March 23, 2022

Living Lab Program for Climate Change and Conservation - Final Report

Project title: Pollinator conservation management for climate change in British Columbia

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Research findings

- As a follow-up to preliminary investigations conducted in 2019 examining bumble bee species occupancy and detection (Fig 1), we now have both cross-landscape and within-landscape samples of bumble bee diversity and abundance in fire-mediated forests within Tweedsmuir Provincial Park (see Figs 5, 6).

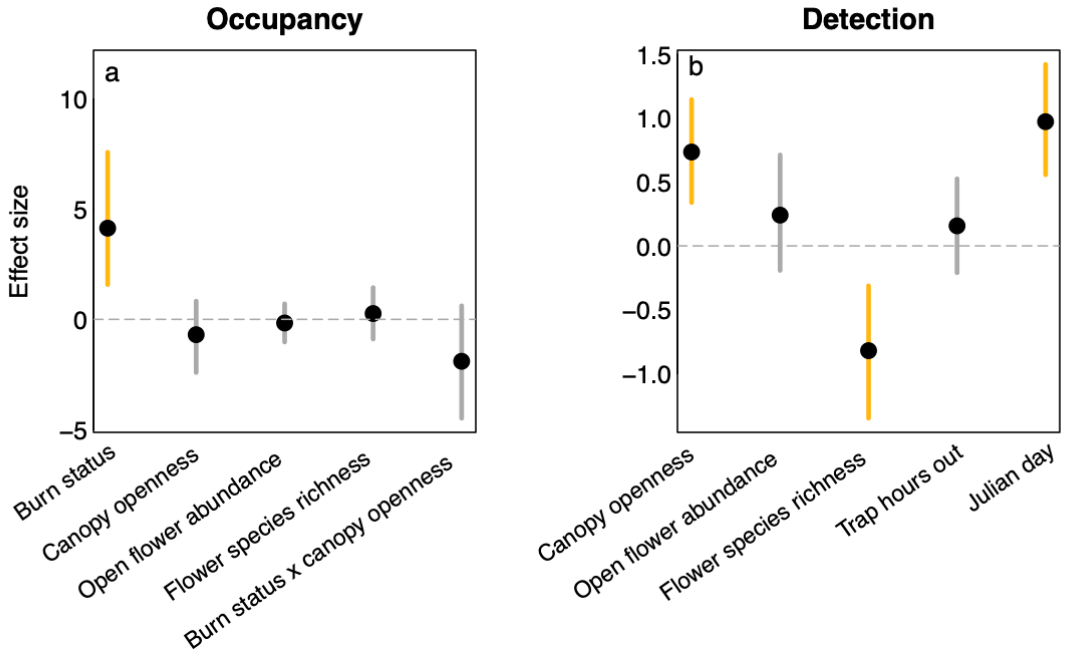

Figure 1. Results from pilot field season in 2019, showing that more bumble bee species were found in burned areas than unburned areas (a) and that traps were more effective (caught more species when those species were present) in sites that were more open, had fewer competing floral species, and later in the season (b). From Johnson et al. (in prep).

- In 2021, we collected bumble bees from over 14 species across 90 sites sampled up to three times each.
    - We increased our sample size and sampled at least two additional bumble bee species (went from 12 species in 2019 to 14+ species in 2021).
    - This is a highly diverse sample for number of bumble bee species in a single landscape.

    - Two are considered species at risk (*Bombus occidentalis* and *Bombus terricola*, see Fig 9).
- We recorded 39 species of flowering plants in 2021, with a clear decline in floral species richness and abundance in all habitat types over the course of the season (Figs 2, 3).

