FINAL REPORT

Title: Native bee nesting habitat use after wildfire in Montana

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Abstract

Changing fire regimes are leading to increasing scale and severity of burns, which may affect habitat for species of concern. Wood-cavity nesting bees are one such community, in that they have discrete foraging and nesting habitats which can both be maintained or removed by wildfire. Our objective is to provide data on how different species of wood-cavity nesting bees use nesting habitat following wildfire, and how habitat differences across burn severities and time since burn affect that nesting. We used bee nesting boxes in four burns in southwest Montana, aged 3-27 years post-burn, to test the bee community while measuring different habitat characteristics in mixed and high severity treatments. Results show that the bee community and nesting habitat variables do not show much variability. However, intermediate levels of floral abundance appear to have a positive effect on many measures of bee nesting success. These results together suggest that a heterogeneous mixture of burn frequency and severity across the landscape would maximize bee nesting success, via achieving intermediate levels of nesting and foraging resource availability for wood-cavity nesting bees.

Objectives

The objective of this research was to discover how different species of wild bees utilize nesting habitat after wildfire, and how habitat differences across different burn severities as well as different aged burns may affect the community of bees nesting in each of these burn severities and ages. The original proposed questions as stated were: i) does burn severity affect bee nesting, ii) does habitat use change with time since burn, iii) which environmental variables and habitat characteristics affect bee nesting habitat use, and iv) is there a spatial relationship between bee nesting location and the diversity and abundance of local floral resources?

Objectives had to be altered slightly after field testing the proposed methods. Locating nesting bees is notoriously difficult (Roulston and Goodell 2011), and our methods were proposed partially to try to innovate on this field of study. Proposed methods of trapping nesting bees with sticky traps at located cavities netted 0 successful captures across 24 hours of trapping spread across three days. Even when a cavity with a bee actively nesting in it was located, this method still failed to capture the individual. We also attempted to track bees back to their nests by hand-netting bees in flight and coating them with fluorescent powder, and later attempting to locate the nests at dusk using an ultraviolet flashlight. This was tested on both bees in the field at multiple locations, as well as on known leafcutter bee nests in an urban environment. We determined that the bees would groom the powder from themselves only immediately after being netted, or once well inside their nesting cavity, leaving this method insufficient for locating the nests.

Our final alternative methods, described below, were only suitable for surveying wood-cavity nesting bees. Therefore, our original objectives did not change, yet we were only able to survey for wood-cavity nesting bees, as opposed to the broad community-level sampling. Additionally, for clarity of presentation, we have combined components of objective ii into objectives i and iii. Rephrased, the questions are: i) does the community of wood-cavity nesting bees vary with burn severity or time since burn, ii) which habitat or environmental differences across burn severities or time since burn affect bee nesting, and iii) is there a relationship between bee nesting location and the diversity or abundance of local floral resources? Our working hypotheses for each objective were i.) that community diversity would increase with time since burn, due to post-disturbance colonization (Potts et al. 2005). High severity burns would demonstrate a lower diversity of nesting bees relative to mixed severity burns, due to the removal of coarse woody debris and snags utilized by these species for nesting, and this pattern would be more apparent in recent burns. ii.) we believed that bee nesting would increase with increasing wood cavity density, canopy openness, as well as the availability of coarse woody debris. We also hypothesize that these variables would vary predictably with burn severity and time since burn. iii.) bees are central-place foragers, yet have discrete nesting and foraging habitats (Westrich 1996). Therefore, we would expect a balance of nesting and foraging resources in an area to show the greatest nesting density.

One objective of the JFSP GRIN is to help address issues with managing fire in wildland ecosystems. Our study fit well within the goals of the GRIN by seeking to provide this baseline data on native bee nesting habitat use after wildfire; an area of study that remains largely unknown. With changing fire regimes (Bowman et al. 2009) and the growing concern for the well-being of native bee species (Tylianakis et al. 2008), these data will be helpful for land managers to make decision which adequately concern the bees' needs. We were able to collect data and provide results below regarding each our stated questions, therefore all our proposed objectives were successfully met, with the simple caveat that they only apply to wood-cavity nesting bee species. Fortunately, ground-nesting species are of less concern regarding wildfire, as even a few centimeters of soil have been experimentally shown to protect bees from lethal temperatures (Cane & Neff 2011).

