Project #: EMC-2021-003

Date: December 1, 2021

Project Title: Evaluating the response of native pollinators to fuel-reduction treatments in managed conifer forests

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Collaborators: Oregon State University, National Council for Air and Stream Improvement, USDA Forest Service, W. M. Beaty & Associates, Collins Pine Company, Sierra Pacific Industries, Manulife Investment Management [formerly Hancock Natural Resource Group]

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Project Duration (Years/Months): The project will run 3 years and 0 months starting June 1, 2022 and will continue until May 31, 2025 (see details in §8 below).

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1. Background and Justification

Animal pollinators represent approximately 300,000 species worldwide (Kearns et al. 1998, Willmer 2011) and play indispensable roles by pollinating >85% of the world's wild flowering plants (Ollerton et al. 2011), 35% of agricultural crops (Klein et al. 2007), and ultimately providing $175 billion in ecosystem services annually (Gallai et al. 2009). Despite their importance, many pollinators have experienced sharp declines, intensifying concerns regarding a "pollinator crisis" (Allen-Wardell et al. 1998; Biesmeijer et al. 2006; Potts et al. 2010; Cameron et al. 2011, 2016) that ultimately threatens global food security and the integrity of natural ecosystems. For example, the Western Bumble Bee (*Bombus occidentalis*) was formerly widespread throughout western North America but its populations have declined extensively in recent decades to the point where it is now being considered for listing under the Endangered Species Act (Cameron et al. 2011, Graves et al. 2020). These declines, and the potential for increased legal protections, have led to a heightened interest in undertaking research to assess how contemporary land management practices influence pollinator populations, including how such practices may be adjusted to improve their ability to contribute to broader pollinator conservation efforts.

Although forests managed for timber production support pollinators (Hanula et al. 2016) our understanding of how forest management influences this group remains in its infancy. Indeed, our recent review found only 14 published empirical studies that were relevant to insect pollinators within temperate conifer forests (Rivers et al. 2018a), highlighting insufficient information for managers who want to consider pollinators when making decisions related to forest management. One particularly important knowledge gap centers on evaluating how forest pollinators are influenced by management actions undertaken to reduce wildfire risk. Wildfires have grown in their extent and severity in recent decades (Pausas and Keeley 2021) and have led to large-scale fires that have occurred on previously undescribed scales in California (Williams et al. 2019) and more broadly throughout western North America (Dennison et al. 2014, Abatzoglou et al. 2021). In turn, the growing footprint of wildfire has been countered by an expanding effort to implement fuel-reduction treatments that reduce large-scale, high-severity fires. For example, Section 40803 of the recent Infrastructure Investment and Jobs Act (H.R. 3684) directs $3.3 billion towards wildfire risk reduction, including $500 million for prescribed fire and $500 million for fuel break construction in the western U.S. (https://www.congress.gov/bill/117th-congress/house-bill/3684/text).

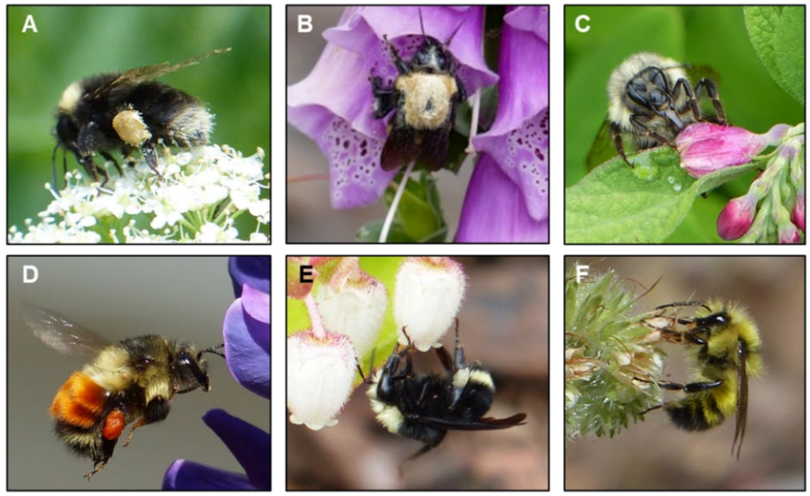

Fig. 1 | Bumble bees (*Bombus* spp.) typically dominate native bee assemblages within managed conifer forests, yet several species are currently being considered for increased protections. Forest-dwelling species are varied and include the (A) Western Bumble Bee (*Bombus occidentalis*), (B) Nevada Bumble Bee (*B. nevadaensis*), (C) Fuzzy-horned Bumble Bee (*B. mixtus*), (D) Black-tailed Bumble Bee (*B. melanopygus*), (E) Yellow-faced Bumble Bee (*B. vosnesenskii*), and (F) Yellow-headed Bumble Bee (*B. flavifrons*). Six bumble bee species are currently being considered for listing in California, including *B. occidentalis*.

Although fuel-reduction treatments are being planned and implemented over broad areas of western U.S. forests, the consequences they will have on forest pollinators remains unclear. Fuel-reduction treatments typically result in a reduction of canopy cover and an increase in light availability to the forest floor, which can create conditions that are favorable to pollinators (Hanula et al. 2016, Rivers et al. 2018a), especially if forests provide pollinators with refugia from pressures they often experience in agricultural settings, such as pesticides and pathogens (Goulson et al. 2015). Despite the potential benefits of managed forests for declining pollinators, however, fuel-reduction treatments vary widely in how they are implemented (e.g., mechanical thinning, mastication, chipping, prescribed fire), and this variation has strong potential to influence pollinator communities through resulting changes to the resources needed by pollinators (i.e., flowering plants, nesting sites). Thus, assessing the response of pollinators to different fuel-reduction methods remains a key knowledge gap, and is a topic that is particularly important when evaluating whether the California Forest Practice Rules (FPRs) that are designed to mitigate fire risk also provide habitat for insect pollinators in managed forests (see §3 below). Because of the rapid expansion of fuel-reduction treatments – in both California and more broadly in western North America – research to quantify how pollinators respond to fuel-reduction treatments in managed conifer forests is urgently needed for understanding of how variation in this management action influences pollinator communities while simultaneously reducing fire risk. Additionally, the Franklin's Bumble Bee (*B. franklini*) was listed as federally endangered in August 2021 (USFWS 2021), and the western (*B. occidentalis*), crotch (*B. crotchii*), and Suckley's (*B. suckleyi*) Bumble Bees have also been petitioned for listing in California (https://wildlife.ca.gov/Data/CNDDB/News/legal-status-of-bumble-bees-in-california). Other native bumble bees have been designated as species of greatest conservation need by western states, so understanding the extent to which current forest management practices provide habitat for species of heightened conservation importance is especially timely and relevant.

