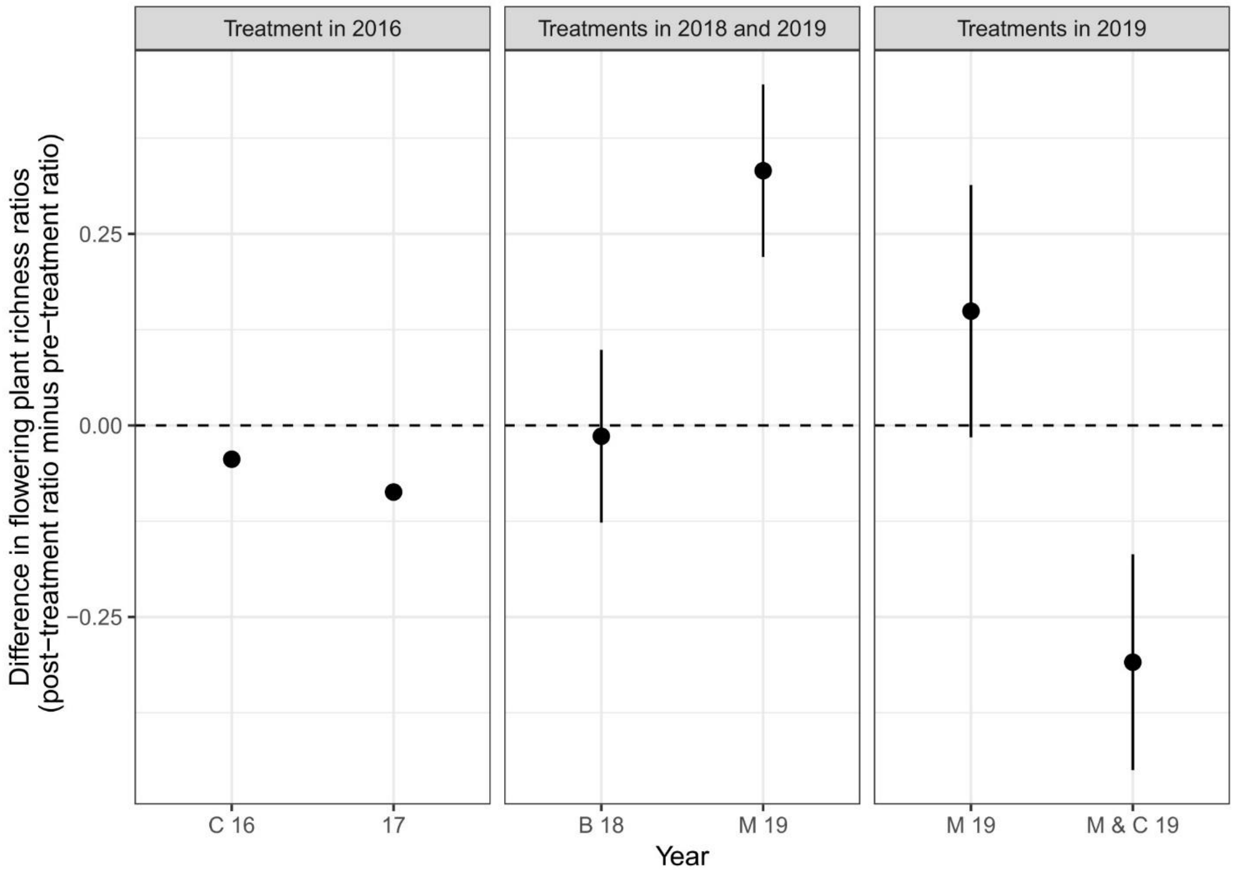

Figure 11. Change in ratio of flowering plant species richness (number of plant species flowering at the time of the survey) at control plots to treatment plots from 2015 to post-treatment in 2016 (‘Treatment in 2016’ panel), pre-treatment in 2015 - 2017 to post-treatment in 2018 and 2019 (‘Treatments in 2018 and 2019’ panel), and pre-treatment 2015-2018 to post-treatment in 2019 (‘Treatments in 2019’ panel). Dots indicate how much the richness ratio in the post-treatment year or years changed relative to the pre-treatment year or years. Lines extending from the dots represent 1.96*SE, though the ‘Treatment in 2016’ panel has no error intervals because there was only 1 year of pre-treatment surveys. Values below the dotted line correspond to a reduction in plant richness in treatment areas relative to controls (negative effect of treatment) and values above the dotted line correspond to an increase in plant richness (positive effect of treatment).

