15 March 2026

Living Lab Program for Climate Change and Conservation - Final Report

Project title: Above and belowground alpine plant responses to climate change and increasing recreational traffic in the Nch'kay region (Garibaldi Provincial Park)

Lead researcher(s): Chelsea Little, Nina Hewitt, Noémie Boulanger-Lapointe, Courtney Collins

Research findings

Our 2025-2026 Living Lab research comprised four different projects, each outlined below:

1. **Trampling study** – Lead investigator: Nina Hewitt, UBC (continuing study)

In summer of 2022, we established long-term transects near the major trails in the park (Taylor Meadows, Black Tusk, Panorama Ridge) to quantify the effects of trampling by recreational users, and resampled them each summer from 2022-2024 for biodiversity responses. In 2025, we built on this study.

Sample sites were extended to the Helm Creek trail, a typically less heavily traveled route intended to provide information on biodiversity responses to trampling in a high-elevation meadow location. Four transects spanning elevations were established following methodology developed for other sites. Sampling design incorporated plots along a gradient perpendicular to trails rather than paired plots. High biodiversity was documented, particularly at the highest elevation site, located above treeline (i.e., above the tree islands that intersperse the meadows at lower elevations in this area). We plotted gradient patterns for those taxa that were most abundant, including shrubs (*Phyllodoce, Cassiope* spp.; *Vaccinium* spp.), select forbs (*Luetkea pectinata, Diphasiastrum sitchense*), graminoids (*Vahlodia purpureans; Carex* spp.), and a moss (*Dicranum* spp.). Preliminary observations indicate:

- Apparent positive effects among graminoids of the moderate trampling that occurs near trails.
- For other taxa, beyond the immediate trail margin, abundance patterns were variable and associated with microsite conditions (e.g., wet depressions) rather than distance from trails.
- A larger sample size of sites would be advantageous to elucidate gradient patterns, e.g., replicates (for 2 total per site). We will implement this design across the study area in future.

Second, in order to assess the importance of invasive alien species introductions, we returned to our Taylor meadows transects where an invasive alien species (IAS), the European invasive grass *Agropyron capillaris,* had been identified in 2024, and we confirmed its presence through resampling. We also collected two tissue samples from flowering individuals, including root tissue, from the Taylor Meadows campground and trail, in order to confirm the identification using dissecting scopes at the UBC Beaty Biodiversity Research Centre. To assess the broader occurrence of this and other potential IAS, we conducted systematic trail surveys across Taylor Meadows, Panorama Ridge, Black Tusk, and Helm Creek to search for invasive species populations. During trail surveys we photographed and mapped suspected *Agrostis capillaris* instances using Gaia GPS waypoints. No additional invasive species were detected above subalpine/alpine zones along surveyed trails.

Community science records (GBIF, iNaturalist, e-Flora) and parallel field observations by a collaborator at UBC, indicate that, while several non-native plant species occur within Garibaldi Provincial Park, these are largely restricted to trailheads, parking lots, and lower-elevation hiking/biking corridors outside of the alpine and subalpine zones. Concurrent searches by a post-doctoral UBC research associate who accompanied our research trips failed to conclusively reveal any other invasive species along major trails above Garibaldi Park's subalpine/alpine zone where we work.

To our knowledge little was known about the relationship between visitor traffic and introduced, non-native grasses in the alpine zone of the park. Two of our observations uploaded to iNaturalist (including images of botanical features keyed out under scope), are currently the only confirmed observations of the grass within the alpine zone of the park uploaded to GBIF (GBIF.org 2026, Feb 8). As visitation rates increase, and the climate changes make the alpine more favorable for lowland, including non-native, taxa, the potential for invasion increases. Findings contribute to development of an initial species list based on sightings along frequently traveled, disturbed sites where introductions are most likely.

Lastly, we captured drone imagery of trails and adjacent meadows across Taylor Meadows, Black Tusk, and Panorama Ridge trail junctions (Google Earth map of flight paths here), augmenting the collection for Taylor Meadows/Panorama Ridge sites obtained in 2024. Imagery was processed using Agisoft Metashape and ArcGIS, including to build a DSM to evaluate trail quality (e.g., incision or widening) and the extent of off-trail trampling in the meadow; and a tree height model to evaluate population dynamics and encroachment into meadows. Datasets provide a continuing fine-scale baseline record of landscape conditions.