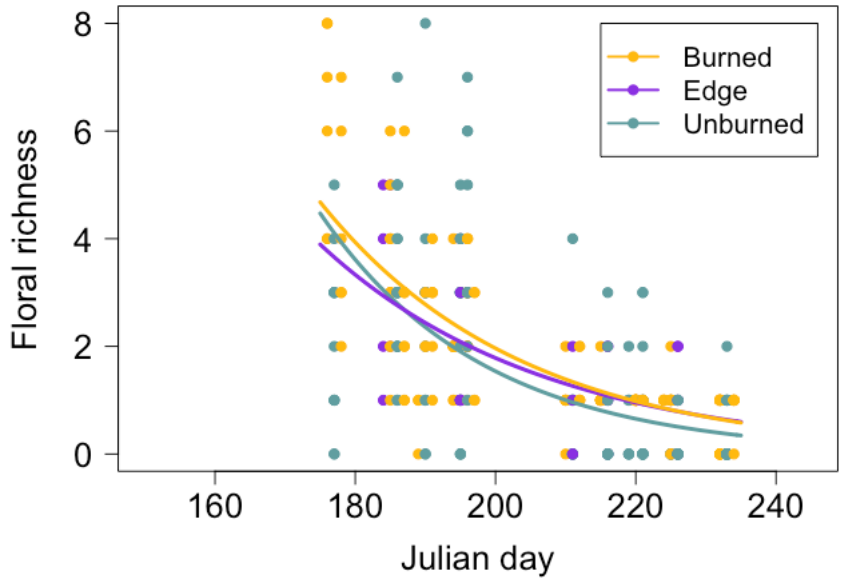

Figure 2. Site and visit level floral species richness over time. Floral species richness declined through the season, similarly in each habitat type.

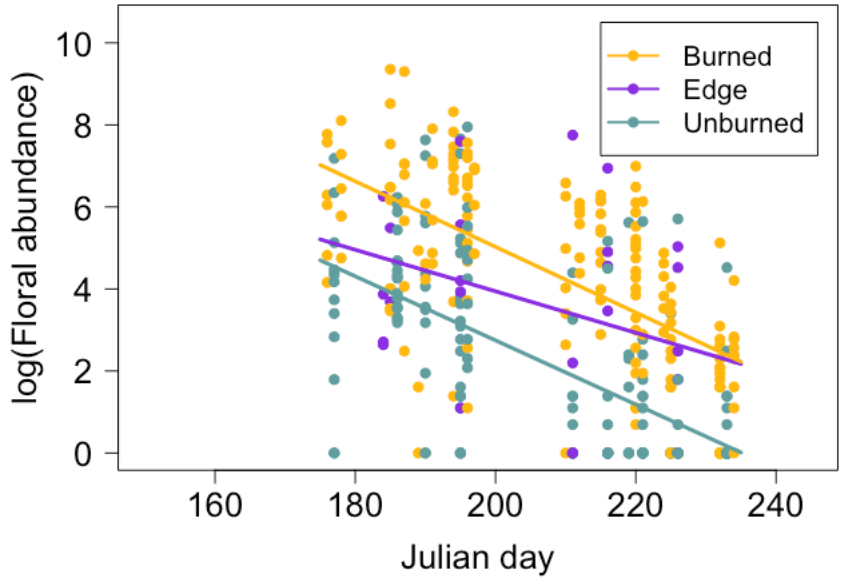

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Figure 3. Site and visit level floral abundance over time. Floral abundance was generally higher in burned sites but declined at a similar rate over time when compared with unburned sites.

- Many species of bumble bee are actively using both unburned and burned habitat, up to 1 km from the edge in both habitats (see Fig 6).

- Once processed (by 2023), our genetic mark-recapture data (Fig. 2) will shed more light on how bees from individual colonies access floral resources at various distances from the edge of the burn and, further, how habitat characteristics may impact these foraging patterns.

