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Ecological monitoring of terrestrial arthropods on *Umingmat Nunaat* (Axel Heiberg Island), Nunavut, in the High Arctic

Introduction: The Arctic is warming at a faster rate than any other place on Earth, yet the effects of this rapid climate warming on Arctic terrestrial ecosystems is not well understood as there is much about the fundamental functioning of these ecosystems that remains to be discovered (Callaghan 2004, Parmeson 2006). Arthropods are the most abundant animal life in the high Arctic, which makes them ideal model organisms for studying high Arctic terrestrial ecosystems (Danks 1992). In recent years, there have been calls in the literature to establish new arthropod monitoring projects in the Arctic to study terrestrial ecosystems and learn how they might be affected by climate change (e.g., Gillespie et al 2019, Høye 2020). The McGill Arctic Research Station (MARS) on Axel Heiberg Island, high Arctic Canada, is an ideal base of operations for the establishment of a long-term arthropod monitoring project. Remarkably, no ecological study of terrestrial arthropods had ever been conducted on this large northern landmass, comparable in size to Nova Scotia or Switzerland. In 2018, I therefore sampled 37,958 terrestrial arthropods on Axel Heiberg Island and also collected associated environmental data for my Master's project, which studied the effects of biotic and abiotic factors on these arthropod communities and also established a baseline collection for proposed longer term arthropod monitoring at the McGill Arctic Research Station. As climate change threatens to cause rapid alterations to high Arctic terrestrial ecosystems, an arthropod monitoring project on Axel Heiberg Island can effectively help us to understand how these ecosystems are being impacted. Having already collected baseline data through my Master's fieldwork, my proposed future fieldwork for an upcoming PhD would build upon the previous study with the establishment of a longer term ecological monitoring program at the McGill Arctic Research Station, functioning in conjunction with other long-term projects already occurring at MARS, with the unified objective of monitoring changes to the Arctic environment over time.

Objectives: The primary ecological research objectives for this proposed PhD fieldwork are to (1) identify relationships between terrestrial arthropod assemblages and their environment in the high Arctic, and (2) predict how these relationships would be impacted by rapid climate

warming. In pursuit of these objectives, a long-term arthropod monitoring program will be established at the McGill Arctic Research Station on Axel Heiberg Island. Additional objectives of this project are to (3) identify specimens within the arthropod assemblages that may represent undescribed species or new northern range records, (4) study host-parasite interactions among high Arctic parasitoids, (5) investigate instances of brachyptery in high Arctic arthropods, and (6) establish an easily repeatable protocol for future work.

Study Area: The study area is the environs of the McGill Arctic Research Station (MARS), itself located at coordinates 79°24'54.5"N 90°44'51.9"W in the rugged interior of western-central *Umingmat Nunaat*/Axel Heiberg Island, Nunavut, in High Arctic Canada. MARS is located about 8 km inland from Expedition Fiord, which cuts deep into the western interior of the island, and the name Expedition Fiord is often applied to this entire region including as a synonym for MARS. Within this region, enclosed by mountains and glaciers, the field station sits on a rise above a small and naturally acidic lake known as Colour Lake. The study area will be a 3.2 km transect running through the basin of Colour Lake and following the lake's drainage into Wolf Creek. Compared to the surrounding polar desert landscape that characterises the island, the basin of Colour Lake is a relatively lush oasis filled with vegetation. Within the study area, Colour Lake drains into a wetland that is characterised by a particular species of cotton-grass, *Eriophorum scheuchzeri* Hoppe—with plenty of other vegetation around the periphery. While fish are absent from these water bodies due to the high acidity. The water from this wetland then drains in a southwest direction through a cut in a basalt dyke to join up with Wolf Creek. Although Wolf Creek is fed predominantly by meltwater from the nearby Wolf Mountain, it is also the outlet for Colour Lake. The creek bed of Wolf Creek consists of variably sized rocks and is sparsely vegetated, however the slopes that flank the creek bed are well vegetated. Wolf Creek carries on outside of the study area and eventually flows into the marine waters of Expedition Fiord, approximately 8 km downstream from MARS. The study area overall is relatively lush compared to much of the surrounding landscape—an oasis within the polar desert of *Umingmat Nunaat*.

