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Living Lab Program for Climate Change and Conservation - Final Report

Project title: Understanding above and belowground alpine plant responses to climate change and increasing recreational traffic in the Coastal Mountains of British Columbia using observational and experimental methods

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Research findings

Warming Experiment

- Greenness and phenology shifted after one growing season of warming but we are still determining the statistical significance and magnitude of these results. https://drive.google.com/file/d/1ei_o8B32L2G6E9aN7fvCQNNsrKAS_NRs/view
- No significant effect on plant height or flower number after 2-3 weeks of warming
- https://docs.google.com/presentation/d/1Ag-NhyiW6sw1KhwKIllqp2jIRg4IvNXlbBPZ7KEOTuc/edit#slide=id.g1aded5c2be2_1_14
- Microbial biomass showed initial increase in response to warming (after 3 weeks) but this effect disappeared later in the season (after 10 weeks).
- https://docs.google.com/presentation/d/1EWR4CU8Pp1yN5MlGuAEeCMT7TTLlFZLbaiiAm1L_w6I/edit#slide=id.p

Trampling study

- Graminoids (sedges) respond very differently to trampling than Ericaceae species (heather and blueberry)
- Trampling reduces the height and width of Ericaceae shrubs but had no significant effect or possibly a positive effect on size of graminoids within plots
- Disturbance effects along elevational gradients vary by species but appeared most strongly in graminoids
- https://docs.google.com/presentation/d/1xLoBIrVUEujAOFhPq3O-d66300VWWS0J/edit#slide=id.p5

Meetings with Squamish Nation

- Initial plan to make signs informing park users about culturally important plants was not supported by the Nation which only became clear after a few initial planning meetings.

- They clarified that they want to use their time and efforts on projects that will directly benefit members of their Nation and that they are facing larger issues currently that should be addressed before making educational signs
- A major issue they are facing in the park is the uncertainty regarding access which includes permits (day-use and camping), cultural harvesting allowance, and access to locked gates both within and near parks.
- This led to a project that is currently in process working with the Nation to highlight regions of the park(s) on a map that contain culturally important plants and/or spiritual sites which currently have some type of limited access so they can determine and clarify their access needs to the Park. This project will be funded from the 2023-2024 grant.
- We specifically are not using the funding we had allocated to the educational signs work since the Squamish Nation wants to be co-designing projects like this prior to grant applications. We do plan to keep working with them on projects more inline with their Nation's goals.

Methods summary

Warming experiment

In the summer of 2022, we established 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 plexiglass warming chambers (OTCs), to experimentally test the effect of warming temperatures (passively warm to 1-3 ºC) on alpine plant communities above and belowground.

Plant communities. Above all plots, we installed tripods and automatic time lapse cameras (Phenocams) to record timing of plant phenology (green-up, flowering, senescence) and determine changes in vegetation greenness throughout the season. We also 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. At peak flowering, we assessed the composition and abundance of the vegetation in all plots using 1 m x 1 m point frames with 100 evenly spaced points. We also measured plant traits including vegetative and reproductive heights and flower/fruit counts of the dominant species in each plant community type. We have processed and are continuing to analyze this data to determine how greenness changes over the season and is affected by warming. It was presented at the BC Protected Areas Research Forum (PARF) in December 2022. We plan to publish the results in an upcoming paper in the Journal of Arctic, Alpine and Antarctic Research.

Soil microbial communities. In 2 plots (one warming, one control) in each plant community type, we installed three root ingrowth cores (7 cm diameter x 15 cm depth). Root cores were left in the ground this summer to allow for infilling and will be removed sequentially throughout the 2023 growing season to measure the effect of warming on both the timing and quantity of root production. To assess soil microbial community responses to warming, we took soil samples and measured microbial biomass carbon (C) and fungal:bacterial ratios using the microbiometer soil test kit at two time points after OTCs were installed (3 weeks and 10 weeks). To investigate the effects of warming on decomposition we buried two tea bags in each plot following the tea bag index protocol: https://besjournals.onlinelibrary.wiley.com/doi/10.1111/2041-210X.12097

Trampling study

In the 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. To address how trampling affects charismatic plant communities (blueberry, heather and sedge meadows) along elevational gradients, we chose sites at multiple elevations per trail. We established transects directly adjacent to the trail and at least a 5 m perpendicular distance away from the trail (control) to compare the effects of trampling on the same vegetation types.