Table 5. Treatment histories for four plot groupings that we used for evaluating effects of treatments on flowering plant species richness (Fig. 11). Treatment history column lists the years when a treatment occurred at treated plots following the first plot visit, but prior to the second plot visit. Codes for treatment history are as follows: YY-Pre (pretreatment year where neither designated control plots nor treatment plots received a treatment), YY-C (year when treatment plots received chemical treatment), YY-B (year when treatment plots received prescribed fire), and YY-Post (year after treatment plots received treatments).

Treatment history	Description	Treated plots (n)	Control plots (n)
15-Pre, 16-C, 17-Post	Plots treated chemically after visit 2 in 2015 and prior to visit 2 in 2016	22	57
15-Pre, 16-Pre, 17-Pre, 18-B, 19-M	Plots treated with some form of prescribed fire after visit 2 in 2017 and prior to visit 2 in 2018, and then mechanical shrub removal prior to visit 2 in 2019	18	83
15-Pre, 16-Pre, 17-Pre, 18-Pre, 19-M	Plots treated chemically after visit 2 in 2018 and prior to visit 2 in 2019	19	83
15-Pre, 16-Pre, 17-Pre, 18-Pre, 19-M & C	Plots treated mechanically and chemically after visit 2 in 2018 and prior to visit 2 in 2019	22	83

DISCUSSION

Bumble bee abundance within our study areas exhibited high interannual variability, perhaps due to differences in precipitation levels across the sampling seasons or other factors not evaluated in this analysis. Other studies have found temperature and precipitation to affect bumble bee populations indirectly by shaping the floral community present in a season (Ogilvie et al. 2017), and directly by impacting overwinter hibernating queen survival (Costa et al. 2020, Woodard et al. 2020) and nest survival (Goulson et al. 2008, Leza et al. 2018). Despite geographic separation between the Fred's and Power fire study areas we saw similar patterns in yearly change in abundance for individual bumble bee species, suggesting that the same mechanisms may be driving population maintenance in both project areas. Given that both areas encompass primarily south-facing river canyons at similar elevations, burned in wildfires that occurred simultaneously, and are only 28 km apart, this is not unexpected. Perhaps most surprising was the rapid growth in captures of *B. melanopygus* at the Power fire from 2015 to 2016 (an increase of 1400%, 11 to 165 captures), and rapid decrease of *B. vosnesenskii* from 2018 to 2019, but dramatic annual increases and declines were pervasive across species (Fig. 12).

Figure 12. Examples of common bumble bee species captured in our study area. Top row (L – R): *Bombus bifarius, B. vosnesenskii, B. flavifrons.* Bottom row (L – R) *B. mixtus, B vandykii, B. melanopygus.* Photos by H. Loffland

A wide variety of plant species were used by bumble bees during our study, but among those upland plants used most frequently were *Chamaebatia foliolosa* and plants in the phacelia, pennyroyal and stickseed complexes (Fig. 13). Riparian plants used most frequently included H*elenium bigelovii*, *Solidago canadensis*, and the yampah complex. The top 10 plants with the most bee captures varied interannually and most were not consistently within the top 10 across years. Another study from northern California, focusing on a similar group of bumble bee species, also showed substantial interannual variation in plant preference (Cole et al. 2020). Plant usage is at least partially driven by the plant community available for the bees to select from, and precipitation and temperature may influence the availability (in terms of both phenology and absolute abundance) of plant species from year to year. By collecting floral use data over multiple years we were able to gain a more complete knowledge of resource use across bumble bee species and build a restoration plant palette for use in reseeding and replanting disturbed areas from wildfire zones to roadsides.