2. Objectives and Scope

In this study, we propose research to determine how wild bee communities respond to widespread fuel-reduction treatments in managed forests that are commonly implemented under current FPRs (Table 1). We focus our research on wild bees because they are considered to be the most important pollinator group in nearly all terrestrial settings (Michener 2007) due to their numerical dominance relative to other insect pollinator groups and because of their life-long dependence on food resources that originate from the floral structures of flowering plants (i.e., pollen and nectar; Michener 2007, Brown and Paxton 2009). Although there is a dearth of research on bees within managed conifer forests in the western U.S. (Rivers et al. 2018a), a growing body of work has found that wild bees commonly occur in open, recently disturbed forest stands where they have access to floral resources and nesting sites, such as early seral forests (Rivers et al. 2018b, Foote et al. 2020, Rivers and Betts 2021, Kormann et al. 2021), and post-fire areas (Heil and Burkle 2018; Burkle et al. 2021; Galbraith et al. 2019a, 2021). In particular, our recent work has found that bee species richness increases rapidly after timber harvest (Rivers and Betts 2021), and that the removal of logging slash from logged sites can enhance bee diversity and abundance (Rivers et al. 2018b). Indeed, in a replicated field study, we found greater levels of bee species richness when logging slash and organic matter was removed after timber harvest (Fig. 2), with a similar relationship found for bee abundance (Rivers et al. 2018b). The majority of bee species nest in soils (Cane 1991, Michener 2007) and nesting resources can determine the structure of bee communities (Potts et al. 2005); however, forest bees are unable (or unwilling) to burrow through litter and duff layers to access mineral soil and create their nests. Therefore, the removal of logging slash enhanced bee communities by creating bare soil areas that were needed by soil-nesting bees (Rivers et al. 2018b). Based on these findings – as well general principles of forest pollinator ecology (reviewed in Hanula et al. 2016, Rivers et al. 2018a), bees are expected to colonize sites after fuel reduction treatments are implemented, given those areas provide the two critical resources needed to support bee populations (i.e., flowering plants, nesting substrates). Nevertheless, little is known about how these resources are influenced by the marked variation that is brought about by fuel-reduction treatments, and how those changes have consequences for wild bee communities. Preliminary findings in markedly different environments (e.g., Arizona) has found that thinned and burned areas can lead to increased bee diversity, especially with sufficient floral resources (Nyoka 2010, Oja 2020). Although promising, it is unclear whether these patterns are relevant to other forest types, necessitating new research in managed conifer forests, including fire-prone forests of the Pacific Coast region.

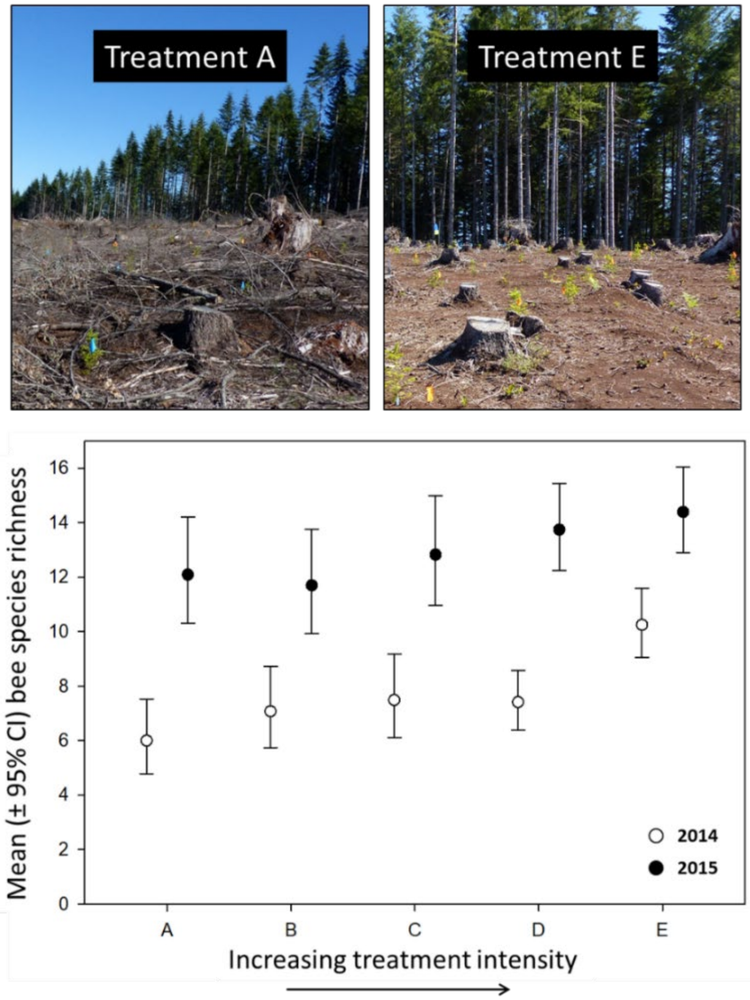

Fig. 2 | Bee richness increased with increases in logging slash and organic matter removal in a replicated field experiment in the Oregon Cascade Mountains; a similar relationship was found for bee abundance. Data from Rivers et al. 2018b where n=28 sites were sampled from May-August in 2014-2015. Logging slash removal provided habitat by exposing soil that was covered by woody materials and impeded access to soil by ground-nesting bees.