Plant communities. We recorded landscape characteristics (slope, aspect, latitude, longitude, presence of trees) for each transect and used 0.5 m x 1 m quadrats to record height, maximum diameter, and bud/flower/fruit counts of our focal plant species (*Vaccinium ovalifolium, Cassiope mertensiana, Phyllodoce empetriformis, Phyllodoce grandiflora, Carex* sp.). Please see N. Chardon's recent work on human trampling for greater detail on this sampling approach:

- https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/1365-2664.13384
- https://onlinelibrary.wiley.com/doi/full/10.1002/ece3.4276

We also used a standardized approach to photograph each quadrat, and are using these images to calculate how vegetation greenness is impacted by human trampling. Our preliminary analyses show that human trampling impacts all aspects of a plant community by decreasing greenness, plant size, and reproduction. These effects are stronger at higher elevations near treeline, suggesting that poorly marked trails in these areas are of particular concern. We have analyzed this data which was presented at the BC PARF in December 2022 and we plan to publish the results in the coming here in the Journal of Arctic, Alpine and Antarctic Research.

Soil microbial communities. We selected representative transects per trail to study microbial activity. As a proxy for measuring litter decomposition by microbes, we buried tea bags at these transects to undergo microbial decomposition for one year following the tea bag index protocol: https://besjournals.onlinelibrary.wiley.com/doi/10.1111/2041-210X.12097

Key outcomes for BC Parks

The warming chambers and trampling transects are helping us determine which species and plant communities are most affected by climate warming and recreational traffic in Garibaldi Park.

The warming experiments help us predict plant responses to future climate change. These results can aid BC Parks' decision making with regard to which areas are most at risk for future trail and infrastructure development. In addition, due to interannual climate variability, this longer term (multi-year) study will be critical in order to correctly determine how not only warming but also extreme events may affect alpine plant populations.

Different global change drivers (i.e. trampling, glacial succession and climate warming) are likely to differentially influence plant communities and thus require different management strategies. Our results directly inform these targeted management approaches and also allow BC Parks to know when targeted approaches are required (e.g. human disturbance and climate cause similar outcomes).

Overall, knowledge of alpine ecosystems sensitivity to climate and trampling will be important for future decision making. As recreational interest in the park grows there will be more proposed developments which will need detailed data on the tundra ecosystems sensitivity to warming and trampling.

Future grants should be aware of the importance of early on communication and lasting relationships with the Squamish Nation. The Nation is very busy with many requests. The more BC

Parks can do to manage and filter what they need to deal with the better. However, for projects working with the Nation it is very important they get in touch early on and co-design their work.

Relevance to BC Parks management

Warming experiment - more time is needed to be sure of results, as other research shows that short vs. longer term studies have different effects on plant populations due to inter-annual climate variability, and plant species acclimation to warming over time.

However, it seems that as the park warms up plants will shift the timing of their phenology (green up, flowering, senescence), likely affecting pollination and seed set timing, herbivore interactions, and carbon fluxes. These changes, combined with extreme events e.g. late snowmelt/flooding or late season droughts could kill off some species in specific regions

Preliminary analyses show an initial increase in soil microbial biomass in the warming plots at the 3 week mark but not after 10 weeks, suggesting a rapid initial response followed by acclimation of soil microbes to warming temperatures potentially relevant in the context of the recent heat waves BC has experienced.

Furthermore, above (greenness/phenology) and belowground (soil microbial) responses to warming were unique across plant community types, with the Cassiope meadows showing the strongest belowground responses to warming and all communities showing distinct above ground responses.

Trampling study - it appears that some plant species (e.g. Ericaceae) are more vulnerable than others (graminoids) in responding to trampling. When choosing new trail locations this could try to be managed better directing trails through the most resilient communities to trampling. Also, trail widening appeared to be the main driving problem in most places and might be solvable with loop trails, boardwalks in wet regions, and more specific/clear locations where people can pass.

Update the introduction and bottom of the page on Garibaldi Park (https://bcparks.ca/garibaldi-park/) to include more information regarding First Nation history (not colonial history) and access requirements for Indigenous peoples (no day use permits needed?, what about camping access?, what should they tell park rangers they meet?, what proof do they need to carry that they are Indigenous?)

Project's challenges/opportunities

Discussions with Squamish Nation taught us about the importance of early consultation before project design begins. We learned about their concerns regarding access to the park for traditional harvesting and are working with them to develop a project more inline with their interests. The Squamish Nation has many other commitments and they want to spend their time wisely. If possible the park should discuss what is the best way to contact the Nation about short term projects just looking for permission versus longer term projects hoping to create an ongoing relationship.

Trampling study - would have been nice to collect information on rare species but this was too difficult this past summer

Warming experiments - would be helpful to have a big picture image of how glacial succession will affect plant change in this area in the next 30 years - also need for longer-term study of warming effects. Challenges with late season snowpack and weather allowing us to coordinate helicopter flights with BC Parks.

Conclusions/next steps

We have received a new grant to continue the warming experiment, and look into glacial succession study to see landscape patterns, collect information on rare species in trampling plots, and continue discussions with the Squamish Nation on access and cultural plant uses in the area next summer (2023).

References and links

Project website: https://garibaldialpine.wixsite.com/garibaldialpine

- Includes summary of the projects and preliminary results, media/past events that shared our results, information about the research team, etc.