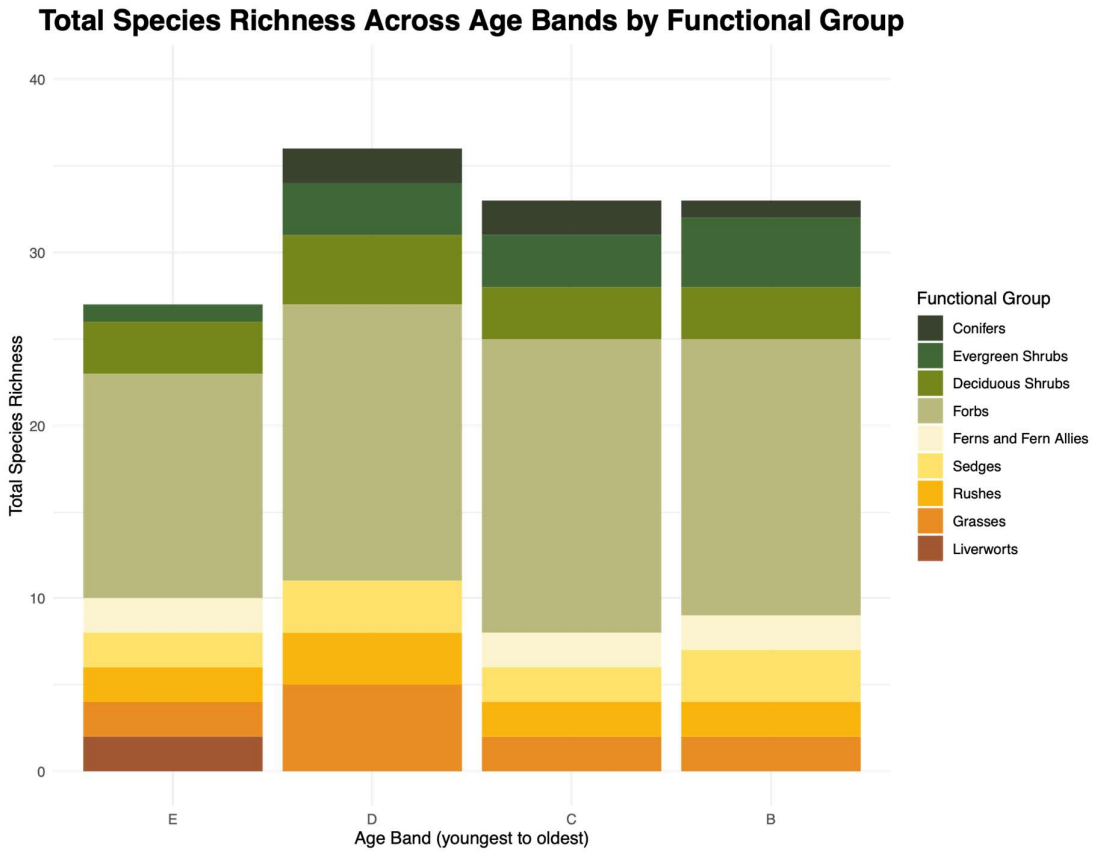
Collectively, the trampling study will support evaluation of plant community responses to trampling and warming, invasive species occurrence, and methodological advances for ecological monitoring. Findings are currently in progress for publication.

2. **Treeline Survey** - Lead investigator: Noémie Boulanger-Lapointe, UVic (exploratory research)

The treeline is an illusive and quickly evolving transition zone. In summer 2025, we attempted to use remote sensing images to assess the extent of the alpine (e.g. treeless area) and subalpine (e.g. transition zone between the alpine and continuous forest) and to validate our interpretation of images with field observations. Preliminary analyses suggest that models relying on easily accessible Sentinel 2 images at 10m resolution are poor predictors of canopy cover. Predicted canopy cover was poorly associated with canopy and tree density measurements in the field.

3. **Long-term vegetation monitoring plots** - Lead investigator: Chelsea Little, SFU (new research)

In summer 2025, we established long-term vegetation monitoring plots to observe plant colonization of new terrestrial habitat following glacial retreat. In each of two glacial valleys leading into Garibaldi Lake, we surveyed plots in four age bands, examining species richness and composition in brand-new terrestrial habitat near glacier tongues, down to areas closer to the lake which had been deglaciated for 80-100 years. Analysis of this data is ongoing, but we found, as expected, that species richness was lower in the youngest age bands (in the plot below, E is the youngest age band and B is the oldest terrestrial habitat).



However, other results were surprising. Particularly in Sphinx Bay, plant community composition did not cluster according to age band, as assessed using ordination techniques. In Sentinel Bay, there was higher similarity of community composition within age bands. This led masters student Hannah Marton to develop new hypotheses about what drives this pattern. In 2026, using Alpine Horizons NSERC Alliance funding, she survey 2-3 more glacial valleys in Garibaldi Provincial Park to explore the hypothesis that the valley geomorphology and frequency of floods in different valleys determines the similarity and stability of vegetation communities in different age bands in deglaciating valleys. This hypothesis was developed based on the observation that in Sphinx Bay, several small lakes lead to a more stable morphological status, while in Sentinel Bay, the stream channel is constantly moving and remodeling the valley floor, providing a less stable habitat for vegetation.

