Alpine arthropods on the Uapishka plateau, Quebec: documenting patterns of biodiversity and developing protocols for rapid assessment

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ABSTRACT

Arthropods perform critical ecological functions in the alpine zone, including pollination, decomposition, and providing food for vertebrates, yet there is relatively little known about their diversity or distribution, especially in northeastern alpine areas of North America. Such a knowledge gap has significant implications for effective management of alpine ecosystems, and also for our ability to detect change in the face of environmental threats such as global warming. This inventory was designed to establish a baseline inventory for several key arthropod functional guilds across five alpine microhabitats within the Réserve de Biodiversité Uapishka, a remote, isolated alpine area in central Québec. Over five days (July 6-10, 2014), we set up pitfall traps (for ground-dwelling predators and scavengers) and bee bowls (for pollinators) at 15 sites on the western edge of the Uapishka plateau. We sampled three replicate sites for each of five alpine habitats: krummholz, snowbeds, rills and small streams, wetland edges, and tundra. Despite formidable weather, we collected 373 arthropods comprising 59 "species" (including three taxa identified only to genus) of bees (Anthophila), ants (Formicidae), common sawflies (Tenthredinidae), flower flies (Syrphidae), ground beetles (Carabidae), spiders (Gnaphosidae and Lycosidae), and butterflies (Lepidoptera). Among these arthropods, many species are arctic/alpine specialists with Holarctic distributions, and several are northeastern North American endemics. To make these data and the project more accessible to the public, all biodiversity results and a project description were posted on the Discover Life website (http://www.discoverlife.org/), which allows interactive exploration of the data, including links to species pages and occurrence maps. The project also piloted and assessed protocols for the rapid inventory of alpine arthropod diversity that may be used for future monitoring efforts, or for comparative studies with other eastern alpine areas.

ACKNOWLEDGMENTS

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Many heartfelt thanks to Ali Hogeboom, who proved to be an ideal field assistant with her fascination of alpine insects, and her good humor and resiliency in dealing with black flies, cold/wind/rain, wet everything, cold food, and powdered instant coffee shots.

I am extremely grateful to several taxonomists who assisted with species determinations: Bob Davidson at the Carnegie Museum of Natural history identified most of the carabid beetles; Dave Smith with the Smithsonian National Museum of Natural History took on the tenthredinid sawflies; Maxim Larrivée at the Insectarium de Montréal identified the (wet!) butterflies; Michelle Locke at the American Museum of Natural History determined and confirmed identifications of the syrphid flies; Gary Alpert at the Museum of Comparative Zoology put names on the ants; and Pierre Paquin confirmed all spider identifications.

INTRODUCTION

Alpine and arctic ecosystems encompass harsh and fragile landscapes in which arthropod species have adapted to survive extreme climatic conditions and short seasons for growth and reproduction (Mani 1968; Danks 1981, 2004). Adaptations to thrive in cold, exposed environments have resulted in a specialized arctic/alpine fauna, and isolation on mountain tops has also led to high rates of endemism (Mani 1968). Although overall diversity of alpine and arctic arthropods is much lower than in temperate biomes, they are still by far the most diverse and abundant component of the northern and high latitude fauna. For instance, more than 2,200 species of arthropods are known from north of the tree line in North America, with many more remaining to be discovered (Danks 2004). Among northeastern alpine areas, the Presidential Range in the White Mountains, NH, has received by far the most attention by arthropod collectors. Alexander (1940) mentioned there were more than 3,000 species recorded from higher elevations in the range.

Arthropod populations in alpine areas are often small, isolated, poor at dispersing, and sensitive to environmental change (Mani 1968). These characters make alpine arthropods especially susceptible to effects from global warming and climate change (Viterbi et al. 2013). Alpine environments are predicted to experience warming temperatures sooner than lower elevations, and alpine-adapted fauna have already been observed to respond with range and phenology shifts (Franzén and Öckinger 2012), which may affect critical interactions such as pollination. Considering the many critical ecosystem functions sustained by arthropods in the alpine zone, including pollination, decomposition, herbivory, scavenging, and predation, it is vital that we understand the composition of these guilds so that we can monitor their integrity in the face of environmental threats such as climate change.

While insect diversity has received some study in arctic Canada above the continental tree line (e.g., Kevan 1972; Danks 1981), little is known from alpine regions in northeastern North America, with the notable exception of the Presidential Range in the White Mountains of New Hampshire (e.g., Slosson 1894, Alexander 1940, McFarland 2003). Many of the isolated alpine regions further north in Quebec, Labrador, and Newfoundland have received virtually no attention from entomologists, due, in large part, to their inaccessibility. The Uapishka plateau in central Quebec, is one such isolated massif, lying more than 700 km north of Quebec City. The elevation of the alpine plateau is relatively low (the highest peaks reach little more than 1,100 m), but it is vast by eastern standards, spanning 90 km east to west (Jones and Willey 2012).

The western portion of the Uapishka massif is designated as a biodiversity reserve (Réserve de Biodiversité Uapishka), and is under the jurisdiction of the Ministère du Développement durable, de l'Environnement et des Parcs, which developed a conservation plan for the reserve in 2009 (Gouvernement du Québec 2009). However, ecological research in the reserve has been limited, with the recent exception of multiple trips made by Jones and Willey (2010) and colleagues between 2000 and 2010 to document vegetation and vertebrate fauna. As a complement to these ongoing inventories, we initiated arthropod surveys in the Réserve de Biodiversité Uapishka to begin to document the eastern alpine fauna of more northern latitudes, and to provide relevant information to land managers.