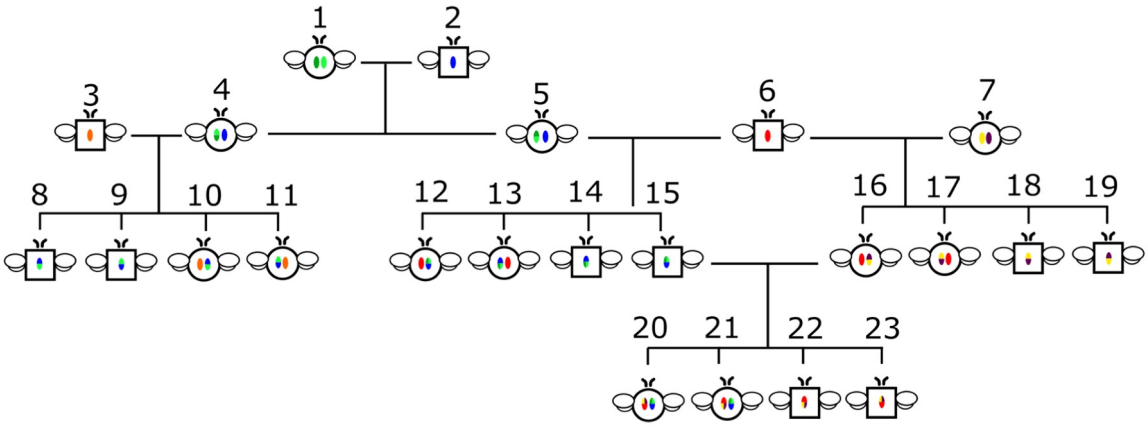

Figure 4. A schematic diagram showcasing how bumble bee genetic mark-recapture is designed thanks to haplodiploidy. Males (squares) arise from unfertilized eggs (only one set of chromosomes, haploid). A father passes on 100% of his genes to each sperm, and sons are 100% related to their mother and have no father. Fathers are 100% related to their daughters, and 0% to their sons. Females (circles) arise from fertilized eggs (two sets of chromosomes, diploid). A queen is only 50% related to her sons (passes on one of her possible two chromosomes). Workers (daughters) are 50% related to their mother, and 50% related to their father. Sisters receive one of a possible two sets of chromosomes from the queen making up 50% of her genes, so there is a 50% chance that 50% of her genes will be same as her sister's, 50% or 50% = 25%. Both sisters get the same set of genes from their father, and he only has one set, so 50% of their genes are identical… 50% + 25% = 75% relatedness between sisters.

- This structure (Fig. 2) allows us to use the genetic relatedness of sisters to learn something about movement: if pair sisters are detected across a landscape (multiple different sites), we can estimate colony-level foraging distance, and the number of pairs of sisters gives approximation of number of colonies in the area.
- This study provides a unique baseline dataset for flowering plants, bumble bees, and site-level habitat characteristics in a highly remote and generally inaccessible area of Tweedsmuir Provincial Park.
    - We located and used only a single access route to our field camp setup through an area of the park not actively used for recreation or other research projects
    - Such a dense sampling effort (thousands of bumble bees sampled) over a large scale (spanning a reasonable range of expected foraging distances for bumble bees) in such a difficult-to-access area is rare, and can be used as comparison to front country sampling, including work conducted

Methods summary

- In 2019, we sampled a total of 26 sites (13 in burned and 13 in unburned locations) twice each throughout the season (June-August), within and nearby to four different fires in a landscape of approximately 20 km by 20 km (Fig 5). We collected bumble bees in traps, along with a suite of floral and habitat variables (open flower abundance, species richness, canopy cover).

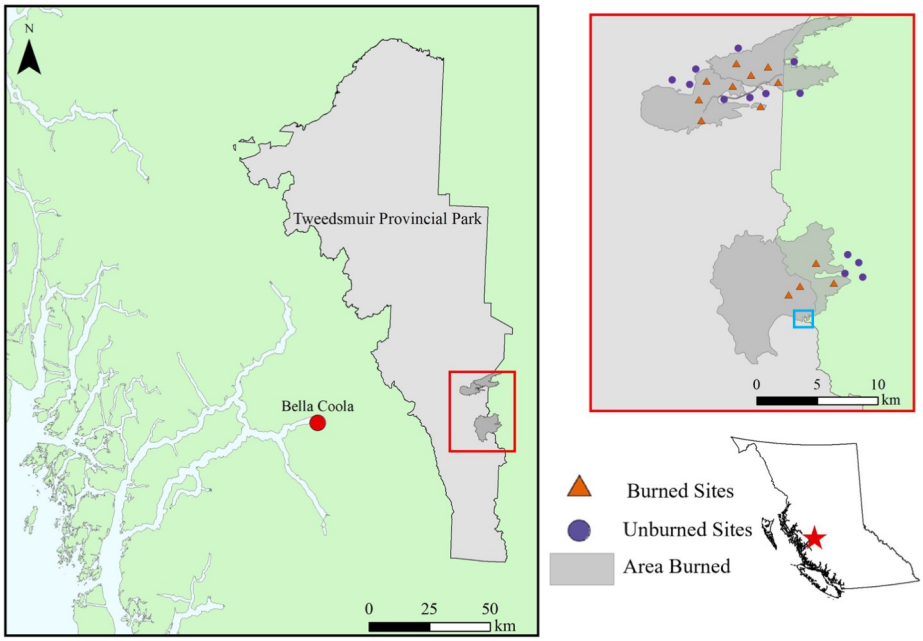

Figure 5. Map of 2019 field season site locations.

- In 2021, we sampled a total of 90 sites (42 burned, 42 unburned, 6 edge) up to three times each throughout the season, along the edge of a single fire that burned in 2017 (Fig 6). We collected bumble bees in traps, along with a suite of floral and habitat variables (open flower abundance, species richness, canopy cover, ground cover).