Background

Wildfire is a globally occurring phenomenon and a natural, necessary part of many ecosystems, yet historical fire suppression and climate change have amplified the extent and severity of fires in recent decades (Bowman et al. 2009). Wild, native bee species are taxa of concern regarding anthropogenic disturbances (Burkle et al. 2013) and are highly sensitive to environmental changes and habitat fragmentation (Tylianakis et al. 2008), such as that which occurs with wildfire. Bee foraging and nesting habitat is often spatially discrete (Westrich 1996), yet these bees are central-place foragers, typically not foraging more than a few hundred meters from where they establish their nests (Gathmann & Tscharnke 2002). Specifically, the availability or distance to forage, of nesting habitat for wood-cavity nesting bees is likely to be altered by wildfire; however, to date there has been no published study which details the effects of fire, wild or controlled, on bee nesting habitat use. Because of bees' discrete habitats, modern fire regimes (Bowman et al. 2009) may have dramatic effects on how and where different bee species forage and nest. Large scale, high severity fires have a homogenizing effect; they cause high tree mortality and remove course woody debris and vegetation (Pierce et al. 2004). This homogenization could strongly affect the presence and relative proximities of both nesting and foraging habitats, where either the nesting resources are unavailable or too distant from preferred foraging habitats. Historical mixed severity fires result in a patchy, heterogeneous landscape, where some areas are cleared of tree cover with enhanced forb growth (i.e., ideal bee foraging habitat) while other areas retain snags and woody debris (i.e., ideal bee nesting habitat). Field studies regarding the use of bee nesting habitat are notably lacking, with most studies using hand-netted foraging bees to infer nesting habitat use for an area (e.g., Potts et al. 2005). This leaves a clear gap in understanding how bees actually use their habitats. For wildfire, forb growth is often markedly increased in the years immediately post-burn, while there remains uncertainty regarding nesting habitat use.

Materials and Methods

Four wildfires from the Absaroka Mountains of southwest Montana were selected: Thompson Creek (6979 acres, July 16, 1991), Wicked Creek (28,674 acres, August 8, 2007), Pine Creek (8572 acres, August 29, 2012), and Emigrant (11,834 acres, August 16, 2013). Additionally, we selected unburned sites which have not burned in at least 75 years, located 4km from any burned sites. We selected two 15ha sampling blocks of high-severity burn and two of mixed-severity burn within each fire. Fire severities were determined by the Monitoring Trends in Burn Severity (MTBS) project (Eidenshink et al. 2007). A high severity block is an area of 15ha which is >95% high severity with 3 sampling plots. A mixed severity block is a 15ha area with 1 low severity sampling plot, 1 moderate severity plot, and 1 high severity plot. This results in a total of 54 study plots: 3 per block, 12 per fire and 6 for the unburned.

Each sampling plot consists of a 25m diameter circular plot. For each sampling plot a bee nesting box was affixed to the snag nearest to the center of the plot in early June 2016; when no standing snags were present either the highest coarse woody debris or stump was used. Nest boxes were always placed with their cavity openings southeast facing, and approximately 1m in height whenever possible. Bee boxes were constructed out of either pine or poplar, and each box had 16 cavities for cardboard bee nesting tubes. Four sizes of tubes were used in each box (3mm, 4mm, 5mm, and 6mm) to maximize the number of species which could potentially nest in the boxes (Figure 1). Nest boxes were checked at least every other week from June through August; full nesting tubes were pulled and replaced. Tubes were then individually stored in plastic bottles where they were kept until the bees emerged during Spring and Summer 2017, and were then identified to species. For the nesting tubes we recorded number of successful bee nesting tubes, the number of individual bees emerged from each tube, species richness, number of unemerged tubes, and the number of tubes from which parasitoid wasps emerged.

Figure 1:

A: Bee nesting box at a high severity plot within the Pine Creek fire. Note the four different sized nesting tubes (clockwise from top-right: 4mm, 3mm, 5mm, and 6mm) as well as the mud and leaves used to seal their nests after eggs have been laid and pollen has been provisioned.

B: Example of a single bee nesting cell from within a 5mm nesting tube, family Megachilidae. Each cell contains a single larval bee and a pollen provision.