Given these uncertainties, our proposed work focuses on (1) quantifying the response of wild bee communities to three widespread and commonly implemented post-harvest fuel-reduction treatments identified in contemporary FPRs (i.e., fuel piling and burning, off-site fuel removal, and fuel chipping and leaving on-site); and (2) assessing how these fuel-reduction treatments vary in their influence on the floral resources (i.e., flower abundance and diversity) and nesting substrates needed to support wild bee communities. By addressing these objectives in concert, our project will provide new information regarding the effectiveness of contemporary FPRs in balancing the mitigation of wildfire risk with the maintenance of habitat for wild bees, a critically important group that is fundamental for maintaining biodiversity in managed forests.

3. Forest Practice Regulations and Critical Monitoring Questions Addressed

Our proposed work encompasses both Critical Question Theme 6 (Wildfire Hazard) and Critical Question Theme 9 (Wildlife Habitat: Cumulative Impacts) of the Effectiveness Monitoring Committee's Strategic Plan (EMC 2018). Together, these themes cover a range of FPRs as outlined in Table 1. Regarding Theme 6, our project is centered around fuel-reduction treatments that occur after commercial timber harvest, with a focus on post-harvest slash and the management of fuel loads to reduce fire risk. Regarding Theme 9, our work focuses on evaluating a poorly understood but critical component of forest biodiversity – wild bees – which have received limited attention by researchers, including at least on species that is a candidate for federal listing by the U.S. Fish and Wildlife Service (Graves et al. 2020). Thus, our work combines these two themes to quantify and evaluate whether current FPRs and associated regulations for reducing fire risk that that arise from timber harvesting plans (14 CCR 2 § 1038, 1051.4, 1052.4), special prescriptions (14 CCR § 913.4 [933.4, 953.4]), and hazard reductions (14 CCR § 917 (937, 957) are effective in providing suitable protection practices for wildlife (14 CCR § 919, 939, 959).

In turn, our work allows us to address four critical monitoring questions (Table 1) as outlined in the EMC Strategic Plan (EMC 2018). The first two questions center around wildfire hazard (Theme 6) and asks whether the FRPs and associated regulations are effective in treating post-harvest slash and managing fuel loads to reduce fuel loads while also retaining wildlife habitat structure, including snags and large woody debris. Of note, a range of native bees require large woody structures as nesting substrates (e.g., beetle exit holes in standing dead trees; Cane

Table 1. Forest Practice Regulations and Critical Monitoring Questions addressed in this study.

<table>
<tr><th>Theme</th><th>FPRs</th><th>Article</th><th>Critical Monitoring Questions</th></tr>
<tr><td rowspan="3">6. Wildfire Hazard</td><td>14 CCR § 1038, 1051.4, 1052.4</td><td>Article 2. Timber Harvesting Plan</td><td rowspan="3">Are the FPRs and associated regulations effective in...
(b) treating post-harvest slash and retaining wildlife habitat structures, including snags and large woody debris?
(c) managing fuel loads, vegetation patterns and fuel breaks for fire hazard reduction?</td></tr>
<tr><td>14 CCR § 913.4 [933.4, 953.4]</td><td>Article 3. Special Prescriptions</td></tr>
<tr><td>14 CCR § 917 (937, 957)</td><td>Article 7. Hazard Reduction</td></tr>
<tr><td>9. Wildlife Habitat: Cumulative Impacts</td><td>14 CCR § 919, 939, 959</td><td>Article 9. Wildlife Protection Practices</td><td>Are the FPRs and associated regulations effective in…
(a) characterizing and describing terrestrial wildlife habitat and ecological processes?
(b) avoiding significant adverse impacts to terrestrial wildlife species?</td></tr>
</table>

et al. 2007, Michener 2007) so retention of these habitat elements is important for promoting such species. At the same time, our recent work has found that post-harvest slash removal appears to benefit ground-nesting bee species by providing access to mineral soil on the forest floor (Rivers et al. 2018b). Thus, a key question is determining whether habitat for these two key bee groups (i.e., woody- and soil-nesting species) is provided by current FPRs that require reduction of logging slash and other fuels, which will be addressed by our proposed research.

The second two questions from the EMC Strategic Plan addressed by our research are focused on the cumulative impacts to wildlife habitat (Theme 9) and asks whether FPRs and associated regulations provide suitable opportunities for terrestrial wildlife and their ecological processes without significant adverse effects. Surprisingly, very little work has been undertaken to understand the effectiveness of fuel-reduction treatments for achieving broader ecological objectives in general, and wildlife in particular. The limited work that has been undertaken on wildlife has focused mostly on endangered vertebrates, such as the Northern Spotted Owl (*Strix occidentalis occidentalis*), with virtually no research undertaken on insects. In fact, a recent systematic review examining published literature on the effectiveness of fuel treatments described the evidence for pollinators as "non-existent" (Kalies and Kent 2016). Similarly, a separate review of post-harvest slash burning also revealed limited understanding of the ecological effects of this practice on arthropods and specifically called for more study of this topic (Mott et al. 2021). Given these clear knowledge gaps, it remains critical to understand how forest pollinators are influenced by management activities undertaken across large geographic regions (Hanula et al. 2016, Rivers et al. 2018a) because the pollination services provided by bees serve as the basis for terrestrial food webs and influence a wide range of organisms that rely on plants for both food and cover (Michener 2007, Brown and Paxton 2009). Importantly, our study takes place within the historic range of the Western Bumble Bee, a species currently being considered for federal listing because it has experienced population declines and range contraction throughout its range (Graves et al. 2020). Unfortunately, it is not the only species of bumble bee that has experienced declines in western North America (Cameron et al. 2011, 2016), so our findings may be particularly salient for understanding contemporary habitat needs for other species facing increased protections in the future. Taken in its entirety, our project will provide results that center on Themes 6 and 9 of the EMC Strategic Plan and evaluate whether current FPRs and regulations aimed at treating fuels to reduce fire risk also provide habitat for wild bees within managed forest landscapes, including species of heightened conservation concern.