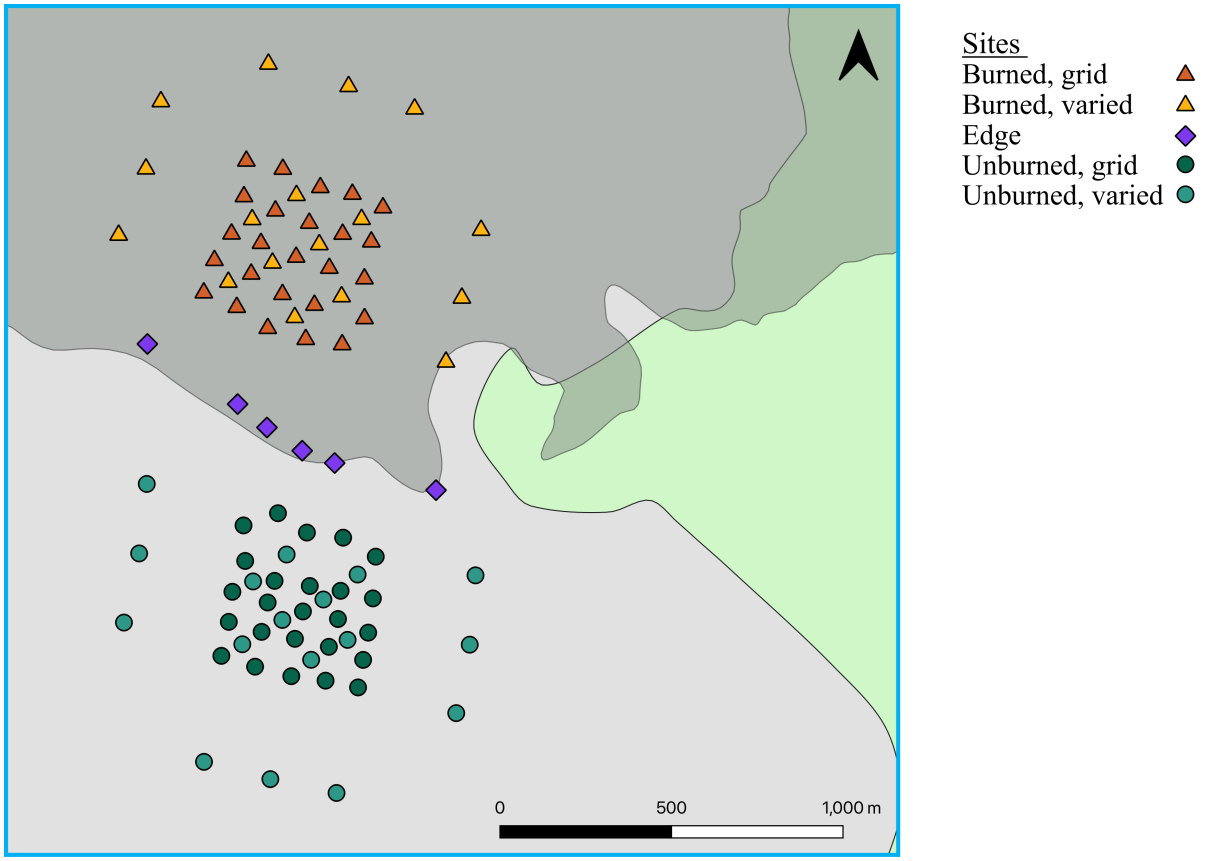

Figure 6. Zoomed-in map of 2021 field site locations. This sampled forest fire burned in 2017, and was initially managed as a backcountry fire but then later actively suppressed due to its proximity to habitable structures in Anahim Lake and nearby small communities to the northeast .