Our main objective was to conduct an inventory of selected arthropods in several alpine habitats within the reserve, with a goal of identifying habitats of high or unusual diversity, as well as endemic, vulnerable, and other noteworthy alpine species. We focused on arthropod taxa that comprise several important functional guilds, are known to vary in their specialization of habitats or host-plants, and taxa which have been used previously in alpine inventory and monitoring programs (e.g., Viterbi et al. 2013). By developing and carefully documenting sampling protocols that are efficient and easily repeatable (as has been developed for plants of alpine summits with the Global Observation Research Initiative in Alpine environments program (GLORIA; Pauli et al. 2004)), we also hoped to promote comparative investigations into arthropod diversity across other northeastern alpine areas, and to allow future monitoring of arthropod biodiversity on the Uapishka plateau, as potential threats such as increased visitor use or warming temperatures encroach. Our results were also intended to inform reserve managers as they prioritize areas and species for conservation and develop natural resource management plans.

SPECIFIC OBJECTIVES

(1) Survey selected alpine microhabitats (krummholz, snowbeds, rills and streams, wetland edges, tundra of exposed ridges and summits) for focal arthropod guilds (predators, pollinators, scavengers).

(2) Identify habitats of high and/or unique arthropod diversity, species strongly associated with particular habitats, and endemics to northeastern alpine areas, to help inform management strategies.

(3) Compile a publicly-accessible arthropod biodiversity database that provides a baseline for future monitoring efforts, and for comparative studies with other eastern alpine areas.

(4) Pilot and assess an efficient and easily replicable protocol for sampling alpine arthropod diversity that can serve to monitor change over time, and to compare alpine faunas across northeastern North America.

(5) Educate diverse audiences about arthropod biodiversity on the Uapishka plateau through a variety of media including an interactive website, an AMC presentation, and popular and peer-reviewed articles.

METHODS

Study area

The Uapishka plateau (also known as les Monts Groulx) lies in central Québec, Canada (51.6ºN, -68.1º W; Fig. 1). The plateau spans approximately 90 km east to west and is surrounded on all sides by boreal forest. Tree line on the massif can be reached by hiking just a few kilometers up from the Quebec-Labrador highway on the western border, and the highest peaks reach little more than 1,100 m in elevation. Mining and forestry are active to the north and south, and the plateau lies just northeast of the Manicouagan watershed which is developed for hydroelectric power (Jones and Willey 2012; Fig. 1).

The vast "alpine tablelands" of the plateau have low relief and poor drainage, resulting in an open landscape of tundra, snowbeds, and numerous wetlands, broken by higher, exposed peaks and ridges, and by shallow sub-alpine basins dominated by white spruce (Jones and Willey 2012). The remote wilderness character of the plateau sustains a full complement of vertebrate wildlife, including many large mammals that are no longer, or rarely, seen further south, such as wolves and woodland caribou. Vegetation communities in the vicinity of the peaks on the western end of the plateau have been most recently surveyed and documented by Jones and Willey (2010, 2012) and Willey and Jones (2012).

Human visitation is limited primarily to the more accessible western end of the Uapishka plateau, but the area receives very few visitors for recreational activities compared to alpine summits further south in Quebec and New England. Three hiking trails allow easy access to the alpine zone from the highway, but there are no established trails through the tundra. We focused our arthropod surveys on the western end of the plateau, within the Réserve de Biodiversité Uapishka. A pilot survey in 2013 focused on the area around Mont Provencher in the southwestern corner of the plateau, while the 2014 study was conducted in the vicinity of Mont Jauffret and Mont de la Tour Boissinot further to the north (Fig. 1).

Study design

Focal habitats

Sampling focused on five common alpine terrestrial habitat/plant community types found on the Uapishka plateau, these are more fully described in Jones and Willey (2012): spruce krummholz, snowbeds, riparian areas next to rills and small streams, edges of small marshes and ponds, and heath-shrub-lichen tundra communities on exposed ridges and summits (Fig. 2).