4. Research Methods

4.1 Study area and experimental design

We have focused our study in northeastern California on private industrial forestland owned by our cooperators (W. M. Beaty & Associates, Sierra Pacific Industries, Collins Pine Company, Manulife Investment Management [formerly Hancock Natural Resource Group]; see Letters of

Support). Our selection of individual study sites will follow the approach we have taken in our previous large-scale forest pollinator research projects where we have implemented a two-step hierarchical selection method that initially identifies potential areas in which to work and is then followed by ground-based surveys to confirm available study sites meet research goals. To accomplish this, we will first obtain GIS data layers from our cooperators to delineate areas of green (i.e., unburned) forest that have been subjected to clearcut harvest and has had one of the following post-harvest fuel-reduction treatments within the last 6 years (i.e., harvested + fuel-reduction treatments applied no later than 2016): (1) fuels piled and burned, (2) fuels chipped and left on site, (3) fuels removed from site; see below for treatment details. We will select sampling areas that provide a balance between representing the range of age classes and land ownerships within our study region, yet are also within a reasonable driving distance to allow regular visitation by field crews feasible during the period of data collection. Once this is accomplished, our second step will be to spend late spring 2022 surveying potential study sites to determine they meet our criteria for data collection. Specifically, we will identify n ≥ 15 sites/treatment that are spatially independent (≥ 5 km from each other), are of sufficient size (≥ 10 acres), and are separated from other open areas by stands of closed-canopy forest (i.e., ≥ 25-years post-disturbance and residual basal area ≥ 150 ft^2/acre) so that pollinator response can be attributed to fuel-reduction treatments and are not confounded by other local environmental factors (e.g., meadows, extensive cleared areas).

For this study we have selected three distinct treatments – fuels piled and burned, fuels chipped and left on site, and fuels removed from site – because they are widespread treatments specified in the FPRs for reducing post-harvest slash and managing fuel loads after clearcut harvest and because they are expected to have varying impacts on wild bee communities through their influence on the floral and nesting resources on which bees depend (Rivers et al. 2018a, b). For example, as noted above the removal of logging slash from post-harvest areas can increase bee species richness and abundance by providing access to nesting substrates for soil-nesting species (Rivers et al. 2018b), and the burning of piled fuels is expected to enhance this effect by increasing exposure of mineral soil in burned areas. However, slash piles can also serve as islands of soil fertility, and the abundance of flowering plants used by insect pollinators can be reduced when slash piles are removed relative to when they are left piled (McCavour et al. 2014) or are dispersed on site (Harrington et al. 2020). Thus, off-site removal of slash may also impact wild bee communities by negatively influencing the flowering plant community on which bees depend within treated areas. Chipping and leaving fuels on site may reduce the negative effects of removing fuels from sites on floral resources, but its unknown if this management approach may enhance, constrain, or have a neutral effect in creating nesting opportunities for wild bees. It is important to note that the types of woody fuels that are removed to mitigate fire risk are typically unsuitable for nesting by wild bees; most species that require woody nest substrates use small-diameter, hollow stems (e.g., dead *Rubus* stems used by *Ceratina* bees; McIntosh 1996) or existing cavities made by other species (e.g., beetle exit holes used by *Osmia* bees; Cane et al. 2007). Only the large carpenter bees (*Xylocopa*) can create nest sites within solid wood (Stephen et al. 1969), of which there are only 3 species in California. Thus, we expect the effects of slash treatment will be indirect on bee communities, and will not arise from the removal of materials that wild bees would typically use as nesting substrates.

When considering our experimental design, it is important to note that a true control would require sites that undergo clearcut harvest and are accompanied by no post-harvest fuel-reduction treatment. Implementing such a control is not possible for several reasons, including current FPRs, so the primary focus in our study is on evaluating how different post-harvest fuel treatments vary their implementation leads to divergence in wild bee communities and their associated floral and nesting resources. However, we have opted to include an additional treatment – mature forest – to serve as a reference treatment that represents pre-harvest conditions and will provide information regarding the magnitude of change incurred by wild bee communities by clearcut harvest and ensuing fuel-reduction treatments. Mature forest sites will be stands ≥ 10 acres that are ≥ 25-years post-disturbance with residual basal area ≥ 150 ft^2/acre, and each mature forest site will be located < 5 km from a site undergoing one of the three fuel-reduction treatments (with which it will be paired) to limit spatial variation in local environmental conditions. Mature forest sites will be sampled identically and concurrently with fuel-reduction treatments to facilitate direct comparisons between paired treatment and pre-treatment areas. Although this additional treatment requires greater sampling effort, its inclusion will allow us to leverage our focal objectives to understand how wild bee communities change as a function of clearcut harvest and fuel-reduction treatments, and it will provide baseline information regarding bee communities in mature forests that will have utility to scientists and managers well beyond the current study.

4.2 Sampling of bee communities

Once we have identified study sites, we will undertake sampling of wild bee communities under our current collecting permits from May–August during 2022–2023. Because solitary bee flight seasons are typically short in length (e.g., 4–6 weeks), we will undertake 3 separate sampling rounds per year, each of which will be separated by 3–4 weeks to cover the majority of the wild bee flight season. We will undertake a combination of sampling approaches that include blue-vane traps (Fig. 3A), pan traps (colored yellow, white, and blue; Fig. 3B), and hand-netting from flowers (Fig. 3C). Together, these approaches provide for the broadest representation of the wild bee community (Cane et al. 2000, Roulston et al. 2007, Popic et al. 2013), with hand-netting providing additional information about bee-flower visitation.