Figure 13. Plant taxa frequently selected by bumble bees in our study areas. Top row (L – R): *Agastache urticifolia*, *Solidago canadensis*, Yampah complex. Middle row (L – R): Phacelia complex., *Hosackia crassifolia*, *Chamaebatia foliolosa*. Bottom row (L – R): *Monardella odoratissima* (Pennyroyal complex), *Hackelia velutina* (stickseed complex), Vetch complex, *Helenium bigelovii*. Photos by A. Schrage or H. Loffland unless otherwise noted.

In general, management treatments of survey plots by either mechanical, chemical, or prescribed fire treatments to reduce shrub density had mixed effects on bumble bee species. Some species had no discernable difference in site occupancy before and after treatment. Flowering plant species richness significantly increased after mechanical thinning, likely due to competitive release of forbs and access to more sunlight during the growing season. However, flowering plant species richness declined after a combination of mechanical and chemical treatments at the same plots in a given year, likely because chemical herbicides may have been sprayed on herbaceous plants surrounding targeted shrub species. Interestingly, *B. flavifrons* and *B. vosnesenskii* both declined in occurrence after the combined mechanical and chemical treatment, but declined to a lesser extent after only the mechanical treatment. The response of both bee species may have been due to the differential change in plant richness between the two treatment types. The degree of chemical treatment of herbaceous vegetation can vary dramatically depending on the local vegetation community and on whether a treatment is intended to prepare a site for planting, reduce fuel loading, or reduce competition for recently planted seedling conifers. In the latter case, most competing vegetation, including forbs and grasses, are treated. We observed this full range of treatments within the study area, including treatments where only target shrubs were chemically treated, and others where herbaceous vegetation was treated as well (Fig. 13). Additionally, target shrubs respond differently to chemical treatment such that some species (e.g., deerbrush) are more likely to experience complete mortality, while others (e.g., bear clover) often only experience mortality of above ground vegetation. This variation in response can alter out-year vegetation responses.

Unfortunately, we had limited ability to clearly determine the effect of treatments on the occupancy of bumble bees corrected for imperfect detections because of generally insufficient numbers of treated plots and very few years of surveys post-treatment. Because of the large variety of treatments implemented at a small number of plots we grouped plots that received a variety of relatively similar treatments. However, these pooled treatments were implemented at various times during the year and varied in the specific treatment type (e.g., mastication of shrubs versus piling), which may have resulted in more variation in the bumble bee response. The response of species to treatments might have been more apparent if a greater number of plots were treated with a uniform treatment type and sampling continued for multiple years following treatment. We could not determine if there were longer-term effects of treatment on bumble bees because of the limited post-treatment surveys. Carryover effects of treatment are possible because the following year’s queens are produced during the summer of a previous year, so foraging resources degraded in a treatment year may yield fewer queens and presumably fewer workers the following year.