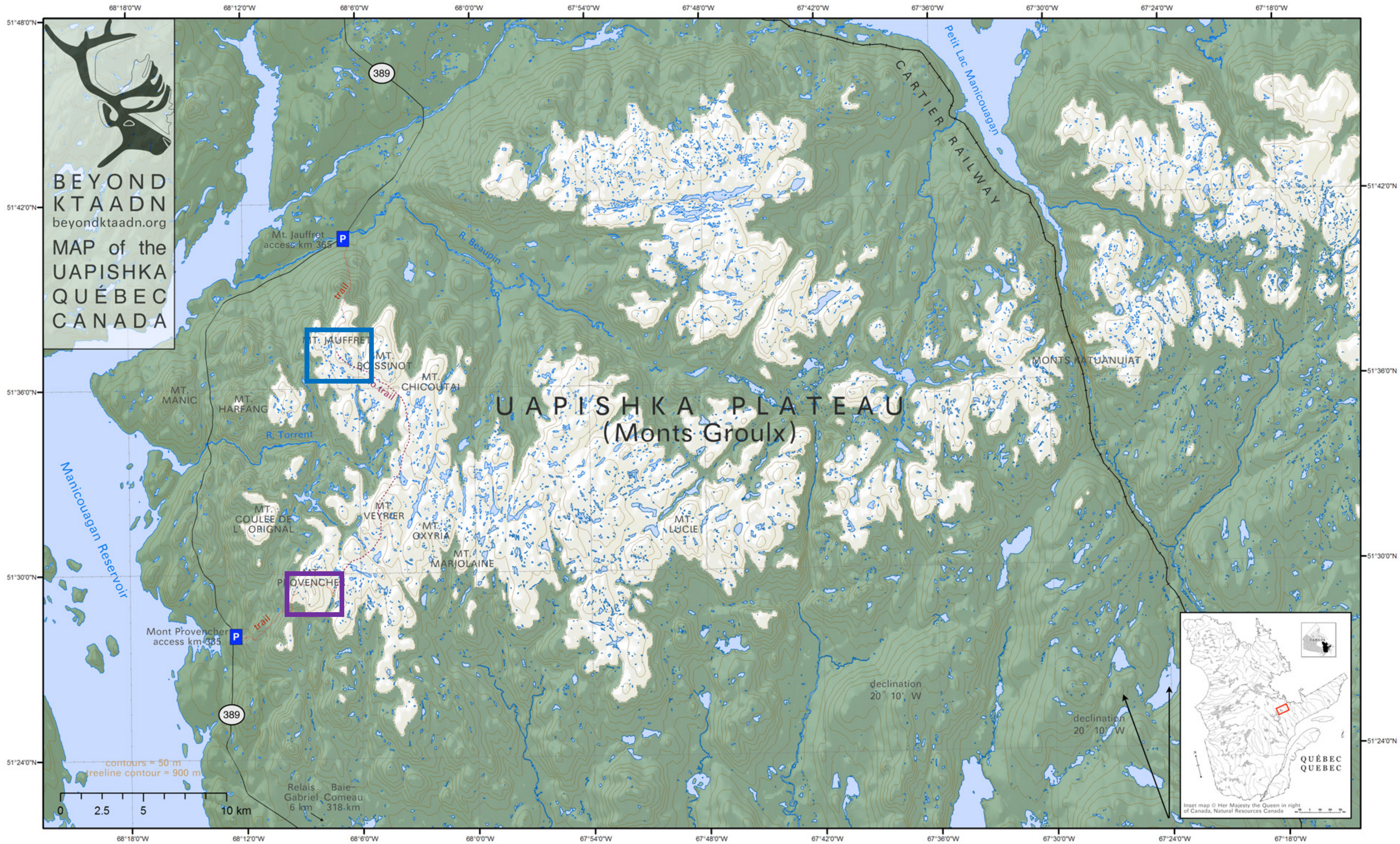

Figure 1. Map showing the Uapishka plateau, Quebec, Canada and its location within the province (inset lower right). Blue box indicates 2014 study area on Mont Jauffret and Mont Boissinot (see also Fig. 3); purple box indicates 2013 pilot survey area on Mont Provencher.

Figure 2. Alpine habitats surveyed for arthropods on the Uapishka plateau, Quebec, in 2014. From left to right, top to bottom: krummholz, snowbed, rill/stream riparian, wetland edge, tundra.

Site selection

Sampling was conducted in early July, when snow melt has typically progressed to leave only lingering, isolated snowbeds, and most arthropods are known to be active. After establishing a basecamp, we selected three sampling areas ("sites") in the vicinity of Mont Jauffret and Mont de la Tour Boissinot (Fig. 3). At each site, we selected one replicate plot of each target habitat (krummholz, snowbed, rill/stream, wetland, tundra), for a total of five plots per site, or, 15 plots total (Table 1). All plots within a site were a minimum of 100 m from other plots. Because ten plots (across two sites) were visited each day, distances between sites were kept at about one kilometer. The dispersal range for some of the focal arthropod taxa (e.g., bumble bees or functionally-winged ground beetles) may be greater than one kilometer, thus the three sites could not be considered as wholly independent replicates.