We will undertake sampling at the center of each study site to confine insect collection to a small part of each stand and minimize the potential for edge effects. We will establish one 3 m x 20 m long transect at the center of the stand, and at the ends of the transect we will place a blue vane trap with a small amount of insect preservative (ethylene glycol) on a 1.5 m metal t-post located 10 m equidistant from the plot center. We will place the transect along a random azimuth from the plot center. At the same time, we will place 9 pan traps (i.e., a white 350 ml plastic drink cup whose interior is painted yellow, white, or blue) placed 45 cm off the ground with ethylene glycol along the transect; one pan trap will be located at the centroid of the plot, whereas the other 8 pan traps will be located every 5 m along the transect, 4 to each side. We will place out blue vane traps and pan traps at the same time and leave them in place for 48 hours during favorable weather conditions (i.e., light or no precipitation, air temperature ≥ 12.5° C), after which we will return to empty trap contents into containers and then store containers at Oregon State University until we undertake specimen identification.

Immediately prior to sampling bees with blue vane and pan traps on each site, we will undertake hand-netting and floral resource surveys. We will hand-net insects during favorable weather conditions (i.e., light or no precipitation, air temperature ≥ 12.5° C, wind <10 km) along the transect. We will net all bees observed making physical contact with flower reproductive components while recording the plant from which each bee is obtained. The transect will be sampled for 30 min (15 min in each direction) by walking at a constant pace using a stopwatch, with the stopwatch paused when processing specimens. Once netting is completed, we will count and record the species of every flowering stem, number of stems, and number of blooms per stem within the transect to quantify floral abundance and floral diversity. If blooms are too numerous to count individually, we will estimate into bins of 50. We will sample floral resources during each sampling round in both years (i.e., 6 sampling periods) to quantify variation in floral resources across each season and between years.

Fig. 3 | Approaches used to sample forest bees in this study. We will employ the use of (A) blue-vane traps and (B) colored pan traps that target bees, along with (C) direct hand-netting of bees from flowers. Note that although a blue pan trap is shown, white, yellow, and blue pan traps will be used to sample bees.

During the last sampling round in each year we will collect data on potential nesting resources for be bees. We will measure (1) the amount of exposed soil, (2) the extent and depth of subsurface soil compaction via a handheld penetrometer, and (3) the amount of appropriate woody debris available to stem-nesting bees (i.e., hollow or pithy twigs) in three size classes (i.e., 1-5 mm, 6-10 mm, 11-15 mm diameter); we will make these measures within a 3-m radius circle centered on each blue vane trap location. We will also measure canopy cover, slope, and aspect at stand center because they may influence pollinator communities.

4.3 Specimen identification and data analysis

We will work with taxonomic experts affiliated with the Oregon Bee Project at Oregon State University (https://www.oregonbeeproject.org/) with whom we have ongoing collaborations to identify bee specimens. We will use keys from Michener (2007) and Stephen et al. (1969) to identify specimens to the generic level, and used both regional synoptic collections and local keys to obtain species-level identifications for such genera as *Agapostemon* (Stephen et al. 1969), *Anthophora* and *Ceratina* (www.discoverlife.org), *Bombus* (Williams et al. 2014), and *Halictus* (Roberts 1973). Species-level keys for several groups in the Pacific Northwest, USA are currently unavailable in our region including *Lasioglossum* (*Dialictus*) and *Lasioglossum* (*Evylaeus*), so we will be restricted to identifying individuals to morphospecies for these groups.

For all statistical analysis we will use the R statistical environment (R Core Team 2021). We will pool all bee samples that are captured from all sampling methods on each stand for each sampling round in each year, and we will quantify floral resources in a similar manner. This will result in three measures (i.e., observed bee species richness, bee abundance, and floral resources) for each stand, which will allow us to evaluate how these response variables are influenced by the timing of sampling within the season and across years. In addition, we will calculate Hill numbers to compare bee diversity measures across treatment types. To quantify diversity measures, we will use the iNEXT package (Hsieh et al. 2020) to create sample-sized-based and coverage-based rarefaction and extrapolation sampling curves for three Hill numbers (q=0, q=1, q=2; Chao et al. 2014, Hsieh et al. 2016). Hill numbers represent the effective number of species for several diversity metrics, including species richness (q=0), the exponential of Shannon index (q=1, hereafter Shannon diversity), and the inverse of the Simpson concentration (q=2, hereafter Simpson diversity). Hill numbers are gaining favor for evaluating diversity measures within ecological communities (e.g., Galbraith et al. 2019b) because they are intuitive to understand, are based on a robust statistical framework, can be used to make "fair" comparisons between different communities based on sample coverage, and offer several additional advantages when compared to traditional diversity metrics (Chao and Jost 2012, Chao et al. 2014, Hsieh et al. 2016). For bee communities in different treatments we will conduct separate (1) sample-size-based rarefaction and extrapolation curves, (2) coverage-based rarefaction curves, and (3) sample-completeness curves, each with 95% confidence intervals which, when not overlapping, provide evidence of strong differences in ecological communities (Chao et al. 2014, Hsieh et al. 2016). In addition, we will use non-metric multidimensional scaling (NMDS) in the vegan package (v2.5-6; Oksanen et al. 2020) to evaluate the degree to which treatments share member species. Specifically, we will use the metaNMDS function for ordination, and the adonis2 function to evaluate differences between bee communities in sites subjected to different treatments, setting the permutation level to 1000 (Oksanen et al. 2020).

Finally, we will use linear mixed modeling to quantify how observed bee species richness and abundance varies as a function of stand-level characteristics. First, we will use the glmmTMB function of the glmmTMB package (Brooks et al. 2017) to construct a model with a Poisson distribution and a log link that contains observed species richness as the response variable, year (2 levels), treatment (4 levels), and sampling round (3 levels) as fixed effects, floral resources (continuous) as a covariate, and stand identity as a random effect. We will use the same model structure and approach to model bee abundance with the exception that we may be forced to use a negative binomial distribution with a log link if there is high heterogeneity in the number of individuals trapped across sites. We will construct separate models that evaluate how floral resources and nesting resource response variables are influenced by treatment type independently of bee response measures. Finally, we will test for spatial autocorrelation for measures of abundance and richness between study plots over the course of the study.

