ACA Grants in Biodiversity
2022-2024 Funding Application Form
PART B

Alberta Conservation Association

Applicant Name (Last, First, Middle):	**Date:**
Rahn, Olivia, Jane	30/11/2021

Department:	**Institution:**
Biology	McGill

Type of Applicant:

Ph.D. ☐ Masters **X** Not yet in graduate school ☐

On April 1, 2022, how many years will you have been registered in the program indicated? Please round to the nearest quarter year; e.g. 1.25 years. (See “Instructions for Completing Application” for written materials that must be provided)

Years: 0.75

Project Title:

Does habitat availability decline towards the range edge of *Rhinanthus minor*?

Your application package will include:

- PART A - one original
- Attachments as indicated on the checklist – one copy (attached to Part A Application Form)
- PART B - one original

E-mail the completed package as outlined in the Application Instructions. The package must be received by the Grants Coordinator by 4:00pm Wednesday, December 1, 2021.

NAME: Olivia Jane Rahn

RESEARCH PROPOSAL (*This page and 2 additional freeform pages are allowed)*

Use the following headings:

1. Scope and rationale for the research
2. Research objectives
3. Research methods
4. Schedule
5. Significance

Scope and rationale for the research

Every species has a limited geographic range, with upper and lower range limits in both latitude and elevation. Understanding the ecological causes of these range limits remains a central question in ecology and is increasingly important to conservation. Climate change is prompting many species around the world to shift their ranges *(1)* but different range limits have shown widely varying responses, even within species *(2).* This variation suggests that the ecological factors that limit ranges, range shifts, and therefore species' potential responses to climate change are complex.

When a range limit occurs along a gradual environmental gradient, the most intuitive explanation is that habitat *quality* (for that species) decreases gradually, eventually becoming too poor to support populations. However, habitat is also often assumed to become patchier toward range limits *(3),* and patches of unoccupied but seemingly suitable habitat are not uncommon beyond species' ranges *(4)*. Therefore, an additional explanation for range limits is that they are driven by declines in habitat *quantity*. If patches of suitable habitat become smaller and further apart, a range limit will arise at a point in space where the rate at which empty patches are colonized does not keep up with the rate of random patch extinction *(5)*. Patchy habitat means we cannot predict species success based on only warming and continuous trends in biotic and abiotic gradients- it becomes important to consider fine scale variation in the environment, the effects of small population sizes, and dispersal limitation between patches. Current models of species distributions are often done on large scales *(6)* and cannot account for these factors. Integrating small scale information about habitat quality and quantity with population demographics across species' ranges can significantly improve our accuracy when predicting where populations can persist *(7)*.

This 'meta-population' approach to range limits has been well modelled *(eg. 3,5,8),* but rarely tested in nature. My MSc research will test how habitat quantity and quality contribute to the elevational range limits of a native herb, *Rhinanthus minor* (Fig. 1), in Kananaskis, Alberta.

Fig 1. A *R. minor* (yellow rattle) plant in Kananaskis

One reason we lack experimental data about gradients in habitat quality is because of the way habitat is assessed in range-limit experiments. The gold standard for assessing how habitat quality varies across a range limit is to transplant individuals into sites within and beyond the range, and measure lifetime fitness *(9)*. While transplants have been used for decades to test gradients in habitat *quality,* they usually select putatively good habitat in all sites *(eg 10, 11),* and so cannot detect trends in habitat *quantity*. Measuring quality and quantity requires transplants to be placed randomly or evenly across each site. A second limitation of transplant experiments is that they are labour intensive, and therefore usually limited to a few sites. Yet habitat patchiness can vary at multiple scales, including a landscape-scale that is too large to capture experimentally. A potential solution, initially developed for agriculture, is to quantify habitat quality using multi-spectral images *(12,13)*. If habitat quality could be reliably inferred from these photos, habitat quantity could be measured at a landscape scale by mounting the multi-spec camera to an Unmanned Aerial Vehicles (UAVs or drones).

This page and 2 additional freeform pages ONLY are allowed for your Research Proposal. Mark each additional page with your name and page number (B-3, B-4). All margins must be at least 1 inch in width and font size at least 11 pts.