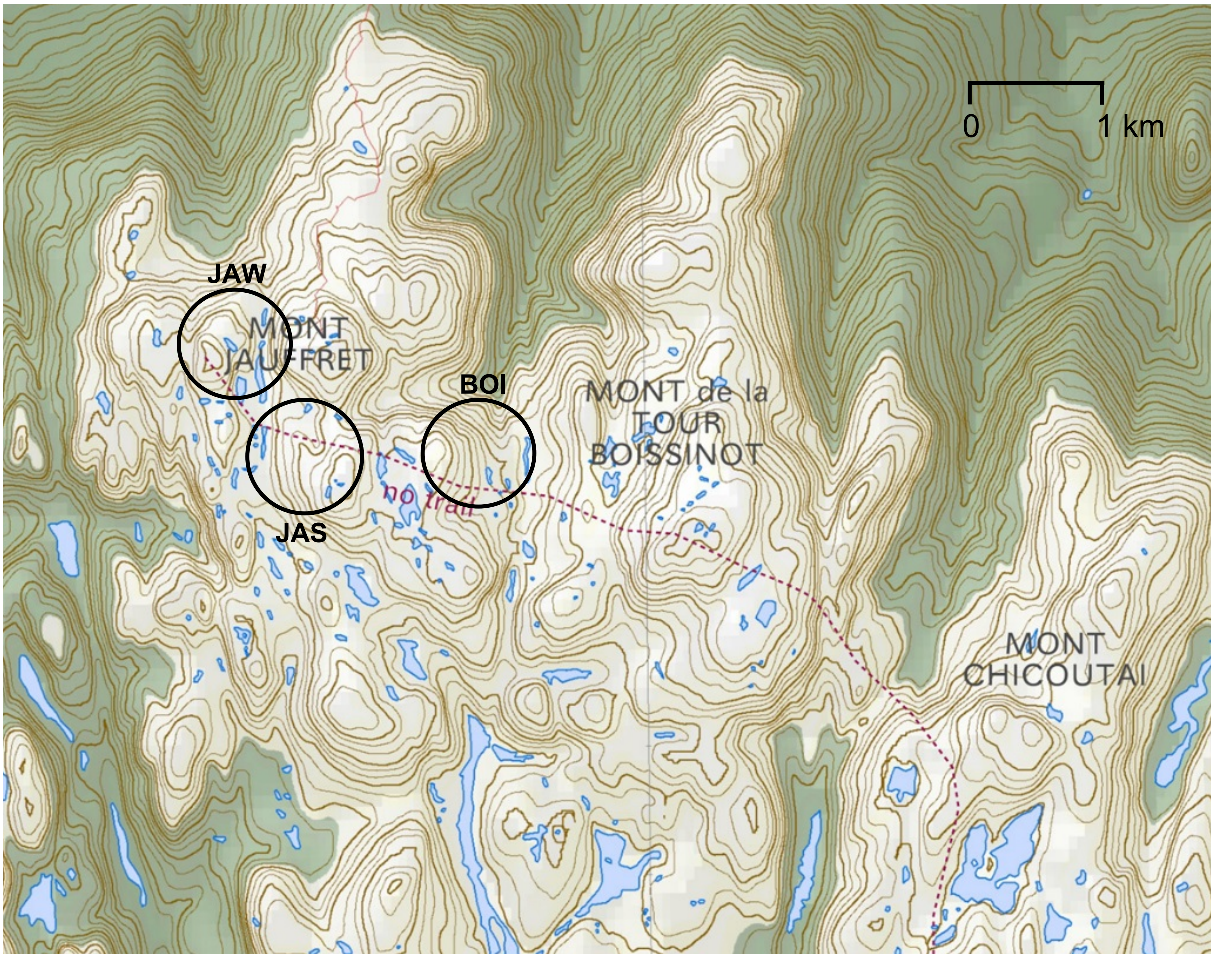

Figure 3. Map showing three sampling sites (JAW, JAS, BOI) on Mont Jauffret and Mont de la Tour Boissinot, on the Uapishka plateau, Quebec. Within each circle, we selected five plots to represent the five focal alpine habitats.

Table 1. Arthropod sampling site habitats, collection methods, location, elevation, and dates on Mont Jauffret (2014), Mont de la Tour Boissinot (2014), and Mont Provencher (2013).

Site	Habitat	Bowl	Pitfall	Net	Hand	Latitude	Longitude	Elevation	Date start
Mont de la tour Boissinot	krummholz	x	x	x		51.6170	-68.1031	987	7/6/2014
Mont de la tour Boissinot	rill	x	x	x	x	51.6196	-68.0996	931	7/6/2014
Mont de la tour Boissinot	snowbed	x	x	x	x	51.6196	-68.0996	952	7/6/2014
Mont de la tour Boissinot	tundra	x	x	x	x	51.6180	-68.1055	1043	7/6/2014
Mont de la tour Boissinot	wetland	x	x			51.6194	-68.0957	946	7/6/2014
Mont Jauffret-east	tundra	x		x		51.6193	-68.1096	1016	7/6/2014
Mont Jauffret-south	krummholz	x	x			51.6162	-68.1179	1029	7/7/2014
Mont Jauffret-south	rill	x	x	x	x	51.6171	-68.1236	925	7/7/2014
Mont Jauffret-south	snowbed	x	x	x	x	51.6193	-68.1179	1036	7/7/2014
Mont Jauffret-south	tundra	x	x	x		51.6180	-68.1146	1074	7/7/2014
Mont Jauffret-south	wetland	x	x			51.6202	-68.1242	975	7/7/2014
Mont Jauffret	various			x		various	various	various	7/7/2014
Mont Jauffret	various			x		various	various	various	7/8/2014
Mont Jauffret-west	krummholz	x	x			51.6299	-68.1247	994	7/8/2014
Mont Jauffret-west	rill	x	x			51.6290	-68.1226	968	7/8/2014
Mont Jauffret-west	snowbed	x	x	x	x	51.6277	-68.1290	985	7/8/2014
Mont Jauffret-west	tundra	x	x			51.6256	-68.1280	972	7/8/2014
Mont Jauffret-west	wetland	x	x		x	51.6271	-68.1237	991	7/8/2014
Mont Provencher	various			x	x	various	various	various	7/3/2013

Focal taxa

Arthropod families to be included in the survey were selected based on the following criteria: (1) they represented three important functional guilds in alpine systems: pollinators, predators, and scavengers; (2) all taxa are diverse, abundant, and easy to sample with standard methods; (3) all taxa are relatively well-known taxonomically. The following groups were selected as focal taxa:

Pollinators	Predators	Scavengers
Anthophila (bees)	Carabidae (ground beetles)	Formicidae (ants)
Syrphidae (flower flies)	Lycosidae (wolf spiders)	
	Gnaphosidae (ground spiders)	

Additionally, butterflies and skippers (Lepidoptera) and common sawflies (Hymenoptera: Tenthredinidae) were included among our focal taxa after field work had ended, because taxonomists offered to identify specimens from our bee bowl samples. However, we did not actively collect these two taxa (i.e., with nets) while in the field. Both taxa were included in the pollinator guild in our analyses, even though the genus *Tenthredo* are largely predaceous (on pollinators!) as adults. *Tenthredo* adults spend much of their time in flowers and may also feed on nectar, so it is likely they are carrying pollen between plants (D. Smith, pers. comm.)

Field sampling techniques

At each plot, we installed a transect of 15 bee bowls and 5 pitfall traps (see descriptions of trapping techniques below). When time and weather allowed, we also used active net and hand-collecting techniques at each plot to document additional species that traps may have missed. Environmental measurements made once at each plot included: latitude/longitude, elevation, and dominant plants in bloom. Microclimate variables (air temperature, average wind speed, relative humidity) were made on multiple visits to each plot.

Arthropod collecting methods

We used four standard methods for collecting arthropods, all of which are cheap, simple, and easily replicable.