5. Scientific Uncertainty and Geographic Application

Currently, there is a high degree of uncertainty about how forest management activities such as fuel-reduction treatments influence pollinator communities (Rivers et al. 2018a) and, in particular, whether current FPRs are sufficient to support wild bee communities within California's forests. What is clear, however, is that different fuel-reduction treatments have the potential to both positively and negatively influence wild bee communities, depending on the degree to which they influence the foraging and nesting resources that are required to maintain bee populations. Thus, studies such as ours are needed to understand the extent to which different fuel-reduction treatments may be promoting – or limiting – wild bee communities in managed forest landscapes. Moreover, it is worth nothing that as we investigate the influence of fuel-reduction treatments, we will also provide a repository of distribution information, which is critical for making management decisions about species of special concern.

As noted above, our recent review found a dearth of studies that have examined how contemporary management practices influence pollinator communities within managed conifer forests. Since its publication, several additional studies have become available on conifer forest bee communities in western North America (e.g., Heil and Burkle 2018, Galbraith et al. 2019a, 2019b, 2021; Foote et al. 2020; Rivers and Betts 2021). The picture that is emerging from this growing body of work is that western U.S. forest bee communities are dominated largely by species that are generalist foragers, with few bees detected that are plant specialists. Wild bee communities in forests include species that encompass a range of body sizes, vary in their use of nesting substrates (e.g., ground-nesters, stem-nesters), and are species present in non-forest ecosystems, such as grasslands and agricultural settings. Given this, we expect that the findings that will emerge from the bee communities on our proposed study sites will be directly relevant and applicable to the Northern District of California. However, we also hypothesize that our findings will be broadly relevant to other districts in California and beyond given that forest bee communities appear similar in their general structure, although they vary in their component species.

6. Collaborations and Project Feasibility

Our proposed worked is a multidisciplinary effort involving wildlife biologists, foresters, and entomologists, and our research team includes scientists and managers from academia, private industry, and agencies. The leaders of our research team (Rivers, Moriarty, and Verschuyl) have worked together collaboratively on a number of field research projects examining the response of wildlife to forest management activities. They bring unique strengths from the OSU College of Forestry (Rivers) and private forest industry (Moriarty and Verschuyl) that enhances the ability to facilitate and execute our proposed research with other key collaborators, including Sierra-Pacific Industries (lead: Kevin Roberts), Collins Pine Company (lead: Bennie Johnson Howell), W. M. Beaty & Associates (lead: Ryan Hilburn), Manulife Investment Management [formerly Hancock Natural Resource Group] (lead: Jenniffer Bakke), and the USDA Forest Service (lead: Sarah Sawyer). These collaborators are fully committed to all elements of this study, including permitting access to study sites, sharing data related to past management treatments, and providing logistical support for study implementation (see details in Letters of Support).

This project is expected to have high feasibility, as our research team has extensive experience conducting large-scale research in managed forest ecosystems, which includes studies focus on forest pollinators that have successfully implemented using all of the techniques described here in both moist- and dry-forest ecosystems (Rivers et al. 2018b; Galbraith et al. 2019a, b; 2021; Rivers and Betts 2021). Continuing our ongoing work with research collaborators will allow us to finalize study sites quickly before summer 2022 to ensure the timely execution of and ultimate success of this project.

7. Project Deliverables

We will share results from our study broadly with land managers, scientists, and the general public through regular project updates to funders and stakeholder groups, and through presentations at local, regional, and/or national scientific conferences. In addition, we will provide at least one field tour (expected during summer 2023) to showcase our project to funders, collaborators, and other interested parties such as forest managers, scientists, policy makers. This project will result in the production of a M.S. thesis at Oregon State University, and all data products from this study will be digitally archived and available for future use. We anticipate the production of at least two articles for submission to peer-refereed journals in the fields of forest entomology and/or wildlife ecology centered around core components of this research. Finally, a technical project report summarizing findings will be submitted to the Effectiveness Monitoring Committee at the conclusion of the study.

8. Detailed Project Timeline

	Year 1 (2022-23)				***Year 2 (2023-24)***				***Year 3 (2024-25)***			
Activity	***Su***	***Fa***	***Wi***	***Sp***	***Su***	***Fa***	***Wi***	***Sp***	***Su***	***Fa***	***Wi***	***Sp***
Establish study sites												
Sampling of bee communities and habitat elements – 2022												
Matriculation of M.S student at OSU College of Forestry												
Specimen identification at OSU from 2022 field season												
Project update to funders & collaborators												
Sampling of bee communities and habitat elements - 2023												
Field tour for funders & project collaborators												
Specimen identification at OSU from 2023 field season												
Project update to funders & collaborators												
Conference presentation(s) of results												
Submit final report to EMC												
M.S. student defense												
Submission of manuscripts to peer-refereed journals												

9. Requested Funding

Category	Description*	Year 1	Year 2	Year 3	Total
Personnel	*PI Rivers* *MS Student*	*$5109* *$24,920*	*$10,524* *$25,419*	*$10,840* *$6,482*	*$26,473* *$56,821*
	Subtotal	$30,029	$35,943	$17,322	$83,294
Fringe Benefits	*PI Rivers* *MS student*	*$2,861* *$8,723*	*$6,104* *$9,405*	*$6,504* *$2,528*	*$15,469* *$20,656*
	Subtotal	$11,584	$15,509	$9,032	$36,125
Other	*Services* *MS Tuition & Fees* *Publications*	*$76,721* *$19,568* *$0*	*$70,495* *$20,449* *$0*	*$7,200* *$5,990* *$2,000*	*$154,416* *$46,007* *$2,000*
	Subtotal	$96,289	$90,944	$15,190	$202,423
Operating Expenses	Materials & Supplies	$11,875	$3,525	$0	$15,400
Indirect Cost	15% of total funds	$29,809	$30,136	$7,331	$67,276
Travel	Domestic	$19,140	$24,852	$0	$43,992
Total Cost		$198,726	$200,909	$48,875	$448,510
Matching or In-Kind Contributions ‡					
EMC Funding Requested		**$198,726**	**$200,909**	**$48,875**	**$448,510**

* Detailed Description of Costs

Personnel - Rivers 0.5 month/year in year 1 and 1.0 month/year in years 2 and 3 using a base monthly salary of $9,920 for a total of $26,473. A 3% annual escalation was applied beginning in year 1. MS Student at 0.49FTE (9 terms) using a base monthly salary of $4,155 for a total of $56,821. The A 2% annual escalation was applied beginning in year 1.