I will combine transplant experiments and multi-spectral images to provide one of the first real-world tests of habitat quantity across a species range. My study organism, *R. minor*, is an annual plant, so lifetime fitness can be assessed in one growing season. *R. minor* lives in grassy meadows *(14)*, and in our study region occurs from ~1300 masl to treeline. Previous transplants (2011-2014) suggest habitat quality does not decline toward the range limit and that there may be suitable habitat patches above the range- therefore, gradients in habitat patchiness may contribute to limiting the range.

Research question and hypothesis

Question 1: Does habitat quantity decline towards *R. minor*'s high-elevation range edge?
Hypothesis 1: Habitat quantity declines towards the upper range limit, causing simultaneous declines in the number of successful *R. minor* populations.
Question 2: Can we measure *R. minor* habitat quality and quantity using multi-spectral imagery?
Hypothesis 2: Multi-spectral images from a UAV will be capable of identifying suitable habitat and quantifying the amount of suitable habitat available in a given area, based on the prior success of UAVs in conducting landscape-scale agriculture and biodiversity surveys.

Research methods

I will first measure habitat quality and quantity via transplant experiments. In fall 2021, I planted *R. minor* at 8 sites across its elevational range across Mt. Allen (Nakiska Ski Area), Kananaskis. The sites are located along 2 replicate transects. Each transect has a low elevation and mid elevation site, a site at the *R. minor* high-elevation range limit, and a site above its range. At each site I planted 30 1x1 m plots (Figure 2), with 25 seeds per plot. I planted plots in a grid, ensuring that at 5 were in suitable *R. minor*

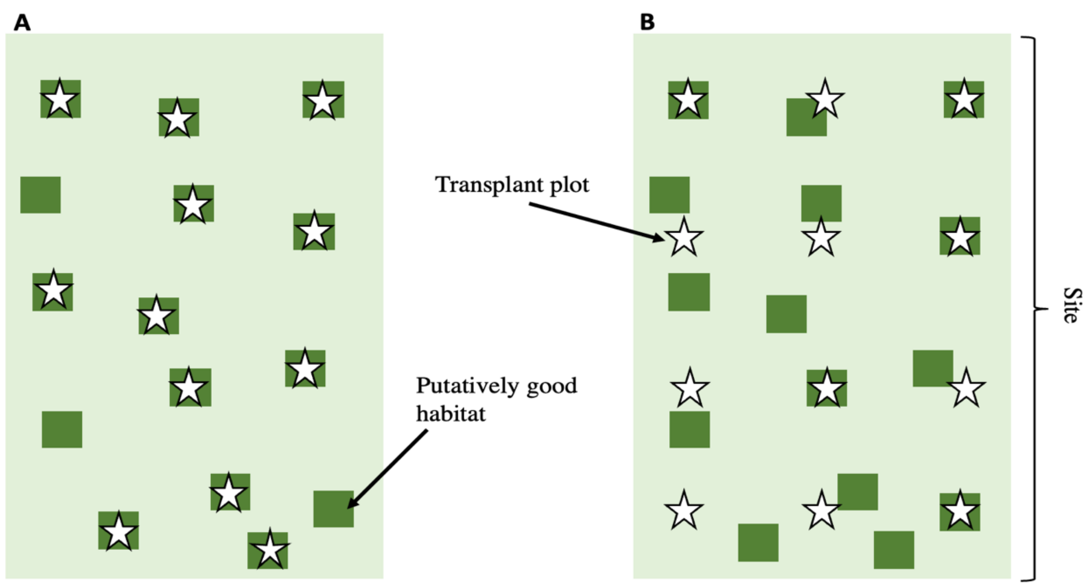

Figure 2. **(A)** Example of a typical transplant experiment setup, with transplant plots in putatively good habitat. **(B)** My experimental setup. Transplant plots are evenly spaced on a predetermined grid. Plots are sometimes in good habitat and sometimes in poor habitat. Note that in reality there are 30 plots per site- this is reduced to 12 for the purpose of this figure.

habitat (reproductive plants nearby), while also capturing a representative sample of habitat at each site. Each plot contained 20 seeds from the most local population, and 5 seeds from a standardized mid-elevation population. The standardized seeds will reveal differences in habitat quality among sites independent of any differences in seed quality among sites (previous work shows populations are not locally adapted along this elevational gradient) *(15)*.