Bee bowls: We set out small (3.25 oz.) plastic bowls painted blue, yellow, or white to target pollinators (bees and flower flies; Fig. 4). At each plot, 15 bowls were set out along a transect in alternating colors, spaced 5 m apart. Bowls were filled to ¾ with water and a drop of soap to break the surface tension. Pollinators are attracted to the color of the bowls, and drown in the water. Ideally, bee bowls are set out on warm, calm, sunny days, when pollinators are most active. At each plot, we set bowls out for approximately 24 hours, so that they could be open during the warmest daylight hours. At the end of the sampling period, contents of all 15 bowls were poured through a strainer (Fig. 4) and transferred into a plastic bag with 95% ethanol. In addition to our focal groups, the bowls also collected other insects, including butterflies, tenthredinid sawflies, and many other types of true flies (Diptera). Lepidoptera were transferred to separate plastic bags so that wing scales would not contaminate other specimens.

Figure 4. Left: blue bee bowl with a captured bumble bee; **Right:** pouring bee bowl contents through a strainer.

Pitfall traps: We used larger (10 oz.) plastic cups dug into the ground to capture ground-dwelling arthropods (beetles, spiders, ants; Fig. 5). Five pitfall traps were arranged along a transect, spaced 5 m apart, with soapy water (as for bee bowls). The traps were dug flush with the ground surface so that active arthropods would fall in unexpectedly, and drown in the water. Small plastic plates supported by three nails served as roofs for the buried cups, to keep out rain and other debris (Fig. 5). At each plot, we set the pitfall traps out for three nights in order to allow time to accumulate specimens, many of which are night-active. At the end of the sampling period, contents of all five pitfall traps were poured through a strainer and transferred into a plastic bag with 70% ethanol. In order to assess the benefit of leaving pitfall traps out for three nights versus one night, we emptied the cups after one night (when collecting bee bowls on the day following trap deployment), and tallied these specimens separately from the subsequent two nights of the pitfall catch.

Figure 5. Left: pitfall trap with spiders in bottom; **Right:** roof over pitfall trap.

Aerial nets: We used aerial nets to catch flying insects (bees, flower flies) while in flight or while visiting flowers to gain additional information on plot species diversity.

Hand collecting: We used hand-collecting as a method to find secretive or ground-dwelling arthropods (e.g., spiders, ground beetles, ants) from our focal groups under objects such as rocks, logs, and bark, or from flowers.

Specimen processing, identification, and curation

Specimens were preserved, curated, and labeled with standard entomological methods. Flies, bees, beetles, and voucher specimens of ants were pinned or point-mounted, depending on their size. Spiders were preserved in glass vials of 70% ethanol; only sexually mature adults were identified and counted. Prior to pinning, bees were washed and dried using methods described in the Handy Bee Manual, compiled by S. Droege and others (http://bees.tennessee.edu/publications/HandyBeeManual.pdf), in order to remove pollen and fluff the fur to make identification easier. Bycatch from pitfall traps and bee bowls (i.e., arthropods of non-focal groups, including many flies) were stored in 70% ethanol and await further attention from specialists.

Species identifications for bees, spiders, most ants and some beetles and syrphid flies were made by J. Rykken. Syrphid flies were identified with help from Michelle Locke at the American Museum of Natural History (AMNH), and most of the ground beetles were identified by Robert Davidson at the Carnegie Museum of Natural History (CMNH). Gary Alpert at the Museum of Comparative Zoology (MCZ), Harvard University, helped with ant identification. Maxim Larrivée at the Insectarium de Montréal (IM) in Quebec identified butterflies and skippers (Lepidoptera) collected in bee bowls and cataloged them in eButterfly (http://www.nab-net.org/program/ebutterfly). Dave Smith, from the Smithsonian National Museum of Natural History (NMNH) identified all of the common sawflies (Tenthredinidae). Pierre Paquin confirmed identifications of spiders. Permanent specimen repositories include the MCZ (some ants), CMNH (some ground beetles), IM (all butterflies), and NMNH (some sawflies).

2013 arthropod samples
Prior to the 2014 study, J. Rykken spent three days (July 3-5, 2013) on the Uapishka plateau, collecting arthropods with two colleagues (J. Milam and M. Veit) in the Mont Provencher region, approximately 20 km to the south of Mont Jauffret (see Fig. 1). Arthropod specimens from the same focal groups used in the 2014 study are included in this report (Appendix 1). These 2013 data were not used in structured analyses, but were included to examine larger biodiversity patterns in the region.

Data analysis
All specimen, sample, and associated data were entered into an MS Access relational database and graphs were created with MS Excel. I used the program EstimateS (Colwell 2013) to generate rarefaction curves for comparing expected numbers of arthropod species collected in each habitat as sample number increases (based on the total that were actually collected in each habitat). The slopes of these rarefaction curves also indicate how much more sampling is required to capture the full diversity of each habitat. Arthropod community similarity was compared between all pairs of habitat types using the Classic Sørensen incidence-based similarity index to evaluate the uniqueness/similarity of habitats.

RESULTS

Weather constraints

On the first two days of sampling, July 6-7, 2014, we measured mean air temperatures between 60 and 61ºF. Skies were generally sunny, with breezy conditions. On July 8, the weather began to turn overcast and rainy, and the mean measured air temperature dropped to 57.3ºF. On July 9, severe rain storms dominated the first half of the day, with sun returning in the afternoon, but strong winds prevented us from net sampling. By July 10, it was too cold (mean air temp. 45.7ºF), rainy, and foggy to continue sampling so we were forced to collect all traps and head off the plateau, two days earlier than anticipated. Thus, our last set of pitfall traps (at Mont Jauffret-west) were picked up after only two nights, rather than three.

Arthropod diversity and abundance

In 2014, we collected a total of 376 arthropod specimens in our focal groups, comprising 59 species (Appendix 1). The ground-dwelling predators (spiders and ground beetles) made up more than half the total catch in abundance, and almost half the species richness (Fig. 6). Ants and common sawflies had the fewest species. It should be noted that several hundred specimens of the ant, *Myrmica alaskensis*, were captured in pitfall traps at one wetland plot, likely placed in the vicinity of a nest of this social species. These numbers are not reflected in Fig. 6, nor in the following analyses (15 specimens were pinned to confirm the identity of the larger group of ants, and this number was used for analyses).