Fringe Benefits - Rivers starts at 56% in year 1 with a 2% annual escalation for a total of $15,469. MS Student starts at 35% in year 1 with a 2% annual escalation for a total of $20,656.

Other - (1) Services – Temporary personnel services contract for summer field crew costs are based on weekly rates for leader and 5 techs. Crew leader is needed in year 1 only as the graduate student will be responsible in year 2 with costs calculated at $959/week for 14 weeks. Years 1 and 2 tech rates are $904.21/week for 14 weeks for total of $76,721 and $63,295, respectively. Analytical services for bee specimen identification in Years 2 and 3: cost estimate is 120 hours per year at $60.00 per hour = $7,200/yr for two years = $14,400. **(2) Tuition and Fees -** graduate student tuition is budgeted for 9 terms with AY term costs at $5,485 and SU costs at $3,113 with an annual increase of 4.5% applied per institutional guidance. **(3) Publication Costs/Page Charges -** Costs of $2000 are based on one publication in peer reviewed journal.

Operating Expenses (Supplies) – Year 1 costs are $11,875 for Garmin eTrex GPS units, field tablets, meter tapes, storage coolers, insect nets and traps, specimen pinning and storage supplies, and miscellaneous supplies such as PPE gear. Year 2 costs are $3,525 and include insect collection supplies, and specimen pinning and storage supplies.

Indirect Charges – calculated at 15% on total funding request as specified in RFP

Travel – Domestic

(1) Fieldwork in years 1-2 for *six* fieldwork crew to travel to northern CA:

- per diem+ $15/night x 115 nights for 6 people = $10,350;
- vehicle $390/month x 11 months $0.3/mi x 15,000 miles = $8,790;
- per trip total = $10,350 plus monthly vehicle costs $8,790 = $19,140 x 2 years = $38,280

(2) Professional conferences in year 2 for *two* people (location TBD):

- airfare $800 plus per diem $71/day x 6 days+ $226/night x 5 nights for 2 people = $4,712
- ground transportation $250; PI registration $500, student registration $250
- total = $5,712

‡ Matching or In-Kind – OSU does not allow voluntary match and thus we have not quantified the additional resources being provided.

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Letters of support for the proposal: ***Evaluating the response of native pollinators to fuel-reduction treatments in managed conifer forests***

Collins

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November 17, 2021

Ms. Kristina Wolf
California State Board of Forestry and Fire Protection

Dear Ms. Wolf,

I am writing to express support for an Effectiveness Monitoring Project Proposal being submitted to the California State Board of Forestry and Fire Protection by Drs. James Rivers, Katie Moriarty, and Jake Verschuyl titled **"Evaluating the response of native pollinators to fuel-reduction treatments in managed conifer forests."** Collins Pine Company is committed to all elements of this study, including permitting land access to study sites, sharing data related to past management treatments, and providing logistical support for implementing the study.

As a private landowner, Collins Pine Company recognizes that the California Forest Practice Rules are critical for mitigating wildfire risk and enhancing and maintaining habitats for forest biodiversity. This is especially true for wild bees, a group that is poorly understood in managed forest settings despite its importance and relevance to contemporary forest management and policy decisions. We believe the work proposed by Drs. Rivers and his team will greatly expand our understanding of how contemporary fuel reduction treatments influence bee communities and their critical resources, while also determining whether California Forest Practice Rules are currently sufficient for maintaining bee nesting and foraging habitat.

This research project is important to Collins Pine Company, particularly in lite of the Dixie Fire. We believe that the team Dr. Rivers has assembled will conduct an excellent research project and produce results that will provide foundational information that has relevance for millions of acres of commercial timberland in California and beyond. Therefore, I am writing to indicate that Collins Pine Company supports this proposal, and we strongly hope you will consider funding this important work.

Sincerely,

Bennie Johnson Howell, CWB ®
Wildlife Biologist, Collins Pine Company

FORESTLAND
MANAGEMENT

W. M. BEATY & ASSOCIATES, INC.

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November 23, 2021

Ms. Kristina Wolf
Effectiveness Monitoring Committee
Board of Forestry and Fire Protection
P.O. Box 944246
Sacramento, CA 94244-2460

Re: Landowner Support for Fuel-Reduction Treatment proposal

Dear Ms. Wolf:

W.M. Beaty & Associates manages 280,000 acres of private forestland in Northern California. Previously, to maintain healthy forests, we have implemented a wide range of fuel-reduction treatments under the California Forest Practice Rules. We would like to better understand how these treatments maintain habitats that provide for improved forest biodiversity including potential benefits to native pollinators. Accordingly, we are writing to support the Effectiveness Monitoring Committee (EMC) proposal being submitted by Drs. James Rivers, Katie Moriarty and Jake Verschuyl titled "*Evaluating the response of native pollinators to fuel-reduction treatments in managed conifer forests*".

As a private landowner our participation in this proposal is focused on providing access, in-kind field logistics and coordination, and sharing of all data generated during the project. As we continue to implement fuel-reduction treatments in the future, we believe it is critical to better understand how these treatments that may potentially benefit pollinators including bee communities and their habitats.

We look forward to your review of the proposal and please do not hesitate to contact us if you have any questions regarding our participation in this proposal.