Sampling plot habitat characteristics were sampled once for the summer season. Coarse woody debris (CWD) was measured along a 25m intercept transect through the sampling plots, calculated as volume in m^3/ha for the plot following Harmon and Sexton (1996). The number of wood cavities was recorded for all CWD and snags within 2m of the intercept transect. The number of stumps were counted for the circular plot. Canopy photographs were taken from the center of the plot using a fish-eye lens and canopy cover was calculated using Gap Light Analyzer (Frazer et al. 1999). The floral community was measured along the 25m transect, where all actively blooming flowers within 2m of the transect were identified, counted, and recorded. Statistical analyses included ANOVAs of linear models with post-hoc Tukey HSD tests as well as non-metric multidimensional scaling. All analyses were performed in R using the vegan, labdsv, and agricolae packages (R Core Team 2016, Oksanen 2016, Roberts 2016, de Mendiburu 2017)

Results and Discussion

Wood cavity nesting bee community

641 total nesting tubes were collected: 307 (47.9%) had no emergence, 241 (37.6%) had bees emerge, 14 (2.2%) emerged as parasitoid wasps, and 79 (12.3%) had flies or non-parasitoid wasps emerge. For bees, a total of 676 specimens were identified from 18 species, primarily *Megachile lapponica* (402), and *Hoplitis albifrons argentifrons* (129). No bee emergence was observed from 47 nesting tubes collected in unburned sampling plots.

Bee species richness was statistically similar across all burns and treatments except for unburned, where we observed no nesting bees, and in the Thompson Creek Mixed plots, where only 3 nesting tubes showed bee emergence (Figure 2). The number of unemerged tubes, number of parasitoids, and number of bees per emerged tube did not significantly differ between burn localities or severity treatments (Figure 3A, B, & C). The number of successful bee nesting tubes showed some minor differences, with the mixed severity treatments from Emigrant and Wicked Creek showing greater emergence relative to most other locality/treatment combinations (Figure 4). Despite these differences, there is no consistent pattern with changes in nesting tube success between burn severities or across time since burn.

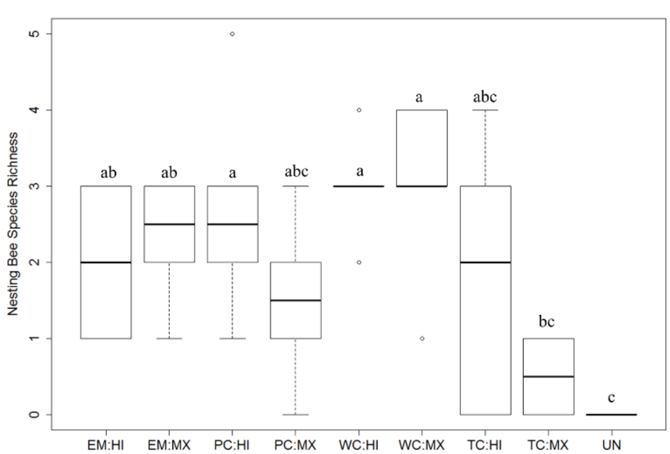


Figure 2: Nesting bee species richness. HI = High severity plots, MX = Mixed severity plots, EM = Emigrant, PC = Pine Creek, WC = Wicked Creek, TC = Thompson Creek, UN = Unburned. Letters denote statistical grouping from Tukey HSD test.