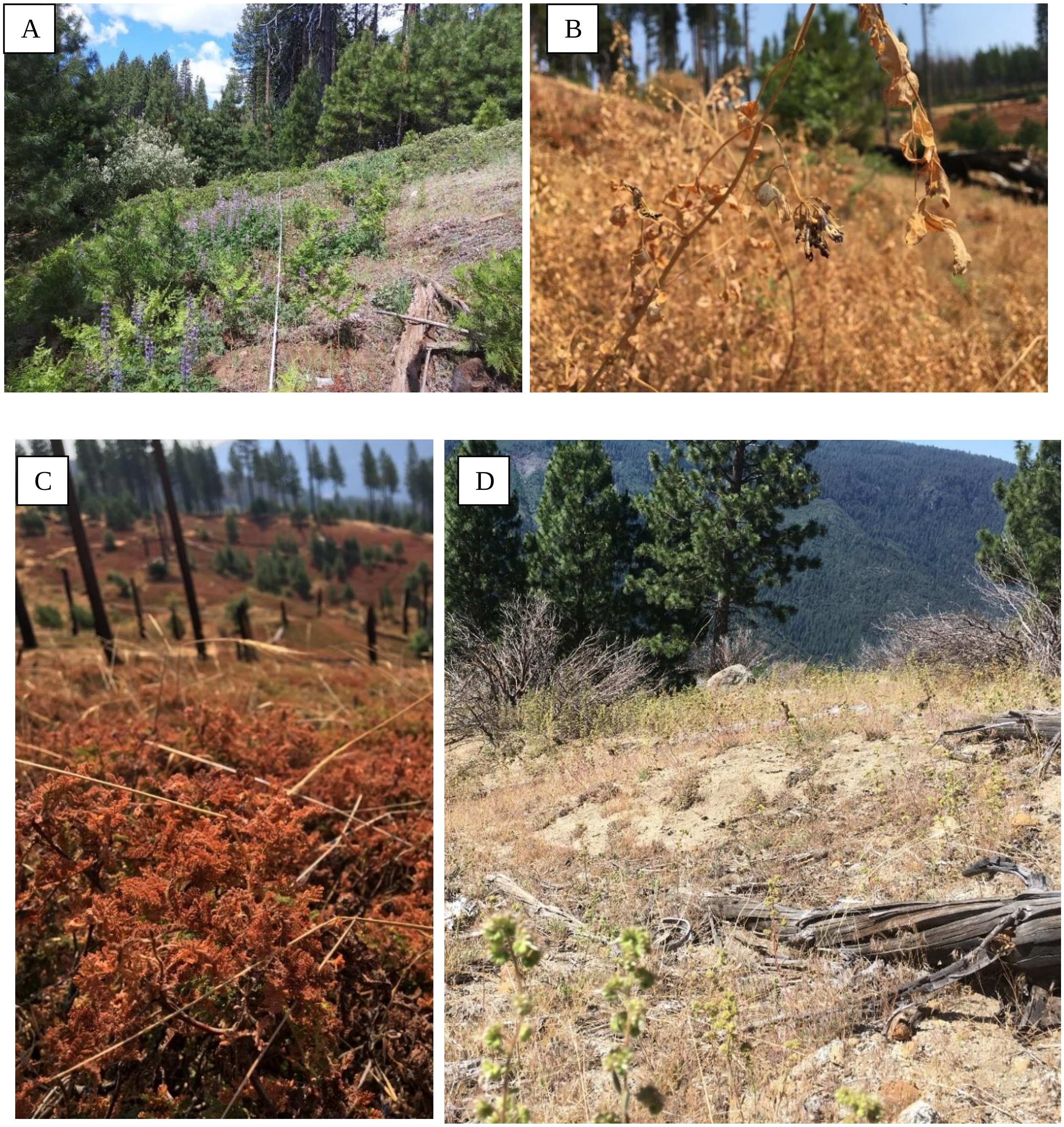

Figure 14. **A**. Untreated site with a mix of herbaceous floral resources in the foreground and target shrubs (bear clover and deer brush) in the background; **B**. Chemically treated herbaceous vegetation including *Hosackia crassifolia*, a commonly used floral resource for bumble bees in our study area; **C**. A chemically treatment unit where shrubs (bear clover) were chemically treated with herbicide and make up a relatively contiguous community with little interspersed herbaceous vegetation; ***D.*** Example of a chemical treatment unit where scattered shrubs (manzanita in background) were chemically treated with herbicide but *Phacelia egena* patches (foreground and center back) and other herbaceous vegetation was not. Photos by H. Loffland