Methods: Within the study area described above, I will establish four sampling sites (i.e., replicates), labelled Sites 1-4, spaced approximately 800 m apart and following the direction of

flow of water from Colour Lake and its outlet Wolf Creek. Site 1 will be located at coordinates 79°25'14.2"N 90°44'48.1"W, on the north shore of Colour Lake. Site 2 will be located at coordinates 79°24'58.9"N 90°46'42.4"W, bordering the Colour Lake wetland. Sites 3 and 4 will both be located along Wolf Creek, with Site 3 located at coordinates 79°24'40.2"N 90°48'11.5"W on the south side of the creek, and Site 4 further downstream at coordinates 79°24'45.4"N 90°50'20.9"W on the north side of the creek.

Each of the four sampling sites will consist of a 10 m x 60 m transect, oriented perpendicular to the water. An insect pan will be placed every 10 m along each transect, for a total of 14 insect pans per site, and 56 insect pans across all sites. The pans are plastic bowls dug into the ground to combine the roles of both a pan trap and a pitfall trap (Ernst et al 2016). The bowls function as pan traps because insect pollinators are attracted to the colouration; and by digging them into the ground, the pan traps double as pitfall traps since ground-dwelling arthropods will then fall. Half of the insect pans will be yellow, and the other half will be purple, so that the two most common colours of wildflowers on *Umingmat Nunaat* are represented. In each yellow pitfall trap, a few centimetres of 50% propylene glycol solution will be added to act as a non-toxic, mild preservative. Finally, a few drops of biodegradable dish soap will also be added into each trap to break the surface tension, causing any arthropods that fall in to sink.

The study period will be from the beginning of July into early August 2022. The four study sites with their combined 56 insect pans will active continuously during that period. I will collect the contents of each trap every four to five days, depending on weather conditions. I will service each trap by pouring out their contents over a fine mesh square to separate the arthropods out from the fluid, and then folding that piece of mesh—containing the arthropods—and placing it into a Whirl-Pak® sample bag with a small squirt of ethanol solution added for preservation. Samples from three of the sites will be preserved in a 70% ethanol solution, while samples from one of the sites will be preserved in a 95% ethanol solution so that molecular work can be done later on in the lab. Collecting the contents of each trap every four to five days should give me about six or seven sampling periods during the study period.

Climate data will be collected from compact cases located at each site (one per site) containing Campbell Scientific weather instruments for collecting local climate data at each site.

Ground cover data will be collected using a 1 m x 1 m quadrat. At the location of each insect pan, I will place the quadrat down on the ground directly beside each trap—always on the interior face of the transect—and take a photo of the quadrat from directly overhead. Repeating this procedure for all 56 of the insect pans across all four sites, I will have a total of 56 photos showing local ground cover beside each trap. I will then analyze the ground cover from each photo by further organizing the quadrat into 81 subdivisions, and assigning each of those 81 subdivisions one of the following ground cover classifications:

F = graminoids (grasses and sedges)
H = herbaceous plants
M = mosses
L = lichens
S = shrubs (*Cassiope* and *Salix*)
Br = bare rock
Bs = bare soil

In addition to sampling at the locations described above, I will also do some opportunistic sampling. That is, if during the field season I locate a previously unknown area that is of potential interest—for example, a microhabitat with very lush vegetation compared to the surrounding area—I will place down a few insect pans at that location to sample some of the arthropods there. These specific locations are not known at this time, but are within the area that I have designated in the NPC application.

Finally, I will use a small quadrotor drone with a camera to map out the area of concentrated study. In late July, when local birds are finished nesting, I will use the drone to photograph every bit of ground cover in the basin of Colour lake, as well as the adjacent 1 km stretch of Wolf Creek (i.e., the area where my four primary sites are located). Later, photogrammetry software will stitch these images together to produce a 3-dimensional map of the study area, providing detailed information about ground cover.

Contributions to Arctic Science: As climate change continues to alter the Arctic environment at an unprecedented rate, this project fills a vital gap in our understanding of Arctic ecosystems by addressing a High Arctic location that is severely understudied in this regard. Research activities at MARS already include several long-term monitoring projects, but none concerning ecology, and so it is proposed that this research will see the start of a long-term ecological monitoring program on Axel Heiberg Island—operating in conjunction with the other long term projects— using arthropods as model organisms for the unified goal of detecting changes to the Arctic environment over time.