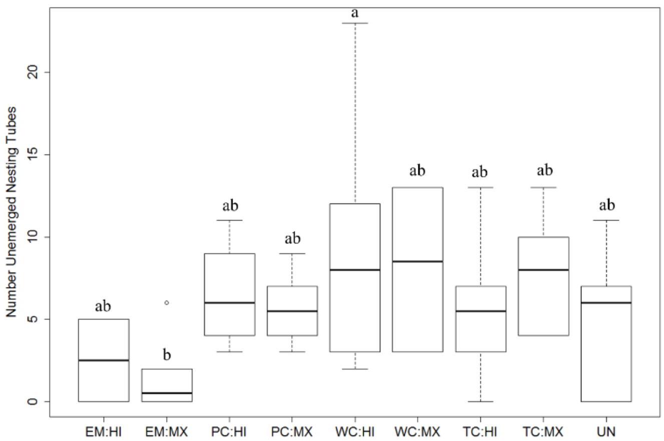
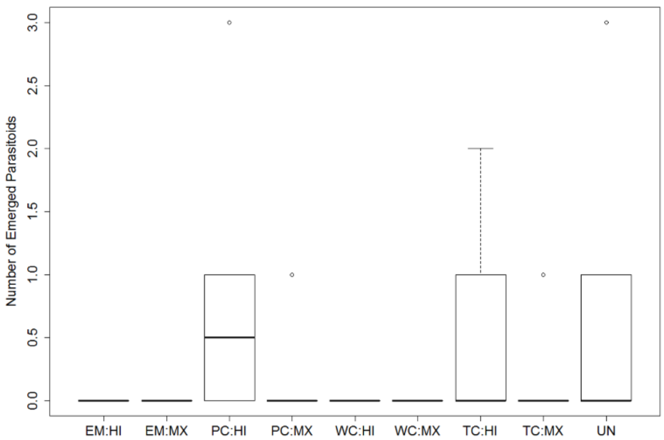
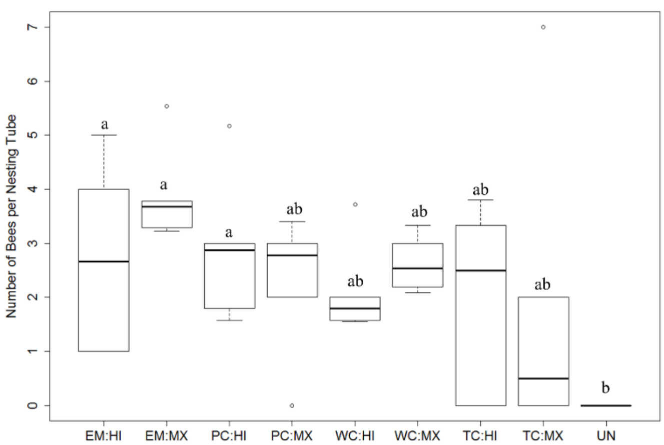


Figure 3: HI = High severity plots, MX = Mixed severity plots, EM = Emigrant, PC = Pine Creek, WC = Wicked Creek, TC = Thompson Creek, UN = Unburned. Letters denote statistical grouping from Tukey HSD test.

A: Unemerged nesting tubes.



B: Emerged parasitoid tubes.



C: Number of bees per emerged tube

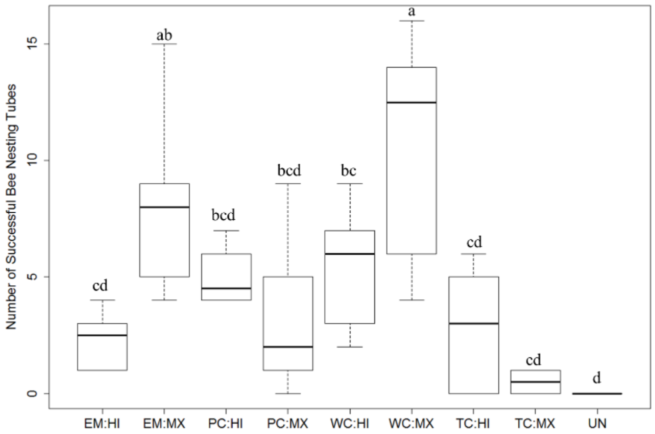


Figure 4: Successful bee nesting tubes. HI = High severity plots, MX = Mixed severity plots, EM = Emigrant, PC = Pine Creek, WC = Wicked Creek, TC = Thompson Creek, UN = Unburned. Letters denote statistical grouping from Tukey HSD test.

No clear patterns of community dissimilarity between either burn severity or burn locality emerged when performing NMDS ordinations (Figure 5), however when looking at the distribution of our most dominant taxa across all locality/treatment combinations, it becomes apparent that some genera nested in greater density in some areas. *Megachile* species were more abundant in Emigrant mixed plots, *Hoplitis* in Wicked Creek mixed plots, and *Hylaeus* in Emigrant high plots (Figure 6A, B, & C). These three genera comprised 94.1% of all bees observed. Similarly, these patterns are not consistent across either burn age or severity.