Sincerely,

W. M. BEATY & ASSOCIATES, INC.

By: ______________________________
Ryan Hilburn
Chief Forester

cc: Stuart Farber

SIERRA PACIFIC INDUSTRIES

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November 23, 2021

Ms. Kristina Wolf
California State Board of Forestry and Fire Protection
P.O. Box 944246
SACRAMENTO, CA 94244-2460

Dear Ms. Wolf,

I am writing to express support for an Effectiveness Monitoring Project Proposal being submitted to the California State Board of Forestry and Fire Protection by Drs. James Rivers, Katie Moriarty, and Jake Verschuyl titled "Evaluating the response of native pollinators to fuel-reduction treatments in managed conifer forests." Sierra Pacific Industries fully supports this scientific investigation and will be providing access to study sites, share data related to past management treatments, and provide logistical support for implementing the study.

Sierra Pacific Industries (SPI) is a family owned vertically integrated timber products company. SPI owns 2.3 million acres of timberland, approximately 1.8 million acres in California. Sierra Pacific Industries is committed to aligning the maximum production of high-quality timber products in ways that supports the persistence of plant and animal life diversity that utilize those forests. A critical aspect for managing forests for timber, water and wildlife resources is mitigating wildfire through various fuel treatments. The California Forest Practice Rules is the general framework that guides many of the practices that Sierra Pacific Industries employs to accomplish these goals.

An area of research that is poorly understood is whether fuel treatments in managed stands support wild bees. The work proposed by Drs. Rivers and his team will expand our understanding of how fuel reduction treatments on private forests influence resource availability supportive of bee life requisites. Using this data, the California Forest Practice Rules can be analyzed for their influence in the creation or maintenance of key elements or habitat conditions which are supportive of bee nesting and foraging habitat. We think that the team Dr. Rivers has assembled will conduct a superior research project and produce results that will provide foundational information that has relevance for millions of acres of commercial timberland in California and other western states. Sierra Pacific Industries urges the Effectiveness Monitoring Committee to fund this important work.

Sincerely,

Cedric Twight, RPF #2469	Len Lindstrand III	Kevin Roberts
Regulatory Affairs Manager	Botany Program Manager	Wildlife Program Manager
Sierra Pacific Industries	Sierra Pacific Industries	Sierra Pacific Industries

Manulife

Ms. Kristina Wolf
Effectiveness Monitoring Committee
Board of Forestry and Fire Protection
P.O. Box 944246
Sacramento, CA 94244-2460

November 23, 2021

Dear Ms. Wolf,

This letter is to confirm our support of the proposal titled "*Evaluating the response of native pollinators to fuel-reduction treatments in managed conifer forests*" being submitted by Drs. James Rivers, Katie Moriarty, and Jake Verschuyl. We are committed to supporting this project by providing access to study sites, providing in-kind field logistics and coordination, and sharing of data related to past management treatments.

Manulife Investment Management manages approximately 20,000 acres of timberland in northern California on behalf of institutional investors. We recognize the role California Forest Practice Rules play for mitigating wildfire risk and maintaining or enhancing habitat for a variety of forest-dwelling wildlife species. As a participant of the Sustainable Forestry Initiative®, our company maintains a long-standing commitment to research programs that support the management and stewardship of its forests. We would like to better understand how contemporary fuel reduction treatments influence biodiversity, particularly wild pollinators. Additionally, we would like to better understand the extent to which current California Forest Practice Rules promote wild bee nesting and foraging habitat. Therefore, the work of Dr. Rivers and colleagues is highly relevant to our overall stewardship mission.

We appreciate the Effectiveness Monitoring Committee for its consideration of funding this important project. Please do not hesitate to contact us if you have any questions regarding our participation in this proposal.

Sincerely,

Jenniffer Bakke

Jenniffer Bakke
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Date: 11/29/2021

Ms. Kristina Wolf
California State Board of Forestry and Fire Protection

Dear Ms. Wolf,

I am writing to express support for an Effectiveness Monitoring Project Proposal being submitted to the California State Board of Forestry and Fire Protection by Drs. James Rivers, Katie Moriarty, and Jake Verschuyl titled **"Evaluating the response of native pollinators to fuel-reduction treatments in managed conifer forests."** The US Forest Service (USFS) plans to be an active and committed partner in this study, which would include support to study site selection, access and permitting; data sharing and information on past and planned management; and logistical support, as needed, during implementation. Partnering would also include ensuring management applicability of study results and supporting co-production and communication of results to agency and partner managers and decision-makers. As the former Regional Wildlife Ecologist for USFS's Pacific Southwest Region, and the current National Wildlife Ecologist for the Agency, it is my job to help ensure that management-relevant wildlife science is produced and effectively communicated at multiple levels to inform decision making. Partnering with Dr. Rivers and his team on this study would provide an ideal opportunity to do so, and I will help ensure that when my replacement is selected in the Pacific Southwest Region, they will be up to speed and engaged in this work rapidly.

With the extreme nature of recent fire years in California, as well as the recent signing of the Infrastructure Investment and Jobs Act into law, effective management for fuels risk reduction and forest resilience are at the forefront of current USFS priorities in California. However, USFS has multiple goals for such land management, including the provisioning of ecosystem services and providing habitat for California's native wildlife. Balancing these goals can be challenging, and science to inform the practices that support each of these goals while increasing ecological resilience is critically important. This study focuses on evaluating how contemporary fuel reduction treatments influence bee communities and their resources, while also determining whether California Forest Practice Rules are currently sufficient for maintaining bee nesting and foraging habitat. By partnering across ownership and management types, this study can examine a range of fuel-reduction treatment types and outcomes. Thus, this project will provide the very type of information needed by forest managers to understand the implications of critical fuels management practices on a broad scale and better design these important practices to meet multiple objectives and provide multiple services. The research team, led by Dr. Rivers, is well-suited to implement, conduct, and share results from this study with scientists, managers, and policy makers, and by partnering with multiple landowners and land management agencies, the team will ensure broad applicability of results. Therefore, I am writing to indicate my support for this proposal, and I urge you to consider funding this important work.

Sincerely,

Sarah Sawyer
National Wildlife Ecologist