These plots are permanently marked, with GPS coordinates recorded, so that they can be revisited in future years to monitor continued plant colonization and see how plant communities develop with increasing time since deglaciation.

4. **Warming Study** - Lead investigator: Chelsea Little, SFU (continuing research)

In the summers of 2022-2025, we set up open-top chambers (OTC's) in the alpine tundra and paired these with control plots (see methods below), allowing us to monitor the effects of climate warming on alpine vegetation. Quadrats in warmed and control plots were surveyed in 2022 and 2024, and will next be surveyed in 2026, funded by the Alpine Horizons NSERC Alliance grant. Because we do plant surveys every other year, in even years, we have no new results to report from the warming survey, however it was essential that we install the OTC's each summer to enable monitoring of long-term warming responses,, and we are grateful to BC Parks Living Lab funding for enabling these fieldwork trips to set up and take down the OTC's in the summer of 2025.

Methods summary

- **Trampling/vegetation surveys:** we set up long-term transects, adding a perpendicular, gradient transect to our existing design, in Helm Creek and conducted vegetation surveys and abundance assessments across plant functional groups at this new set of sites.
- **Invasive species surveys:** We re-sampled select transects to confirm presence and abundance of an invasive alien species observed in 2024; sampled tissue for lab verification; conducted a systematic trail-margin survey with GPS waypoint mapping; We also examined and integrated community science databases (GBIF, iNaturalist). We collaborated with a post-doctoral associate from an affiliated (Williams) lab at UBC who accompanied us to search for invasive species and our findings.
- **Drone photogrammetry:** We flew a DJI Mavic 3M (50m above ground level), capturing multi-spectral and RGB imagery, and used an EMLID Reach RS3 RTK GNSS receiver to accurately compute target locations (>2 per photo mosaic). Drone imagery was processed using software listed above.
- **Treeline survey.** We attempted to model tree canopy cover using 10 m resolution Sentinel-2 images and tested prediction using canopy cover measures using a spherical densiometer and tree density measured as the distance to the 10 nearest trees.
- **Long-term vegetation monitoring plots.** We established plots in the Sphinx and Sentinel valleys that can be repeatedly surveyed in future years to monitor plant colonization of new habitats, and in summer 2025 performed the first vegetation surveys in these plots. In each glacial bay (Sphinx and Sentinel), we used a stratified random sampling design to establish a set of 24 1mx2m sampling plots. Each valley was stratified with respect to community age, using the maps in Koch et al. 2009 to divide the valley into four areas bounded by temporal observations of glacial extent. Within each age band, two sites were chosen in different areas, and within each site, plots were established in each of three microhabitat types (ridges, depressions, and slopes). GPS locations of each plot were recorded and small metal tags were inserted into the soil in the corners of each plot to aid in future relocation. We used the subplot frequency estimation method to survey plant species composition in all 48 plots, using ten 20cmx50cm subsections for each quadrat.
- **Warming study.** In the summers of 2022-2024, we set up 24 (1 x 1 m) plots for long term monitoring of alpine plant communities in Sphinx and Sentinel Bays across three major plant community types: dry-mesic heather dominated heaths, mesic willow dominated sites and wet sedge meadows. In half of these plots, we installed Open-top Chambers (OTCs), to experimentally test the effect of warming temperatures (passively warmed by 1-3 ºC) on alpine plant communities following an internationally-recognized protocol (International Tundra Experiment: ITEX). We installed microclimate (TOMST) loggers in each plot to determine how local microclimates near the plants (air temperature, soil temperature and

soil moisture) vary in response to warming as well as record longer term weather and climate at the site.

Key outcomes for BC Parks

Trampling: The trampling study findings assist park planning by indicating which plant community types and species are vulnerable recreation. Our findings so far suggest that forbs and shrubs respond negatively; bryophytes variably, but generally negatively; and graminoids are more resilient, particularly sedges. The findings also confirm limited detection of invasive species in alpine zones. Finally, they provide metrics of trail area and width across Taylor, Black-Tusk and Pano Ridge via the drone photogrammetry. This generates fine-scale spatial datasets of trail disturbance and demonstrates applicability of drone-based monitoring approaches.

Treeline survey: The alpine is sought after by recreationalist for its aesthetic and biological diversity. Mapping the extent of the alpine zone and its change through time will require high spatial resolution (>10m) remote sensing product.

Warming experiment: To date, the warming experiment has begun to identify which species and functional groups will respond positively to future climate conditions. This will aid in conservation and allow park management and users to envision what the park landscape might look like in the future: for example, are these species ones that are considered culturally valuable, or will the future vegetation seem less desirable?

Long-term vegetation monitoring plots: Because they were stratified across age bands with time since deglaciation, the data from these plots gives a picture of what landscapes will look like as glaciers continue to retreat. This is helpful for both conservation and recreation planning, as it indicates how quickly new terrestrial habitat will be colonized at glacier tongues.