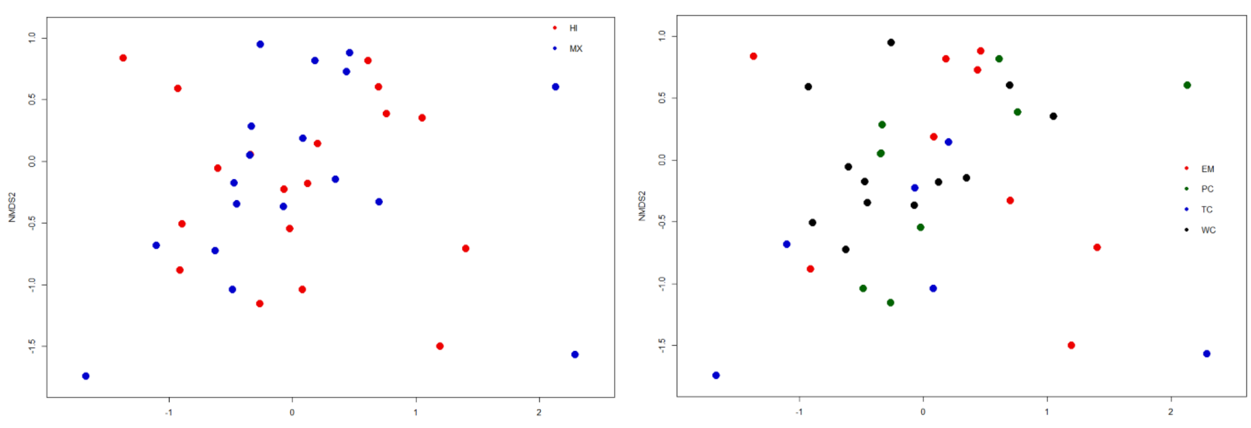


Figure 5: Non-metric multidimensional scaling ordination plots of the bee nesting community colored by treatment (Left, HI = High Severity, MX = Mixed Severity) and burn locality (Right, EM = Emigrant, PC = Pine Creek, WC = Wicked Creek, TC = Thompson Creek, UN = Unburned). Stress of 0.15 on 20 iterations.

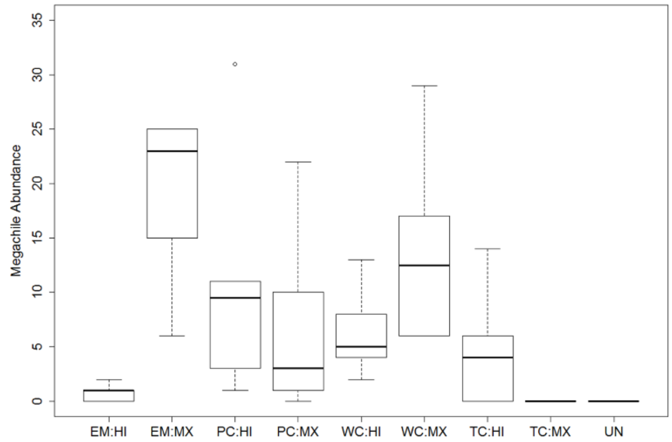
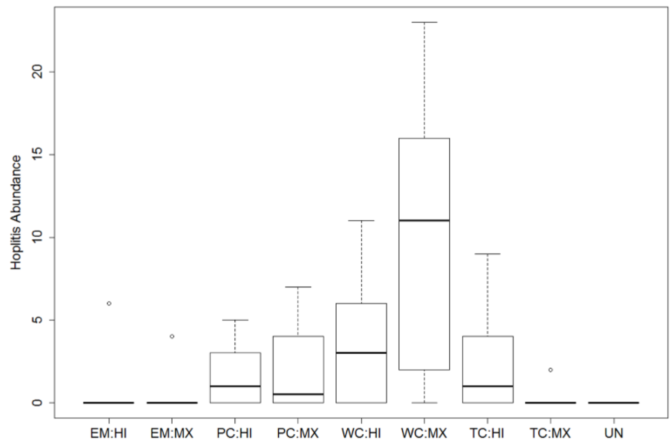
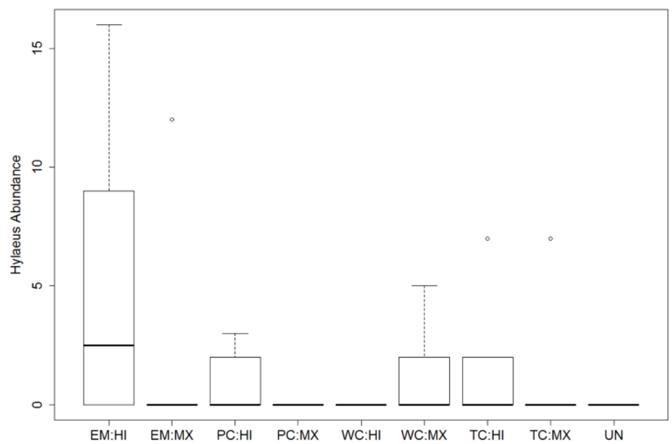