Recent research on the direct effects of herbicide on bumble bees found that lethal and sublethal effects were detected but varied significantly based on the formulation of the herbicide (Straw et al. 2021). Of particular note is the finding that the surfactants used to coat the herbicide onto plant surfaces similarly coated and prevented respiration in bumble bees, leading to decreased fitness and sometimes death. In our study area, a variety of chemical formulations were used to treat a variety of shrub species. We documented bumble bee use of chemically treated units within a few weeks after application of herbicide, but response was mixed. It is unknown whether observed changes in bumble bee abundance were due to loss of floral resources, effects of herbicide toxicity on bumble bees, or a combination of the two. We can confirm that bumble bees came into contact with herbicide based on our detections of bumble bees continuing to use plots during the post treatment period, but do not know what effect dry herbicide might have on behavior or survival (beyond the changes to floral resources). Due to safety restrictions our survey crews did not survey treated areas within the two weeks directly after treatment. We did however anecdotally observe bumble bees foraging on plants still damp with herbicide along roadsides within our project area. Our mixed results in response to chemical treatment suggest that a complicated relationship exists. If treatment releases more open ground for a variety of herbaceous species that are preferred over target shrub species then bees may respond positively to increased floral resources. We also confirmed that bumble bees are being exposed to herbicide by continuing to forage in areas that have been treated, but we cannot say what effects, if any, direct contact with herbicides is having on the local bumble bee community

MANAGEMENT IMPLICATIONS

Post-fire chaparral communities within the Sierra Nevada are often suppressed or removed to facilitate reforestation efforts and reduce fuels and wildfire risk. We urge forest managers to retain mosaics of montane chaparral shrubs and herbaceous vegetation where feasible in the context of post-fire forest regeneration efforts, to maximize bumble bee foraging resources across time and space. When chaparral removal does occur, in our study area, bumble bees will benefit the most if stands dominated by bear clover are prioritized for retention over stands dominated by *Ceanothus* species (e.g., mountain whitethorn, deerbrush) or greenleaf manzanita. We caution that retention of other chaparral shrub species should be considered as well, to maintain a diversity of plants for other pollinators and wildlife species and to provide for year to year variation in flowering patterns. Retaining patches of native herbaceous plant cover, including those species preferentially used by bumble bees (e.g., phacelia and stickseed complexes in our study), would also benefit bumble bees. In fact, information we report here on the most frequently used plant species in the Power and Fred's fire areas derived over the last 6 years could provide direction on important seed collection efforts for use in post-fire or post-disturbance restoration. Utilizing plant species known to be locally important in restoration seed mixes and prioritizing reseeding as a restoration tool could provide benefits to at-risk bumble bee species and other pollinators. Knowledge of important plant species should also be incorporated into local chemical application practices. Herbicide contracts often include a list of plants that are to be avoided during application (oaks, elderberry, sensitive plant species, etc.) and could be updated to include some of the highest priority bumble bee floral resources.

Any chemical or hand treatments in post-fire tree areas should be applied narrowly to unwanted shrub species only, such that the disturbance to non-target vegetation is minimized. Furthermore, if ecosystem restoration is a goal, managers should consider planting or seeding such areas with forb species that are used frequently by bumble bees. Where mechanical or chemical treatment of herbaceous or chaparral plant species used by bumble bees does occur, bumble bees would likely benefit if it is delayed until late summer or autumn, or at least after the local peak bloom period. For noxious weed abatement (especially noxious forbs known to provide bumble bee forage) that may require chemical treatment early in the season, we recommend replanting or seeding with native plants with similar bloom phenology to replace foraging resources that are lost in instances where large areas are being treated.

Although our results were mixed, they suggest that some bumble bee species and floral resource diversity may increase in abundance with mechanical removal of vegetation that opens space for a variety of other forb species and less competitive shrubs and subshrubs. Our results suggest that bumble bees responded to chemical and manual treatments of competing vegetation, but those effects were nuanced. To conclusively determine the effects of the varied treatments common in postfire and regenerative forestry on bumble bees and their key floral resources research needs to be conducted in a more controlled research setting. We found that it was challenging to record and tease apart impacts in a real world silvicultural setting where treatment types (chemical, mechanical, and prescribed fire) and methods (back pack sprayer, mastication, hand thinning, pile burning, etc.) were applied in nearly endless combinations as required by site-specific needs and also implemented by separate contractors under different requirements and timelines. Similarly, unavoidable delays in treatments resulted in a limited ability to conduct post-treatment surveys over multiple years. With complex treatments and varied response by both plants and bumble bees we would expect that monitoring for at least 2 to 3 years or more post-treatment would be needed to fully characterize bumble bee responses.