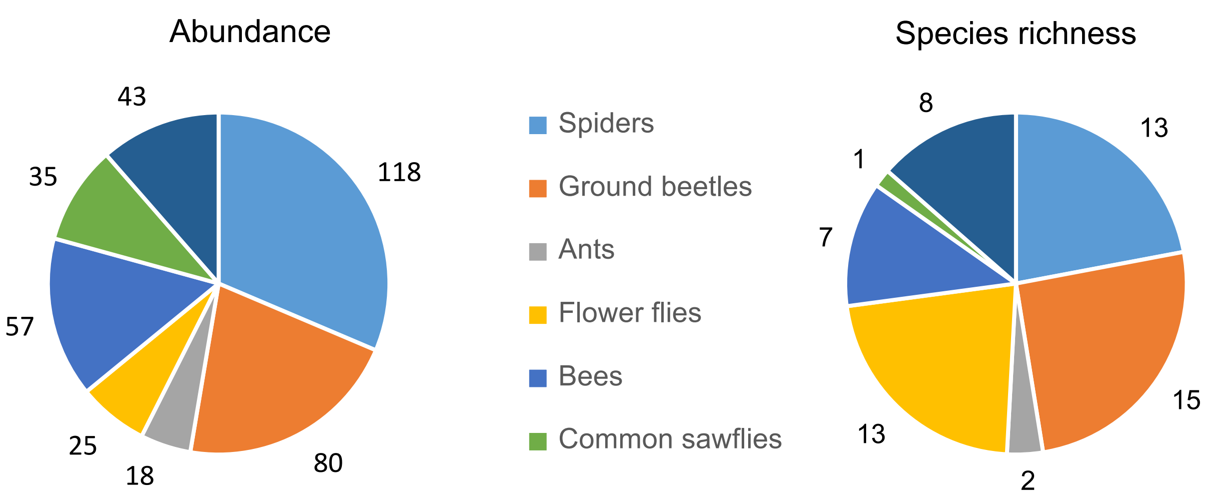

Figure 6. Proportion of total abundance (376 specimens) and species richness (59 species) represented by various arthropod taxa collected on the Uapishka plateau in 2014.

Habitat comparisons

Snowbed plots had the highest mean abundance and diversity of arthropods, while krummholz plots had by far the lowest (Figs. 7,8). Tundra, rill, and wetland plots were quite variable in both metrics across the three different sites.

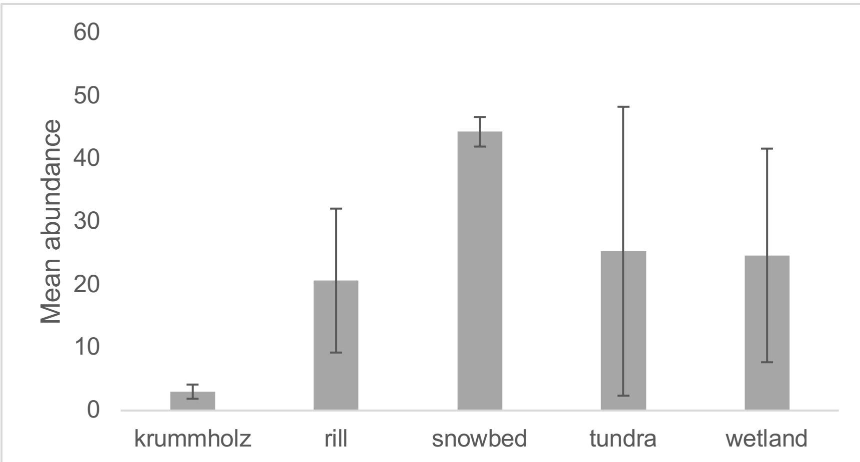

Fig. 7. Mean abundance (±95% CI) of arthropods collected in five habitats on the Uapishka plateau, QC.

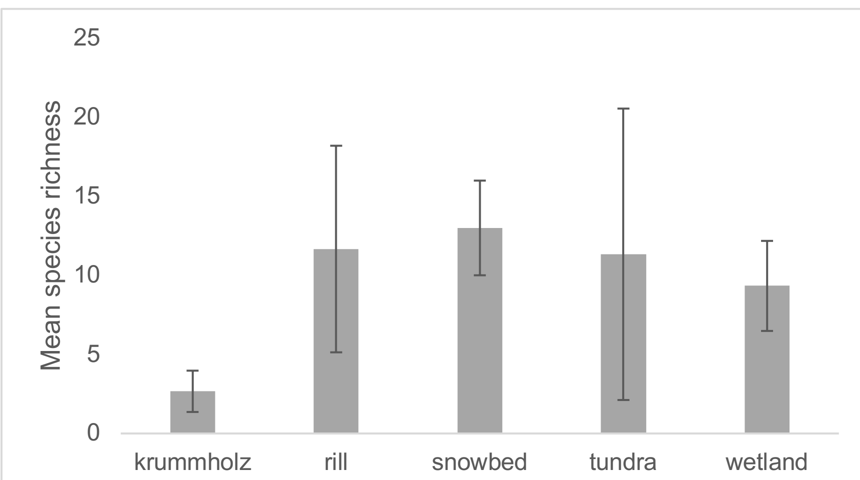

Fig. 8. Mean species richness (±95% CI) of arthropods collected in five habitats on the Uapishka plateau, QC.