Figure 6: HI = High severity plots, MX = Mixed severity plots, EM = Emigrant, PC = Pine Creek, WC = Wicked Creek, TC = Thompson Creek, UN = Unburned.

A: Abundance of *Megachile* bees from emerged nesting tubes.



B: Abundance of *Hoplitis* bees from emerged nesting tubes.



C: Abundance of *Hylaeus* bees from emerged nesting tubes.

Habitat measurements and bee nesting

Habitat measurements (i.e., number of wood cavities, number of stumps, and CWD) did not significantly vary between burn localities or treatments with only one exception: canopy cover was much greater overall in our unburned treatment. Similarly, no habitat variable which we measured was found to correlate with any measure of bee nesting success, with the exception that canopy cover was significantly greater in the unburned treatment where no bees successfully emerged. The only other relationship of note we observed was a slight correlation between CWD and the number of bees per tube (Table 1); however, the estimate and model fit were particularly weak.

Table 1: Effects of abiotic habitat variables on bee nesting. P-values less than 0.05 bolded.

	Emerged Bee Tubes		**Bee Species Richness**		**Number of Bees per Tube**	
	Estimate	p	Estimate	p	Estimate	p
Wood Cavities	-0.019	0.162	-0.008	0.071	0.006	0.246
Stumps	0.111	0.469	0.044	0.338	-0.029	0.617
Canopy Cover	0.092	**0.010**	0.042	**0.000**	0.039	**0.004**
CWD	-0.005	0.344	-0.001	0.763	-0.005	**0.025**

	Unemerged Tubes		**Parasitoid Tubes**	
	Estimate	p	Estimate	p
Wood Cavities	-0.001	0.973	0.002	0.436
Stumps	0.154	0.410	0.018	0.507
Canopy Cover	0.027	0.517	-0.004	0.478
CWD	0.003	0.704	0.001	0.440

Floral resource availability and bee nesting

Several measures of bee nesting (number of successful tubes, bee species richness, number of bees per tube, and number of emerged parasitoids) were found to have approximately normal distributions across the range of floral resource availability (Figure 7). Floral diversity was found to not significantly differ between burn locality and treatment combinations, with the exception of unburned being much lower (Figure 8), and to have no strong relationships with measures of bee nesting success (Table 2).

Table 2: Metrics of bee nesting related to floral diversity

	Estimate	**p value**	$\mathbf{R^2}$	$\mathbf{F_{1,52}}$
Bee Tubes	-0.897	0.455	0.008	0.566
Richness	-0.1827	0.643	0.015	0.218
Bee/Tube	0.2685	0.566	0.012	0.334
Parasitoid	-0.4978	0.008	0.111	7.584
Unemerged	1.559	0.227	0.009	1.497