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Appendix.

Table A1. Plant species that were grouped into larger complexes for analyses due to difficulty visually differentiating species.

Scientific name	Analysis grouping
Monardella breweri	Pennyroyal complex
Monardella lanceolata	Pennyroyal complex
Monardella odoratissima	Pennyroyal complex
Phacelia breweri	Phacelia complex
Phacelia cicutaria	Phacelia complex
Phacelia egena	Phacelia complex
Phacelia hastata ssp. compacta	Phacelia complex
Phacelia hastata ssp. hastata	Phacelia complex
Phacelia heterophylla	Phacelia complex
Phacelia hydrophylloides	Phacelia complex
Phacelia imbricata	Phacelia complex
Phacelia mutabilis	Phacelia complex
Phacelia quickii	Phacelia complex
Phacelia ramosissima	Phacelia complex
Phacelia spp.	Phacelia complex
Hackelia californica	Stickseed complex
Hackelia nervosa	Stickseed complex
Hackelia velutina	Stickseed complex
Vicia americana	Vetch complex
Vicia cracca	Vetch complex
Vicia sp.	Vetch complex
Vicia villosa	Vetch complex
Perideridia bolanderi	Yampah complex
Perideridia lemmonii	Yampah complex
Perideridia parishii	Yampah complex
Perideridia spp.	Yampah complex

Table A2. Listing of all treatment activity data obtained from the Forest Service Activity Tracking System (FACTS) and geo-enabled Performance Accountability System (gPAS). Treatment activities were subsequently grouped into broad categories ('treatment category') for the purposes of this study. Treatments that were considered relevant to our study are indicated in the "valid treatment" column.

Treatment category	**Valid treatment?**	**Activity code**	**Activity name**	**Method code**	**Method description**
-	No	1100	Fuel Inventory	100	Manual
Burn	Yes	1111	Broadcast Burning - Covers a majority of the unit	101	Fire
Burn	Yes	1113	Underburn - Low Intensity (Majority of Unit)	101	Fire
Burn	Yes	1113	Underburn - Low Intensity (Majority of Unit)	300	Prescribed Burn
Mechanical thinning	Yes	1120	Yarding - Removal of Fuels by Carrying or Dragging	108	Cut trees and brush
Mechanical thinning	Yes	1120	Yarding - Removal of Fuels by Carrying or Dragging	200	Mechanical
Mechanical thinning	Yes	1130	Burning of Piled Material	100	Manual
Mechanical thinning	Yes	1130	Burning of Piled Material	101	Fire
Mechanical thinning	Yes	1130	Burning of Piled Material	300	Prescribed Burn
-	No	1131	Cover brush pile for burning	100	Manual
-	No	1131	Cover brush pile for burning	300	Prescribed Burn
Mechanical thinning	Yes	1136	Pruning to Raise Canopy Height and Discourage Crown Fire	100	Manual
Mechanical thinning	Yes	1136	Pruning to Raise Canopy Height and Discourage Crown Fire	108	Cut trees and brush
Mechanical thinning	Yes	1153	Piling of Fuels, Hand or Machine	100	

