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Living Lab Program for Climate Change and Conservation - Final Report

Project title: Community and ecosystem responses to climate change and increasing recreational traffic in the Nch'kay region (Garibaldi Provincial Park)

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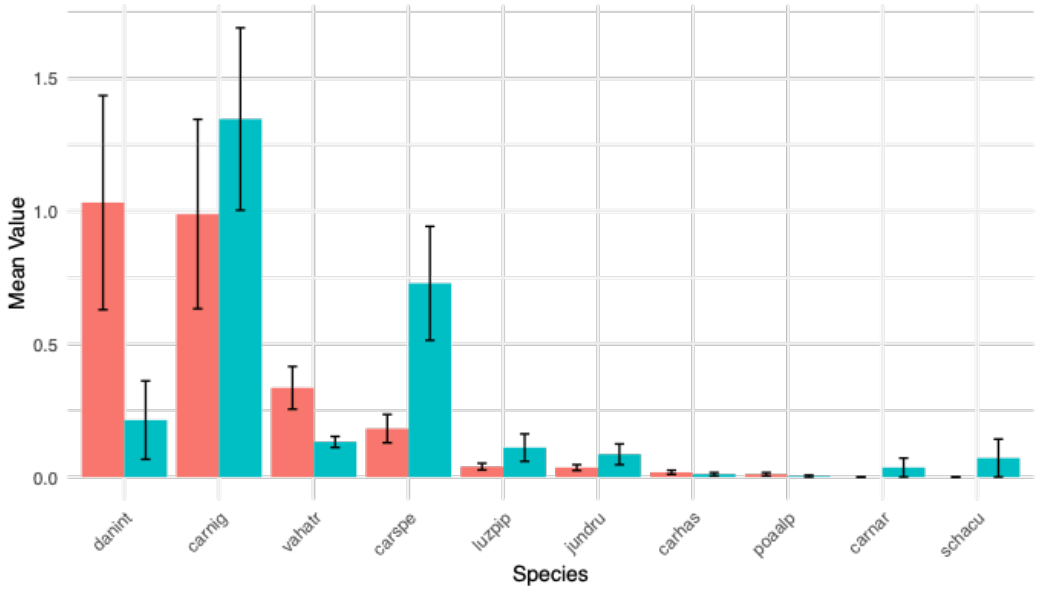
Research findings

Our research in Garibaldi Provincial Park in 2024 built on efforts deployed in the area with the support of the BC Parks Living Lab grant since 2021. During the growing season, we visited our permanent vegetation monitoring plots in Sentinel and Sphinx Bays, revisited sites in Taylor Meadow to study the impact of recreational activities on vegetation, initiated a pilot camera trap study, continue our conversation with the Squamish Nation while completing data analyses.

Trampling study

- We expanded our 2023 plant community composition surveys with finer metrics (% cover to augment frequency data from 2023) and taxonomic classification of grasses and mosses, through partnerships with the UBC Beaty Biodiversity Centre. We found lower species richness and abundances near trails, particularly among forb and shrub taxa. Responses of graminoids and mosses varied, reflecting resilience tied to disturbance adaptations and ecological roles observed in similar environments. The following graph shows the abundance of different species near (blue) and far (red) from trails, with *Carex nigra* (abbreviated carnig) and *Carex spectabilis* (abbreviated carspe) the two species showing major increases in abundance with trampling disturbance:



- We observed a single exotic invasive species (*Agrostis capillaris*, Colonial bentgrass: https://inaturalist.ca/observations/234429417), near high traffic trail sites in Taylor meadows, prompting us to continue pursuing research into exotic species introductions in the future.
- We piloted drone methods to assess vegetation impacts near trails, capturing images at four paired transects. Greenness was quantified in bands extending from trails into undisturbed meadow. Severe denudation occurred on and near trails, but some edges showed higher greenness due to shrubs (e.g., *Vaccinium spp.*), potentially benefiting from increased light (intermediate disturbance hypothesis) or mammal seed dispersal. Further study is needed to confirm these patterns. Drone footage indicated denuded trail widths, which averaged approx. 2 meters. There appeared to be minimal off-trail encroachment, though in high traffic sections (nodes where trails meet), expansion of trails into the meadow may require containment and remediation as visitor pressures increase. Nevertheless, the findings contrast with greater trail-widths observed in other Canadian parks, such as Toronto's High Park (N. Hewitt, pers. obs.)
- A publication of the findings from this study is underway for submission later in 2025.