The total number of samples taken in krummholz and wetland habitats was lower than in other habitats (due to less hand and net collecting), while snowbed habitats yielded the maximum number of samples (bee bowl + pitfall + net + hand collecting x 3 sites = 12 samples; Table 1). Tundra habitats had the most species overall (26), and krummholz the fewest (8). The steep upward trajectories of rarefaction curves for all habitats suggest that with additional sampling, many more species could be collected in all five habitats (Fig. 9).

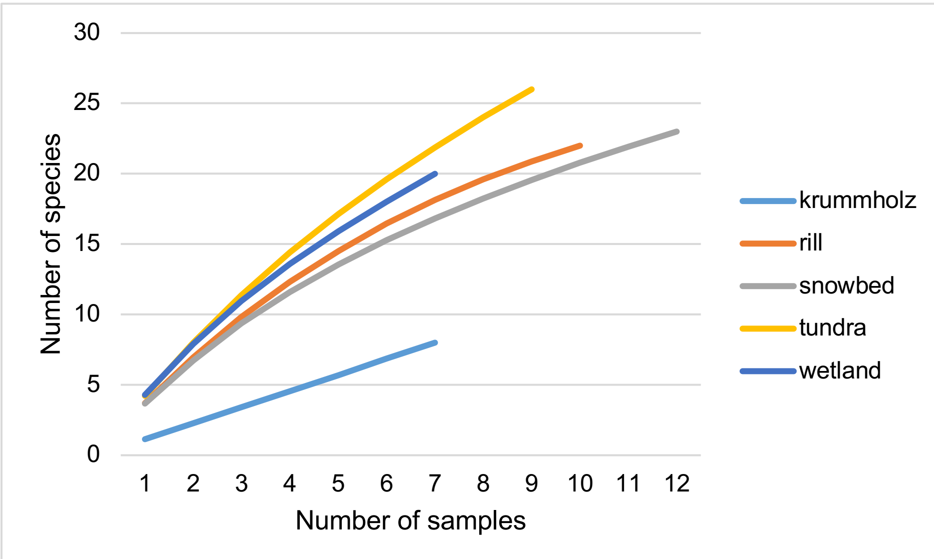

Figure 9. Rarefaction curves for total numbers of arthropod species collected in each habitat on the Uapishka plateau in 2014, using all trapping methods.

When considering only the specimens collected by bee bowls and pitfall traps within each habitat, ground-dwelling predators and scavengers comprised between 50% (wetlands) and 75% (rills) of the total catch (Fig. 10).

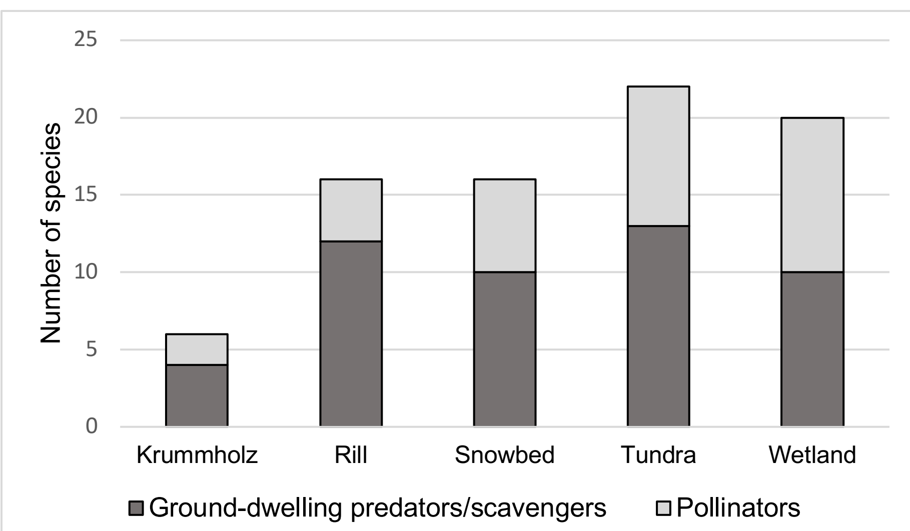

Figure 10. Total number of ground-dwelling predators/scavengers versus pollinators collected by bee bowls and pitfall traps across three sites in each habitat.

Similarity in species composition across habitats was highest for snowbed and rill habitats (Fig. 11). Krummholz, with only 8 species total, had the least similarity with other habitats.

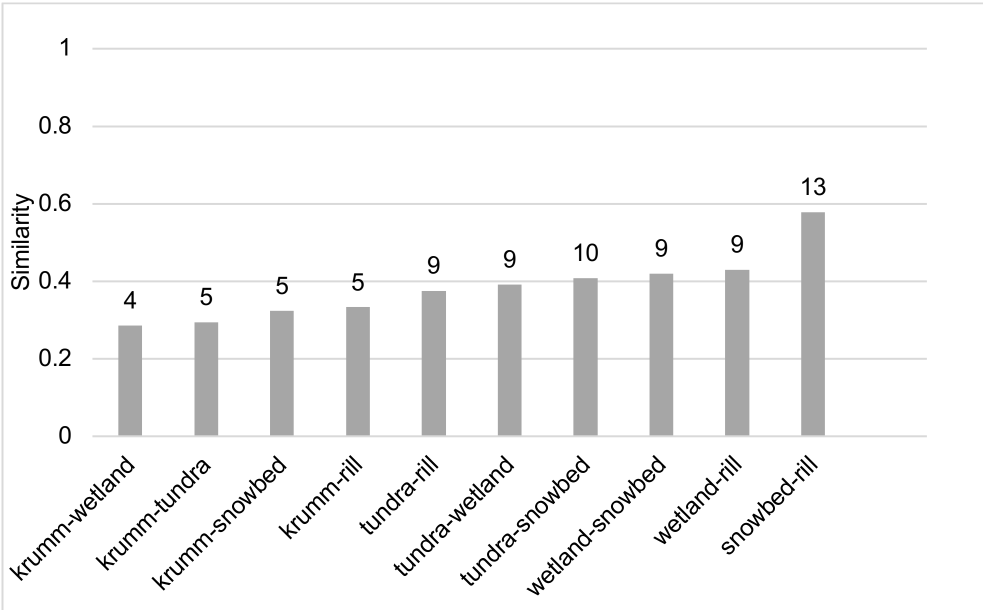

Fig. 11. Similarity in arthropod species composition between pairs of habitats, using the Classic Sørensen incidence-based similarity index. Numbers above bars indicate the actual number of species shared between the two habitats.