Treatment category	**Valid treatment?**	**Activity code**	**Activity name**	**Method code**	**Method description**
Mechanical thinning	Yes	1153	Piling of Fuels, Hand or Machine	200	Mechanical
Mechanical thinning	Yes	1154	Chipping of Fuels	100	Manual
Mechanical thinning	Yes	1154	Chipping of Fuels	108	Cut trees and brush
Mechanical thinning	Yes	1154	Chipping of Fuels	403	Chipping
Mechanical thinning	Yes	1160	Thinning for Hazardous Fuels Reduction	100	Manual
Mechanical thinning	Yes	1160	Thinning for Hazardous Fuels Reduction	108	Cut trees and brush
Mechanical thinning	Yes	1160	Thinning for Hazardous Fuels Reduction	200	Mechanical
Chemical	Yes	2510	Invasives - Pesticide Application	700	Chemical
Mechanical thinning	Yes	2530	Invasives - Mechanical /Physical	100	Manual
Mechanical thinning	Yes	2530	Invasives - Mechanical /Physical	200	Mechanical
-	No	4342	Plantation Survival Survey	941	Staked Rows
-	No	4432	Fill-in or Replant Trees	100	
Mechanical thinning	Yes	4474	Site Preparation for Planting - Mechanical	207	Mechanical pile
Mechanical thinning	Yes	4511	Tree Release and Weed	117	Power Hand
Chemical	Yes	4511	Tree Release and Weed	700	
Chemical	Yes	4511	Tree Release and Weed	710	
Mechanical thinning	Yes	4511	Tree Release and Weed		
Mechanical thinning	Yes	4530	Prune	100	

Table A3. Plant taxa with bumble bee captures sorted by number of captures across all study areas in all years (2015 to 2019).

Plant scientific name	**Bumble bee captures on plant**	**Percentage of captures**
Phacelia complex	833	18.2
Chamaebatia foliolosa	549	12.0
Helenium bigelovii	382	8.4
Stickseed complex	363	7.9
Yampah complex	296	6.5
Cirsium vulgare	269	5.9
Pennyroyal complex	244	5.3
Lupinus polyphyllus	117	2.6
Allium validum	106	2.3
Hosackia crassifolia	96	2.1
Solidago canadensis	71	1.6
Stachys ajugoides	67	1.5
Chamerion angustifolium	64	1.4
Vetch complex	57	1.2
Senecio triangularis	51	1.1
Clarkia rhomboidea	48	1.0
Gilia capitata	47	1.0
Ceanothus cordulatus	36	0.8
Agastache urticifolia	33	0.7
Eriogonum nudum	33	0.7
Bistorta bistortoides	32	0.7
Lathyrus nevadensis	31	0.7
Symphyotrichum ascendens	31	0.7
Hypericum scouleri	30	0.7
Lupinus albicaulis	30	0.7
Delphinium glaucum	24	0.5
Hypericum perforatum	23	0.5
Keckiella breviflora	23	0.5
Eriogonum umbellatum	22	0.5
Hosackia oblongifolia	22	0.5
Ribes roezlii	22	0.5
Cordylanthus tenuis	20	0.4
Sidalcea glaucescens	20	0.4
Rubus ursinus	18	0.4
Wyethia angustifolia	18	0.4
Cuscuta californica	17	0.4
Eurybia integrifolia	17	0.4

Plant scientific name	**Bumble bee captures on plant**	**Percentage of captures**
Mimulus guttatus	14	0.3
Solidago velutina ssp. californica	13	0.3
Trifolium pratense	13	0.3
Asyneuma prenanthoides	12	0.3
Sidalcea spp.	12	0.3
Ceanothus integerrimus	11	0.2
Lathyrus sulphureus	11	0.2
Potentilla spp.	11	0.2
Prunella vulgaris	11	0.2
Symphyotrichum foliaceum	11	0.2
Trifolium hirtum	11	0.2
Penstemon deustus	9	0.2
Spiraea splendens	9	0.2
Helianthella californica var nevadensis	8	0.2
Horkelia fusca	8	0.2
Verbascum thapsus	8	0.2
Apocynum androsaemifolium	7	0.2
Calystegia occidentalis	7	0.2
Castilleja miniata	7	0.2
Cirsium occidentale var. californicum	7	0.2
Drymocallis glandulosa	7	0.2
Lupinus breweri	7	0.2
Aster breweri	6	0.1
Clarkia unguiculata	6	0.1
Ranunculus occidentalis	6	0.1
Erigeron glacialis	5	0.1
Lupinus angustiflorus	5	0.1
Ribes nevadense	5	0.1
Ribes viscosissimum	5	0.1
Symphyotrichum spathulatum	5	0.1
Ceanothus parvifolius	4	0.1
Collinsia heterophylla	4	0.1
Lupinus obtusilobus	4	0.1
Mertensia ciliata	4	0.1
Potentilla gracilis	4	0.1
Solanum xanti	4	0.1
Veratrum californicum	4	0.1
Calystegia malacophylla	3	0.1
Cirsium andersonii	3	0.1