Warming study

- Open-top chambers (OTC's) were installed in 2022, 2023, and 2024 in three vegetation communities in Sphinx and Sentinel Bays. Data collected over these years shows that the warming chambers increase surface-level temperatures by about 3 degrees Celsius during the day.
- Analysis of the 2024 summer data is ongoing, but we can share a couple preliminary results from our quadrat surveys of warmed and unwarmed plots. We found few differences in the plant species present between warmed and unwarmed plots in 2024. After three years of warming, only the heather meadow showed differences in functional group composition between plot types, with more moss and forbs in warmed plots and less bare ground than in control plots. The wet sedge meadow and the willow meadow did not show differences in functional group composition between plot types:

- In the wet sedge meadow in Sentinel Bay, warming resulted in a clear increase in plant height, driven by graminoids growing taller than in control plots:

- Data analysis is ongoing at SFU. A publication of the 2024 plot survey findings is underway and expected for submission later in 2025.

Landscape scale vegetation survey

- We have narrowed the focus of this project to better understand how tree species are colonizing the Sphinx and Sentinel Bays glacial forelands and to define key drivers of subalpine forest succession patterns in areas of glacial retreat. We believe this will be of interest to BC Parks and remain within the scope of the original intent of data collection.
- We anticipate this project to be completed by April 2025 with a publication shortly after.
- Additionally, we completed the drone imagery of the glacier forefront which was interrupted in 2023 due to technical challenges. We now have a full image of the glacier margin which could be used as a reference image in the future.

Wildlife Study

- In 2024, we deployed 20 game cameras in the Park to test how recreation traffic affects habitat use by wildlife. Over the course of the summer, these cameras took 61,000 photos. We were not expecting such a high number of photos, and a team of students at SFU is still working through the photoset to identify wildlife in the photos. Wildlife

spotted so far include marmots, snowshoe hare, black bears, mule deer, a bobcat, pikas, chipmunks, and birds.

- Because the Taylor Meadows campground is in an area with high food resources for wildlife (e.g. berries), we saw high habitat use by wildlife in this area, particularly by bears. The environment in the glacial bays is comparatively harsh with fewer resources, and so (preliminary results show) we did not see an increase in overall wildlife habitat use there, despite less human impact. We cannot provide additional insights about which species did or did not show patterns of habitat use varying with recreation pressure until we have finalized the dataset.
- We encountered two challenges: lack of specificity with the camera model used (that is, taking many photos with no animal in it, triggered by wind on the grass, shrubs, or tree branches) and a major difference in habitat conditions between our higher-recreation areas (Taylor Meadows, Mount Price) and our lower-recreation areas (Sentinel Bay, Sphinx Bay). When the dataset is finalized, we will share it with BC Parks. The challenges encountered mean that we do not anticipate a publication from this study. However, it should yield valuable insights that will help design a larger study on wildlife use of the Park in our recently-funded NSERC Alliance project, in which BC Parks is also a formal partner. Therefore, we consider this project to still have been extremely valuable!

Squamish Nation knowledge of alpine system and access to resources

- We have had conversations with the Squamish Nation since 2021 on how to best engage with Indigenous knowledge holders and governments to strengthen Indigenous stewardship while learning about past and current use of the alpine in the park. As part of the Living Lab project, the Nation indicated that the most appropriate way to engage was to work with one of their Archeology, Cultural and Environment (ACE) technician. We thus hired one technician who spent 3 days with us in the field. This was an opportunity to better understand the work conducted by the Nation and start a conversation about current use by community members while sharing our own work and providing training on drone flight.

Note: In our grant application, we described a streamflow monitoring project we planned to undertake. However, because we received less funding than we requested, we eliminated this planned project from our summer 2025 fieldwork. We appreciate the funding that we received and are excited that we could address the other components of our study!

Methods summary

Trampling study

- We revisited the plots that were setup in 2022 and again in 2023 - paired transects on and off trail. We recorded all species abundances in percent cover classes taking special care to identify graminoids and mosses to species level: Protocol 2024 (Instructions_Trampling_2024) and Protocol 2023 (Instructions_Trampling_2023)
- We further gathered select drone imagery to pilot a workflow for examining trail expansion or containment and look at vegetation patterns from trails into meadow

Warming study

- As in 2022 and 2023, we installed the open-top chambers (OTC's) in set, marked plot locations as soon as was practically possible after snowmelt/lake ice-off. OTC's warmed

the surface temperature and vegetation for the duration of the summer, and were removed in September before snowfall.