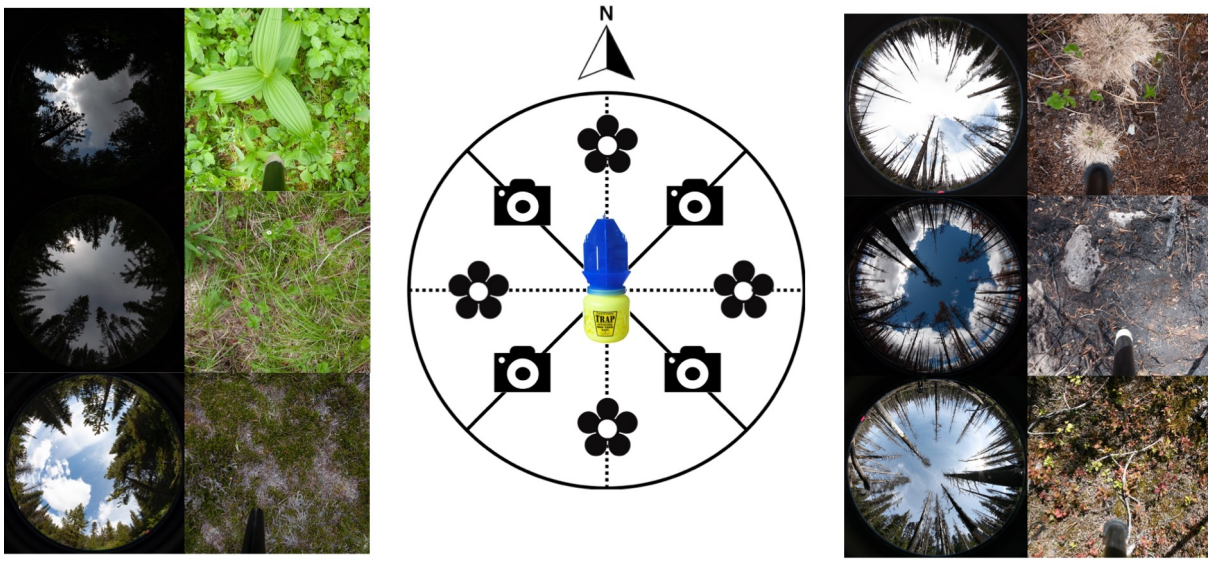

Figure 7. Schematic of sampling setup. In 2019, circular sites had 50 m radii, while 2021 sites had 10 m radii. In 2019, we counted flowers along transects and in 2021 each site was censused for flowers. Photos display canopy and ground cover for example sites in 2019.

Key outcomes for BC Parks

- Forests are important but understudied habitats for bees (Mola et al. 2021), and bumble bees are critical pollinators in the temperate forested regions that are protected by many of British Columbia's provincial parks. As climate change accelerates, the historical forest fire regime experienced across the province is changing rapidly. Some changes in forest fire behaviour in parks (e.g., intensity, size) may necessitate changes in forest fire management in parks (e.g., front country vs. backcountry suppression). Given that pollinators are foundational for habitat regeneration following fires, it's key to quantify how communities of these important pollinators are structured and respond to fire-induced habitat changes on multiple scales, and whether community structure and foraging movement varies in front country vs. back country management zones.
- Explore further research avenues within Tweedsmuir Provincial Park as a key overlap zone for two bumble bee species at risk in BC and Canada – *Bombus terricola* and *Bombus occidentalis.*