During summer 2022, myself and the **field assistant** will monitor transplant germination success, survival, and reproduction. Using this data I will calculate lifetime fitness (seeds produced per seed planted). From this I will determine the proportion of suitable habitat (# plots with positive population growth rate, $\lambda \geq 1$) per site, to assess whether habitat quantity declines toward and beyond *R. minor*'s high-elevation range limit as per **Question 1**.

To address **Question 2**, I will test whether habitat quality can be predicted from multi-spectral images. I will photograph each plot at 3 periods during summer 2022: during seedling emergence, during flowering, and when fruits are mature. From these images I will derive a set of "Vegetation Indices" (eg. NDVI) that assay vegetation health and cover in each plot *(16)*. I will determine whether any of the indices are correlated with *R. minor*'s population growth rates at each site across the range by regressing growth rate against each index, and then comparing R^2 values to determine if any vegetation indices predict *R. minor* growth, and if so which indices are the best predictors.

If I find vegetation indices that succeed in predicting habitat quality for *R. minor*, I will conduct larger-scale assays of habitat quantity using multi-spectral photos collected by drone. Using a principle component analysis of predictive vegetation indices and range position (to account for the possibility that different indices may predict population success in different parts of the range), I will generate a habitat suitability index for *R. minor*. The drone will fly on a pre-programmed flight path over both transects at Mt. Allen. Permission to operate the drone within the Nakiska Ski Area was obtained in Summer 2021. In collaboration with aerial mapping specialists, I will determine what proportion of area in the images collected by the drone contain suitable habitat as defined by the habitat suitability index. This will enable me to quantity trends in habitat quantity continuously across the elevational gradient, in addition to the subsample scale allowed by transplant experiments, answering **Question 1** on an additional scale.

<u>Schedule</u>
<u>Fall 2021:</u> Planted *R. minor* seeds for transplant experiments.
<u>Winter/Spring 2022:</u> Preparation for Summer 2022 field season, including gathering permits to work in Alberta parks and planning surveys of transplant plots. I will take a course in remote sensing and interpretation at McGill, taught by a leading expert in the field.
<u>Summer 2022:</u> Monitoring *R. minor* transplant plots, using UAV to take images of transplant plots and sites.
<u>Fall 2022:</u> Removing transplant plot infrastructure, processing UAV imagery and fitness data.
<u>Winter/Spring 2023:</u> Writing and data analysis.

<u>Significance</u>
This project will be one of the first empirical tests of gradients in habitat quantity across a species range. Gradients in habitat quantity and habitat quality are central to many models *(3)* and are likely to influence range expansion and contraction via patch colonization and extinction. These dynamics govern species' range limits- better understanding these gradients will improve our ability to predict how species' ranges might change in the future. Considering fine scale variation in habitat quantity is particularly important in mountainous areas such as Kananaskis, where topography and elevation create massive heterogeneity in habitat when compared to more continuous latitudinal gradients. Incorporating accurate, fine scale information about gradients in habitat could improve tools currently used to project species' range shifts under climate change and identify priority habitat, such as Species Distribution Models. As range limits become increasingly central to conservation, it is crucial to work towards improving these tools and our understanding of species' abilities to shift their ranges.

NAME: Olivia Jane Rahn

LITERATURE LIST (*This page only)*

Use this page for your bibliography or list of literature cited.

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2) Freeman, B. G., Lee-Yaw, J. A., Sunday, J. M., & Hargreaves, A. L. (2018). Expanding, shifting and shrinking: The impact of global warming on species' elevational distributions. *Global Ecology and Biogeography*, *27*(11), 1268–1276. https://doi.org/10.1111/geb.12774

3) Holt, R. D., & Keitt, T. H. (2000). Alternative causes for range limits: A metapopulation perspective. *Ecology Letters*, *3*(1), 41–47. https://doi.org/10.1046/J.1461-0248.2000.00116.X/FORMAT/PDF

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10) Peterson, M. L., Angert, A. L., & Kay, K. M. (2019). Experimental migration upward in elevation is associated with strong selection on life history traits. *Ecology and Evolution*, *August*, 1–14. https://doi.org/10.1002/ece3.5710

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12) El Hoummaidi, L., Larabi, A., & Alam, K. (2021). Using unmanned aerial systems and deep learning for agriculture mapping in Dubai. *Heliyon*, *7*(10), e08154. https://doi.org/10.1016/J.HELIYON.2021.E08154

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NAME: Olivia Jane Rahn

BUDGET for research in this proposal.