Plant scientific name	Bumble bee captures on plant	Percentage of captures
Delphinium spp.	3	0.1
Erigeron spp.	3	0.1
Eriogonum spp.	3	0.1
Lupinus latifolius var. columbianus	3	0.1
Nemophila maculata	3	0.1
Penstemon laetus	3	0.1
Penstemon newberryi	3	0.1
Pinus ponderosa	3	0.1
Torilis arvensis	3	0.1
Aquilegia formosa	2	0.0
Aster occidentalis	2	0.0
Boykinia major	2	0.0
Calocedrus decurrens	2	0.0
Chaenactis douglasii	2	0.0
Collinsia tinctoria	2	0.0
Convulvlus arvensis	2	0.0
Eriophyllum lanatum	2	0.0
Horkelia tridentata	2	0.0
Iris hartwegii	2	0.0
Lessingia leptoclada	2	0.0
Lupinus spp.	2	0.0
Lupinus stiversii	2	0.0
Madia citriodora	2	0.0
Mimulus torreyi	2	0.0
Prunus virginiana	2	0.0
Quercus vaccinifolia	2	0.0
Rubus parviflorus	2	0.0
Rubus spp.	2	0.0
Sium suave	2	0.0
Spiranthes porrifolia	2	0.0
Spiranthes romanzoffiana	2	0.0
Symphoricarpos mollis	2	0.0
Abies magnifica	1	0.0
Arctostaphylos patula	1	0.0
Arnica discoidea	1	0.0
Aster alpigenus	1	0.0
Astragalus whitneyi	1	0.0
Brodiaea elegans	1	0.0
Castilleja applegatei	1	0.0

Plant scientific name	Bumble bee captures on plant	Percentage of captures
Centaurea solstitialis	1	0.0
Clarkia dudleyana	1	0.0
Collomia heterophylla	1	0.0
Cryptantha echinella	1	0.0
Cryptantha spp.	1	0.0
Delphinium depauperatum	1	0.0
Dicentra formosa	1	0.0
Dichelostemma multiflorum	1	0.0
Erigeron algidus	1	0.0
Eriogonum wrightii	1	0.0
Erysium capitatum	1	0.0
Lathyrus lanszwertii	1	0.0
Leptodactylon pungens	1	0.0
Leptosiphon ciliatus	1	0.0
Lilium parvum	1	0.0
Linum lewisii	1	0.0
Lupinus bicolor	1	0.0
Madia elegans	1	0.0
Madia exigua	1	0.0
Madia gracilis	1	0.0
Mimulus cardinalis	1	0.0
Nasturtium officinale	1	0.0
Navarretia spp.	1	0.0
Polygonum phytolaccifolium	1	0.0
Prunus emarginata	1	0.0
Pseudognaphalium beneolens	1	0.0
Pycnanthemum californicum	1	0.0
Ranunculus spp.	1	0.0
Ribes cereum	1	0.0
Ribes montigenum	1	0.0
Rubus armeniacus	1	0.0
Salix spp.	1	0.0
Senecio integerrimus	1	0.0
Solidago elongata	1	0.0
Trifolium obtusiflorum	1	0.0
Trifolium spp.	1	0.0
Triteleia hyacinthina	1	0.0
Valeriana californica	1	0.0
Verbascum blattaria	1	0.0