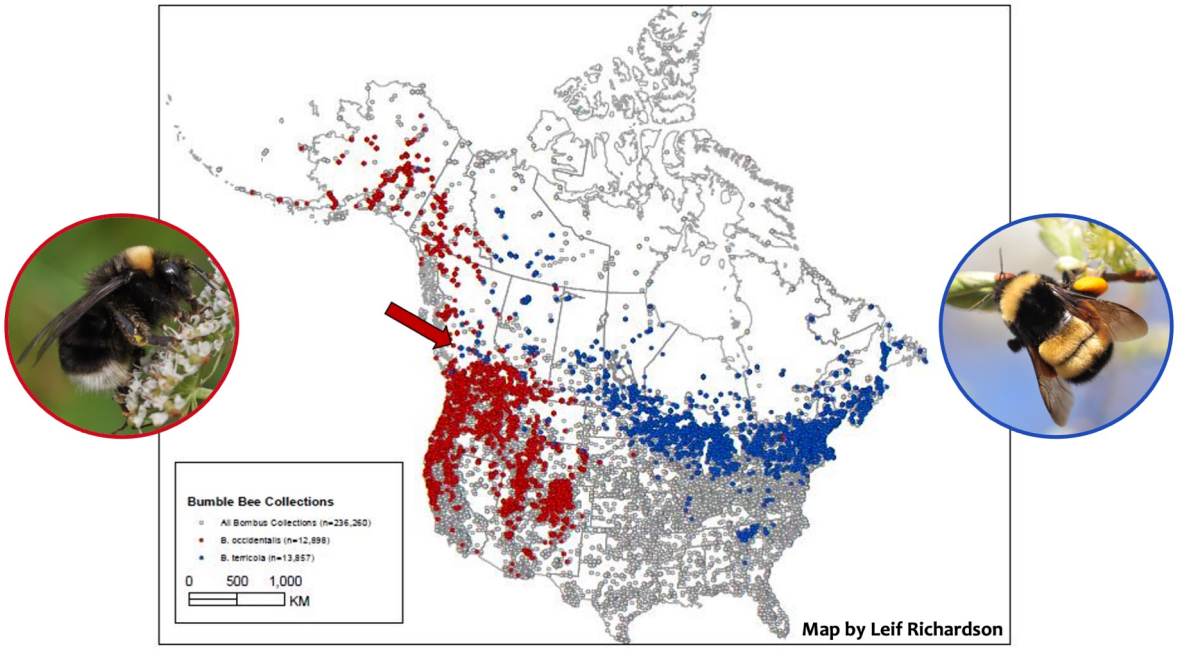

Figure 8. Map of Canada showcasing limited range overlap of two declining bumble bee species, red arrow points to approximate location of Tweedsmuir Provincial Park.

- We have a unique opportunity within the field of bumble bee conservation to use this dataset to compare habitat use between bumble bee species in a single landscape using genetic mark-recapture techniques – it is not common for more than two species to be analyzed at once)
    - Also, there is potential to apply genetic mark-recapture to a declining species (*Bombus terricola*) for the first time.
    - Combining two new and powerful yet underutilized tools (occupancy modelling methods and genetic mark-recapture) may shine light on important factors structuring bumble bee communities in remote, protected areas.

Relevance to BC Parks management

- Front country vs. back country fire management → the densely sampled 2017 fire was managed in part as a front-country fire due to threatening local infrastructure, but our sampling location likely shares characteristics with a backcountry fire due to remote access limitations, distance from roads, etc.
    - Once complete, combining results from 2019 (how burns impact bumble bee occupancy and habitat impacts trap effectiveness across fires at a large scale) and 2021 (how do bumble bees move through space and time in a single fire-impacted landscape) will allow us to ask how climate (through fire and drought) changes resources (e.g., floral, canopy) for bumble bees and what kind of effects that may have on their community structure and movement through protected landscapes.

Project's challenges/opportunities

- Project underwent many logistical and access challenges early in the season, which shaped decisions made during data collection.
    - Sampling was initially proposed to be spread across a larger area incorporating additional backcountry fires, but due to travel and budget limitations (e.g, remote access via helicopter during COVID) and last-minute issues with changes in field accommodation availability (difficulty with sampling setup to minimize time spent travelling and insure all sites were located within park boundaries), we chose to shift the sampling regime to maximize site replication across a range of possible bumble bee foraging locations (< 70 m to > 2 km).
        - Development of grid sampling system (Fig 6)
        - Access to park was limited from our within-budget accommodation arrangements, and so we selected a very remote backcountry location for our intensive grid sampling (Figs 5, 6).
- Overall, these challenges will have led to a unique and useful dataset and study methodology that may be re-applied in future ecological and conservation monitoring projects.

Conclusions/next steps

- Tweedsmuir Provincial Park is a key location for the study of bumble bee community responses to changing forest fire conditions in remote protected areas, given the exceptional number of bumble bee species present (14+ species), fire activity (60+ fires over the past 15-20 years), and its potential as a reservoir for declining species (*Bombus terricola*, *Bombus occidentalis*). Innovative methods used in this study (occupancy modelling, genetic mark-recapture) will also provide methodological advances in the plant-pollinator arena.
- Field collections for this project were completed in August 2021. Due to the large sample size collected, initial sort of bumble bees was completed January 2022, and bumble bees will be counted and identified by summer 2022. DNA extractions and genetic mark-recapture analyses will be completed in 2023.
- Our lethal sampling of bumble bees across a spectrum of habitat variation, including at least two species of conservation concern, will provide a network of specimens that may be further examined to answer many other critical conservation management questions. Stored appropriately, specimens may be dissected later to collect information on parasite and pathogen levels between and within species across the landscape – spread of

pathogens has been identified as a critical component in several Canadian bumble bee species declines. Techniques also exist for quantifying pesticide exposure after a specimen has been collected. This dataset therefore provides many potential avenues for future research expansion.

References and links

Johnson, S. J.*, H. Jackson*, H. Noth, and L. K. M'Gonigle. In prep. Positive impact of post-fire environment on bumble bees not explained by habitat variables in a remote forested ecosystem. (* authors contributed equally)

Mola, J. M., J. Hemberger, J. Kochanski, L. L. Richardson, and I. S. Pearse. 2021. The importance of forests in bumble bee biology and conservation. BioScience 71:1234–1248.