- We conducted point-frame sampling of plant communities in warmed and unwarmed plots. Briefly, we touched a pin down to the ground at each of 100 gridpoints in a $1m^2$ quadrat in each plot. We identified each piece of plant material that touched the pin, to the species level in most cases, as well as identifying whether it was living or dead, and what type of tissue (e.g. stem, leaf). We also measured the height where each piece of plant material touched the pin.
- We are using ordination methods and linear mixed-effect models to analyze this data.

Landscape scale vegetation survey

- Drone imagery was recorded with a DJI Mavic 3 with a multispectral camera
- In 2024, we flew a drone over the back of the Sentinel valley, closest to the glacial tongue, to produce imagery of vegetation communities along the glacial succession gradient. In summer 2023, we had conducted landscape and aerial surveys (using a drone) to test the relationship between field-observations and remotely-sensed community composition, but due to stock restrictions on flight altitude, we were unable to survey the highest elevations at the back of each bay in 2023. We remedied this in 2024 with a higher-altitude flight.
- Initial data processing was completed with Living Labs funding in Fall 2023-Spring 2024 to georeference drone imagery and create digital elevation models of these landscapes. We have now established a sponsored research agreement with SFU and the BC Ministry ofForests, overseen by Courtney Collins.
- A supervised machine learning algorithm (a few models are being tested including SVM, RandomForest, etc.) in Python was built to classify the image pixels depending on their spectral profiles and classify them as a particular plant community or other type (e.g. conifer, willow, water, snow, etc.)

Wildlife Study

- In 2024, we deployed 20 game cameras in four areas of the Park: Taylor Meadows, the base of Mount Price, Sentinel Bay, and Sphinx Bay. Study locations were chosen to be a gradient of recreation pressure. Cameras were mounted ~0.5 meters off the ground to target image capture of small- and medium-sized mammals. Cameras were pointed north whenever practical, for the best exposure and lighting.
- Photos are being processed using the Wildlife Insights data platform (https://www.wildlifeinsights.org). The platform uses computer vision to make a first assessment of whether each photo contains an image of an animal, or is "blank". The tool is imperfect, therefore we also have a human look at each photo to confirm whether the computer vision has correctly identified (1) whether there is an animal, and (2) what species it is.

Key outcomes for BC Parks

Trampling:

- The trampling study findings are significant for park planning because they indicate which plant community types and species are more versus less resilient to recreation. Our findings are quite definitive that forbs and shrubs respond negatively; and that mosses and graminoids are more resilient but that it depends on the taxa.
- The findings also reveal risks of invasion linked to trampling and suggest that park protocols effectively limit damage to a narrow zone near trails.
- Finally, they indicate that trails are relatively constrained in Taylor, Black-Tusk and Panorama Ridge, but that some sections with heavy traffic may need remediation and containment if hiker volumes increase. In the future, we will explore aerial image pixel classifications to map out very specific locations in the park that are best suited to recreation (trails, huts, etc.) and which areas might be more sensitive to recreation either due to the plants lack of resilience or the presence of rare species in a particular location.

Warming:

- Our results suggest so that plant communities are quite resistant to warming in the short term, at least in terms of community composition. The OTC's warm the vegetation by 3 degrees Celsius, which is a level of warming not expected in just one or two years, yet even with this fairly drastic treatment, community composition seems slow to change, likely because of the long-lived nature of many plants in the community. However, it will be important to continue monitoring plant communities in the OTC's in the next 5 year to see how long it takes for community composition to respond; a lack of change in ~3 years does not mean long-term stability.
- Our second key result is that especially in wetter habitat types where plants have the resources needed for additional growth, warming can result in a clear increase in plant height. If other conditions remain the same, we could expect to see taller vegetation in sedge meadows in the future due to warming.

Wildlife:

- Our results show that even in areas with high recreation pressure (Taylor Meadows), wildlife are common and have high habitat use. While some species may avoid these areas due to human presence, others clearly due not. It will not be a surprise to Parks staff that bears are common near the campground; as we finish photo identification we hope to be able to share whether other desirable species (which have less potential to cause conflict) avoid areas with high recreation impacts.

Outreach:

- The online resources we have made include a website explaining our research for the public to refer to, a virtual reality tour that can be used as an educational resource making the park's remote areas more accessible to everyone, and a github repository containing all of our data and links to our protocols so anyone can access, look back at, and work with the data we have collected.

Relevance to BC Parks management

- Areas with heavy recreational traffic may need remediation and containment if hiker volumes increase.