Relevant literature

Bowden, J.J., Buddle, C.M. 2010. Determinants of ground-dwelling spider assemblages on a regional scale in the Yukon Territory, Canada. Écoscience 17: 287-297

Bowden, J.J., Buddle, C.M. 2010. Spider assemblages across elevational and latitudinal gradients in the Yukon Territory, Canada. Arctic Institute of North America 63: 261-272.

Callaghan, T.V., Björn, L.O., Chernov, Y., Chapin, T., Christensen, T., Huntley, B., Ims, R.A., Johansson, M., Jolly, D., Jonasson, S., Matveyeva, N., Panikov, N., Oechel, W., Shaver, G., 2004. Past changes in arctic terrestrial ecosystems, climate and UV radtiation. Ambio 33: 398-403.

Cameron, E.R. 2016. Ecological monitoring in Cambridge Bay (Nunavut): testing the effects of microhabitat and seasonal change on the taxonomic and functional diversity of Arctic arthropod communities. Unpublished master's thesis, McGill University, Montréal, Québec, Canada,

Danks, H.V. 1992. Arctic insects as indicators of environmental change. Arctic 45: 159- 169.

Ernt, C.M., Loboda, S., Buddle, C.M. 2016. Capturing northern biodiversity: diversity of arctic, subarctic and north boreal beetles and spiders are affected by trap type and habitat. Insect Conservation and Diversity 9: 63-73.

Gillespie, M.A.K., Alfredson, M., Barrio, I.C., Bowden, J.J., Convey, P., Culler, L.E., Coulson, S.J., Henning Krogh, P., Koltz, A.M., Koponen, S., Loboda, S., Marusik, Y., Sandström, J.P., Sikes, D.S., Høye, T.T. 2020. Status and trends of terrestrial arthropod abundance and diversity in the North Atlantic region of the Arctic. Ambio 49: 718-731.

Hansen, R.R., Hansen, O.L.P., Bowden, J.J., Normand, S., Bay, C., Sørensen, J.G., Høye, T.T. 2016. High spatial variation in terrestrial arthropod species diversity and composition near the Greenland ice cap. Polar Biology 2016; DOI 10.1007/s00300-016-1893-2.

Hansen, R.R., Hansen, O.L.P., Bowden, J.J., Treier, U.A., Normand, S., Høye, T. 2016. Meter scale variation in shrub dominance and soil moisture structure Arctic arthropod communities. PeerJ 4:e2224; DOI 10.7717/peerj.2224.

Høye, T.T. 2020. Arthropods and climate change—arctic challenges and opportunities. Current Opinion in Insect Science 41: 40-45.

Høye, T.T., Bowden, J.J., Hansen, O.L.P., Hansen, R.R., Henriksen, T.N., Niebuhr, A., Skytte, M.G. 2017. Elevation modulates how Arctic arthropod communities are structured along local environmental gradients. Polar Biology 2017; DOI 10.1007/s00300-017-2204-2.

Høye, T.T., Culler, L.E. 2018. Tundra arthropods provide key insights into ecological responses to environmental change. Polar Biology 41: 1523-1529.

Høye, T.T., Loboda, S., Koltz, A.M., Gillespie, M.A.K., Bowden, J.J. Nonlinear trends in abundance and diversity and complex responses to climate change in Arctic arthropods. PNAS 2021; DOI 10.1073/pnas.2002557117

Kim, K.C. 1993. Biodiversity, conservation and inventory: why insects matter. Biodiversity and Conservation 2: 191-214.

Parmesan, C. 2006 Ecological and evolutionary responses to recent climate change. Annual Review of Ecology, Evolution, and Systematics 37: 637-639.

Sullivan, J., McKillop, R. 2013. Ecology and biodiversity of Cambridge Bay, Victoria Island, Nunavut results of field studies. Google Search.

Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. Annual Review of Ecology, Evolution, and Systematics 37: 637-669.

Rich, M.E., Gough, L., Boelman, N.T. 2013. Arctic arthropod assemblages in habitats of differing shrub dominance. Ecography 36: 001-010.

Sweet, S.K., Asmus, A., Rich, M.E., Wingfield, J., Gough, L., Boelman, N.T. 2015. NDVI as a predictor of canopy arthropod biomass in the Alaskan arctic tundra. Ecological Applications 25: 779-790.