Relevance to BC Parks management

The findings support continued long-term resampling of established plots and transects to provide a baseline and track change over time and to inform adaptive management under changing visitation and climate conditions.

They also suggest that park managers prioritize periodic invasive species surveys along heavily visited trail corridors. There should be a focus on early detection efforts of IAS and vulnerable taxa around disturbance hubs (campgrounds, trail junctions).

Project's challenges/opportunities

The trampling study benefited from the communications with park staff who provided valuable details to inform the study, e.g., park rangers as we explored opportunities at the Elfin Lakes site were open and helpful in sharing with our team about challenges and opportunities. As always, it was a pleasure to work with people so invested in managing and conserving this amazing backcountry location. We were grateful to the efforts to communicate in the back-country and accommodate our logistics. The charging station we were able to build and house with the fund (currently at Taylor shed) contributed to a smooth workflow for drone recharging.

Treeline survey: We will use the field data collected in 2025 to assess the use of LiDAR images for defining the alpine zone in Garibaldi Park. Once an appropriate method is defined, we will be able to automate the process for subsequent analyses looking at changes through time.

Warming study: One challenge is the safety of crossing Garibaldi Lake to set up OTC's early in the season. This year, we greatly appreciated coordination with Parks staff in deciding to camp a the Garibaldi Lake campground the night before traversing the lake to get a better chance at safe paddling conditions. We are also, as always, grateful to be able to use canoes, and leave gear in the boathouse when needed. In terms of opportunities, long-term experiments are uniquely able to help us understand climate impacts, so every year that we are able to keep the warming experiment going is worth its weight in gold scientifically. We are looking forward to surveying the plots again in 2026 and sharing and publishing our findings from 5 years of warming.

Long-term vegetation monitoring plots: An unexpected challenge was that the substrate in Sphinx and Sentinel Bay was so hard that it was difficult to put in plot markers at each of the plot corners. Because it is such a long journey to access our field sites, there was no opportunity to use different tools/methods to mark the corners once we were on location. To improve marking, we plan to revisit the long-term plots in summer 2026 with a more precise GPS, and take coordinates at each corner. We may also bring a larger hammer and nails to try to mark the corners. In terms of opportunities, we are excited about the prospect of having these long-term plots established, and will work to obtain funding and permits to resurvey them in 5-10 years to monitor vegetation community development.

Conclusions/next steps

This was our last year of BC Parks Living Lab funding. These grants have been instrumental in allowing us to build relationships with BC Parks staff as well as with Squamish Nation; thanks to the data collected using these years of BC Parks Living Lab funding, we were able to secure a large NSERC Alliance grant that will fund a large research program for ~five years. As such, the next phase of the project is to expand our research and bring in interdisciplinary collaborators to get an even more holistic understanding of climate and recreation impacts in southwest Coast Mountain parks.

References and links

All projects: findings were presented at the 2025 Ecological Society of America Annual Meeting on August 14 in Baltimore, USA (Little, Boulanger-Lapointe, Hewitt, Collins)

Trampling experiment: techniques and findings were presented at the Western Division Canadian Association of Geographers Annual Meeting on March 7, Vancouver (Croy, Collins and Hewitt)

Trampling experiment: We are preparing our findings for an invited article for a special issue about "Tundra Transitions" for the *Nordic Journal of Botany* (Hewitt et al., in progress).

Long-term vegetation plots: results will be presented at the Canadian Society for Ecology & Evolution Annual Meeting in May, 2026, in Toronto (Marton, Little)

Long-term vegetation plots: results will be incorporated into Hannah Marton's masters thesis (SFU, Department of Biological Sciences) and concurrently developed for a peer-reviewed manuscript (Marton et al., in progress)

Warming experiment: analysis is being finalized and developed into a peer-reviewed manuscript, target journal *Ecosphere* (Little et al., in progress)

Checklist

- Have you filled out the separate Living Lab Story Form? If not, this is due no later than 30 days after the end of the term of your agreement.
- Have you added any relevant Living Lab project data or reports to the BC Data warehouse and/or EcoCat? Please contact Stephen Ban (Stephen.ban@gov.bc.ca) or Jeanine Bond (Jeanine.bond@gov.bc.ca) for assistance.
- Invoice submitted? An invoice is required to receive the final instalment of your Living Lab transfer agreement funds. The invoice should include:
    - the university address,
    - the Transfer Payment number (as per your agreement),
    - a one-line description of what the project is about,
    - the amount due (you may need to send this via your financial arm) and indicate that this is the final instalment. The invoice should follow or accompany the completion of this final report template of which both are due on or before March 17th, 2025. **If we do not receive an invoice from you by this date, we will not be able to issue your final payment.**