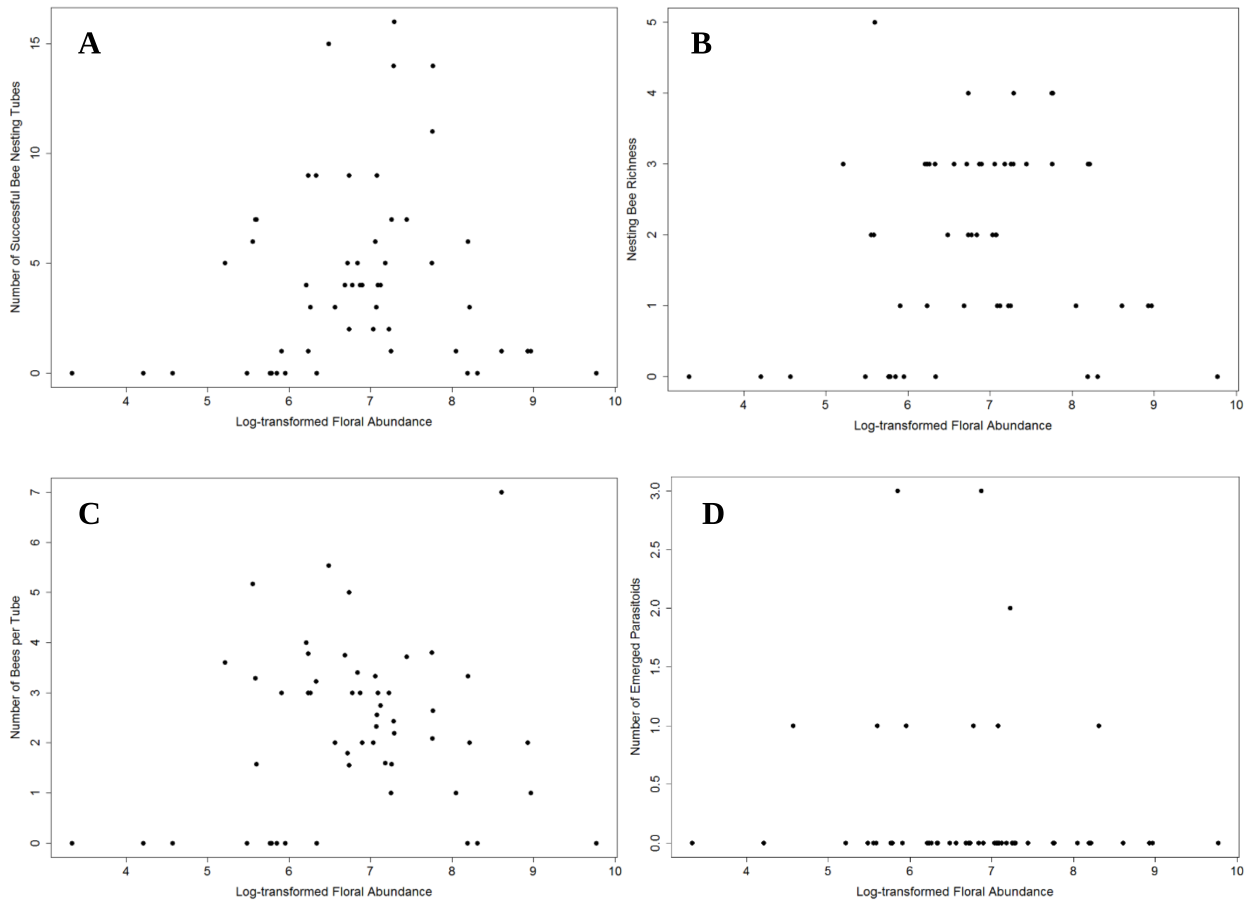


Figure 7: Measures of bee nesting success compared to floral abundance; A: emerged bee tubes, B: bee richness, C: number of bees per emerged tube, D: emerged parasitoids. HI = High severity plots, MX = Mixed severity plots, EM = Emigrant, PC = Pine Creek, WC = Wicked Creek, TC = Thompson Creek, UN = Unburned.

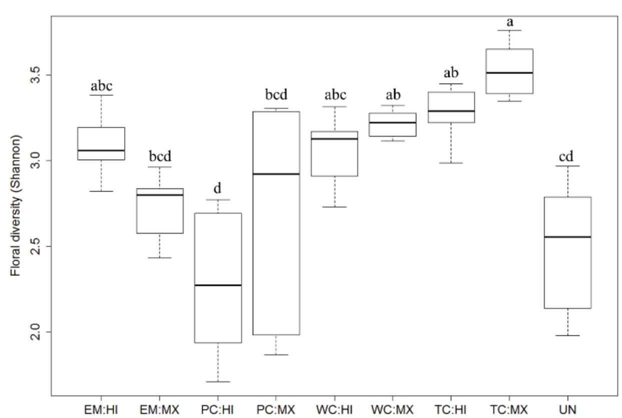


Figure 8: Floral diversity. HI = High severity plots, MX = Mixed severity plots, EM = Emigrant, PC = Pine Creek, WC = Wicked Creek, TC = Thompson Creek, UN = Unburned. Letters denote statistical grouping from Tukey HSD test.