Amount requested from ACA cannot exceed $20,000. Budget must fit on this page; blank lines may be removed.

Category	Description	$ Amount requested from ACA	$ Funding needed from other sources	$ Total
Costs of Assistants (in your proposal please state duties of each individual):				
Field Assistant Salary	NSERC USRA ($6000) and ACA ($2400). 16 weeks @ 35 hr/wk ($525/wk)	$2400	$6000	$8400
Field Travel (calculate mileage reimbursement at $0.50 per km for budgeting):				
Rental vehicle	Rental SUV (the shared lab vehicle is used primarily by another field crew for 4 months). 1200/month*4 months	$4000	$800	$4800
Lab Vehicle Mileage	7,000 km based on 2021 mileage	0	$3500	$3500
Trips to and from Alberta	$400 (gas) each way + $200 (accommodation)	0	$1200	$1200
Gas for shared field vehicle	For miles driven when I have primary access to the lab vehicle (1 month of field season). $350/mo	$350	0	$350
Gas for rental vehicle	$350/month *4 months based on 2021 field season	$1400	0	$1400
Materials and Supplies:				
Field notebooks, pencils, flags, quadrats, seed envelopes, wooden stakes for planting, other misc. field supplies	$500 based on receipts from supplies in 2021	$250	$250	$500
Other Required Expenditures:				
Housing at Barrier Lake Field Station	Field Station rent: $700/mo + $75/person/month. [1 x 2 people x 4 months (assistant and myself)] + [1 x 1 person x 1 month (myself only)] + [2 people x 1 month (collaborators for drone data collection)] = $4575/year	$4575	$0	$4575
TOTAL COSTS ($)		**$12,975**	**$11,750**	**$24,725**

NAME: Olivia Jane Rahn

Additional Budget Information (to be completed jointly with supervisor)

Indicate other sources of funds applied for in support of this program or the larger program within which this project falls. Include support sought/received and indicate current status: Applied (A) or Held (H).

Money required to complete this project

a) From this application:	$12,975
b) From other sources	$11,750

Short title of project	Agencies applied to	Amount Requested	Status (Applied or Held)
Alexander Graham Bell Canada Graduate Scholarship- Masters	Natural Sciences and Engineering Council of Canada (NSERC/CRSNG)	$17,500	Held
Sarah Baker Memorial Scholarship	Yellowstone to Yukon Conservation Initiative	$5000	Applied
A. Hargreaves' NSERC Discovery Grant (for larger lab research program)	Natural Sciences and Engineering Council of Canada (NSERC/CRSNG)	$165,000	Held
A. Hargreaves' CFI Grant (for larger lab research program)	Canadian Foundation for Innovation	$350,000	Held
Undergraduate Student Research Awards (NSERC USRA) (field assistant salary supplement)	Natural Sciences and Engineering Council of Canada (NSERC/CRSNG)	$6000	February 2022 deadline
Graduate Mobility Award	McGill University	$3000	April 2022 deadline
McGill Graduate Student Excellence Award	McGill University	$2500	Held
QCBS Graduate Student Excellence Award	Quebec Centre for Biodiversity Science	$2000	January 2022 deadline

Additional Support – Comments

List amount of either financial and/or logistical support available to student; please identify type and amount of support expected (i.e., logistical, computer time, laboratory equipment and analyses, financial support).

From Department: The Graduate Mobility Award from McGill would cover up to $3000 of travel costs. The department has also provided $2500 of financial support via a Graduate Student Excellence Award.

From Supervisor: A. Hargreaves is providing partial use of the lab vehicle, and financial support from both an NSERC Discovery Grant and a CFI grant for field costs. AH will also mentor OJR during writing and data processing. AH's CFI grant was used to purchase the drone that will be used for aerial imaging of sites.