- Some of the plant species which show the strongest growth responses to warming are the same species which increase in abundance with trampling disturbance. These sedges may become more common and robust around trails in the future, and management should consider whether this is a desirable outcome or whether restoration and remediation should be undertaken to maintain other species.
- There remains a high potential for human-wildlife conflict, especially in the Taylor Meadows area where areas with high berry output are the same as areas with high recreation traffic.

Project's challenges/opportunities

- Opportunity: This year, we brought a Squamish Nation ACE (Archaeology, Culture, and Environment) Technician to Sphinx and Sentinel Bays with us. We hope this is the start of a better working relationship with the Squamish Nation, and see a big opportunity to work more closely with ACE technicians in the future; we saw clear benefits both to the project, and the Nation (as well as the individual ACE technician, who enjoyed seeing a part of his traditional Territory that he had never been able to visit before).
- Challenge: Our project included multiple subprojects, and it was challenging to accomplish all of them within budget. We relied on some volunteer help, which we would prefer to avoid as there are diversity and equity considerations in terms of which students have the ability to perform unpaid work. Opportunity: In the future, we will focus on fewer subprojects with a higher level of support and attempt to ensure that all students spending time on the project are paid. We anticipate that this will enable even higher-quality work by not spreading ourselves so thin.
- Challenge: We continued to encounter challenges with hiring for the summer field season. At all three universities, hiring begins in winter and usually needs to be finalized by early May. The late confirmation of the funds from BC Parks means that we often need to use other funding sources to pay students on the project for the first weeks of their employment, which puts strains on the PI's and creates issues with budget management.
- Opportunity: The plant surveys in the trampling study, landscape-scale survey, and warming study have given us many interesting leads to follow in the future. This has allowed us to identify species which seem robust to disturbance, or even to thrive under disturbance. Furthermore, we identified that invasive species should be an area of future research effort. This funding has allowed us to gain insights and develop questions that are of both conceptual and practical interest, that we otherwise may not have considered.
- Challenge: We had issues with the study design of our wildlife study, as well as with the camera model. Opportunity: We will remedy these problems with a larger-scale, more complex wildlife study in the NSERC Alliance project, where we will not only choose camera locations differently, but also will have access to better camera models.
- Challenge: We have some safety concerns about crossing the lake, especially early and late season when it is cold. Purchasing wetsuits or drysuits is prohibitively expensive and not aligned with the overall budget of this project. We are still seeking a solution that will give us more confidence in safety. For 2025, we will change our logistical planning and stay on the "near" side of the lake overnight before canoeing across, since the water is usually calmest and safest in the morning; when we have hiked up in the past, we are unable to start the canoe across the lake until the mid-afternoon. We appreciate the cooperation of the Park staff in helping us find places to camp to make this safety-related change.
- Opportunity: As this project goes on, we are learning better how Parks staff would like us to communicate and what the smoothest ways to coordinate are. We really thank BC Parks for

your patience and support. We feel confident that our working relationship is getting better and better!

Conclusions/next steps

- We have provisionally been approved for continued Living Lab funding for the 2025 summer season:
    - Warming study: we will put up the OTC's for a fourth summer of experimental warming. We do not plan to do the point-frame surveys again in 2025 as we observed slow responses to the first 3 years of warming; we will survey again in 2026 in the 5th year of warming. It is important to place OTC's every summer however to create a long-term dataset that can identify medium- and long-term impacts of warming.
    - Trampling study: we will expand the trampling study to the Helm Creek area. We will also focus on invasive grasses in our 2025 fieldwork, as this was identified as an area of concern from our 2024 data collection.
- Thanks to the Living Lab funding through which we have obtained initial results, we were able to secure a 5-Year NSERC Alliance grant with BC Parks and Squamish Nation as partners. Work will commence this summer on several subprojects that were inspired by our work through the Living Lab. We will develop the specifics in close cooperation with BC Parks staff:
    - Identification of freshwater habitats that are potentially impacted by trail and campground infrastructure
    - Using historical photos to understand changes in treeline in the last ~100 years of ongoing global change
    - Further investigations of plant and wildlife responses to recreation and warming

References and links

The following online resources are available for anyone wanting to learn more about the project:

- Website: https://garibaldialpine.wixsite.com/garibaldialpine
- Virtual Reality Tour (in progress - a draft is available at): https://object-arbutus.cloud.computecanada.ca/garibaldivr/index.htm
- Other links:
    - Youtube
    - Github
    - Caltopo
    - inaturalist
    - Plant IDs

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.**