Discussion
The overarching trend is that while there were some minor differences between nesting success or community composition, the results were not consistent with either of our primary treatment designs of burn age and burn severity. A possible explanation would be that these burn localities and treatments were different based on features or bee communities unique to the localities alone; however, we did not detect significant habitat variation between any of our fire localities and no habitat variable which we measured was strongly related to bee nesting metrics. One hypothesis is that we have missed measuring some key way by which wood cavity nesting bees survey their abiotic habitat and make nesting decisions. We built this study with a tight focus on variables important to wood-cavity nesting bees, yet it is possible that other nesting variables, or forage availability as suggested by the floral abundance results, have more influence on nesting decisions or nesting success.

Additionally, our bee nests were dominated by abundant generalist species, with 83% of bee samples consisting of just two species. We could infer that we did not find habitat variables to significantly affect bee nesting simply because the species which comprised most of our samples have very flexible demands for nesting habitat. The low abundance and patchy distribution of our rarer species makes this difficult to test beyond conjecture. This leaves our inference at the community level relatively limited; therefore, it's likely that rare or specialist species are underrepresented in this study. For example, our artificial nesting blocks may have been unsuitable for species which were not captured, or biased our selection towards the species collected.

An important result is our finding that measures of bee nesting were approximately normally distributed across floral abundance. If we consider high floral abundance to be lacking in nesting resources and low floral abundance to contain higher quality nesting habitat then this result that bees would prefer a middle-ground balance of nesting and foraging resources is somewhat intuitive. This would suggest that bees make nesting decisions, or show greater nesting success, with balancing the abundance of nesting and foraging resources in an area.

Conclusions, Implications for Management, and Future Research:

Our proposed objective was to identify how different species of wild bees use nesting habitat in post-burn habitat, and how potential habitat differences with burn severity and time since burn may affect the community of nesting bees. We did not detect any dramatic differences in the bee nesting success based on individual habitat measurements. Despite being unable to find specific habitat metrics which influence bee nesting, there is evidence that taxa nested in different areas across our study area; however, these differences in species composition were not consistent with either burn severity or time since burn. We did find evidence that bee nesting success has some relationship with floral abundance, and it appears likely that nesting success increases at intermediate levels of floral density.

Currently, we still lack an understanding of the limiting factors on wood-cavity bee nesting, as well as clear insight into which habitat characteristics bees hone in on to make nesting decisions. The distribution of bee species appears to be localized and not arranged by burn severity or time since burn. The most apparent result is our finding that an intermediate level of floral density supports greater nesting success. From a landscape ecology and management perspective, this suggests that supporting the theory of a mosaic of post-disturbance habitats would be ideal for assisting wood-cavity nesting bees, in that it provides a variety of post-disturbance habitat available for species. I.e., the burn severity of a smaller discrete area could be unimportant in the context of the relative availability of different burn severities and ages within the landscape of interest. Furthermore, it would suggest that large-scale high severity burns, i.e., those with greatest floral abundance post-burn, could be detrimental to the nesting success of wood-cavity nesting bees. Likewise, as noted in our unburned habitat, a total lack of fire leads to areas being relatively unoccupied by these taxa.

More work is required on the link between floral resource availability and bee nesting density. While our results suggest that there may be improved nesting density and success at areas of intermediate floral density, our lack of significant findings regarding nesting habitat measurements means we lack a mechanism by which to explain this link.

New methods need to be developed for detecting and censusing nesting bees in the field, more specifically, methods which do not rely on artificial traps or nests. While bees are easy to sample when foraging, it remains difficult and inefficient to locate their natural nesting places, particularly for wood-cavity nesting bees. Because of these issues, we continue to have poor understanding of how bees select nesting habitat, and therefore it remains difficult to assess or predict how these species respond to disturbances such as wildfire, leaving managers without the information necessary to even assess bee communities.

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Appendix A: Contact Information for Key Project Personnel

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Appendix B: List of Completed/Planned Scientific Products

Completed:
Conference Talk - Presentation at Ecological Society of America Annual Conference – August 2017
Planned:
Refereed Publication – Submission of manuscript regarding this work to a peer reviewed journal – Spring 2018
Dissertation – Defense of PhD dissertation – Summer 2018

Appendix C: Metadata

Data will be added to the JFSP preferred Research Data Archive maintained by the Forest Service upon publication of the refereed publication or within two years of the completion of this project, as originally stated in the proposal.