Habitat specialists and generalists

Several species were collected in just one habitat, or only in wet (rill, snowbed, wetland) or dry (krummholz, tundra) habitats, and are also reported from the literature to be habitat specialists (Table 2). Other species were found in almost all habitats, so appeared to be habitat generalists. Most of the habitat specialists were found among the ground-dwelling predators. Three of the ground beetles strongly associated with wet habitats (*Elaphropus lapponicus lapponicus, Stereocerus haemotopus, Trechus crassiscapus*) each had a single individual also occur in a dry habitat (tundra or krummholz), but these were considered “outlier” individuals.

Table 2. Arthropod species collected from the Uapishka plateau in 2014 that are associated with dry or wet habitats, or are habitat generalists. Species had to be represented by at least three specimens, and to occur in more than one site (see Table 1) and at least two habitat plots (max. = 15). Habitats (indicates habitat occurrences for each species): K = krummholz; R = rill; S = snowbed; T = tundra; W = wetland.

	# Specimens	# Sites	# Plots	Habitats	Specialization
Spiders					
Gnaphosa orites	6	2	2	T	tundra, dry
Pardosa furcifera	40	3	12	K,R,S,T,W	habitat generalist
Pardosa fuscula	32	3	7	R,S,W	wet places
Pardosa labradorensis	7	2	2	T	tundra, stony
Pirata piraticus	11	2	2	W	wet places
Ground beetles					
Agonum affine	7	2	4	R,S,W	wet places
Amara alpina	4	2	2	T	tundra, dry
Elaphrus lapponicus lapponicus	20	3	4	K,S	wet places
Patrobus foveocollis	5	1	2	R,S	wet places
Patrobus septentrionis	11	2	4	R,S	wet places
Stereocerus haematopus	6	3	4	S,T,W	wet places
Trechus crassiscapus	12	3	8	K,R,S,W	wet places
Bees					
Bombus mixtus	11	3	5	R,S,T,W	habitat generalist
Bombus sylvicola	31	3	8	K,R,S,T,W	habitat generalist
Common sawfly					
Tenthredo ungava	40	3	8	K,R,S,T,W	habitat generalist
Butterflies					
Boloria eunomia	3	2	3	R,W	wet places
Colias pelidne	23	3	5	R,S,T,W	habitat generalist

Trapping efficiency

Bee bowls and pitfall traps were successfully deployed at all 15 habitat plots, although bad weather forced us to collect all traps at one of the sites (Mont Jauffret-west) a day earlier than planned. The two types of passive traps collected very different taxa (Fig. 12). Active collecting (with net and hand) was more opportunistic, depending on available time and weather conditions when researchers were at the plot. As a result, eight habitat plots were not sampled by net and/or hand (Table 1). However, net samples at eight of the plots notably increased the total species catch for pollinators, while hand-collecting at seven plots added only one species to the total catch for predators/scavengers (Fig. 13).

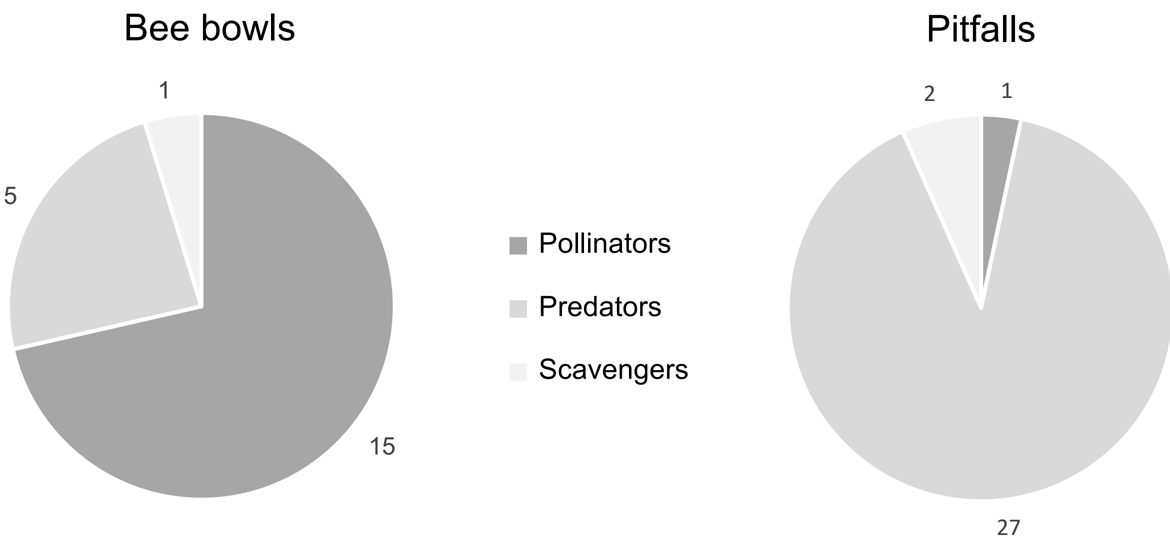

Figure 12. Proportion of total species richness represented by three functional groups collected by bee bowls (21 species total) and pitfall traps (30 species total) on the Uapishka plateau in 2014.

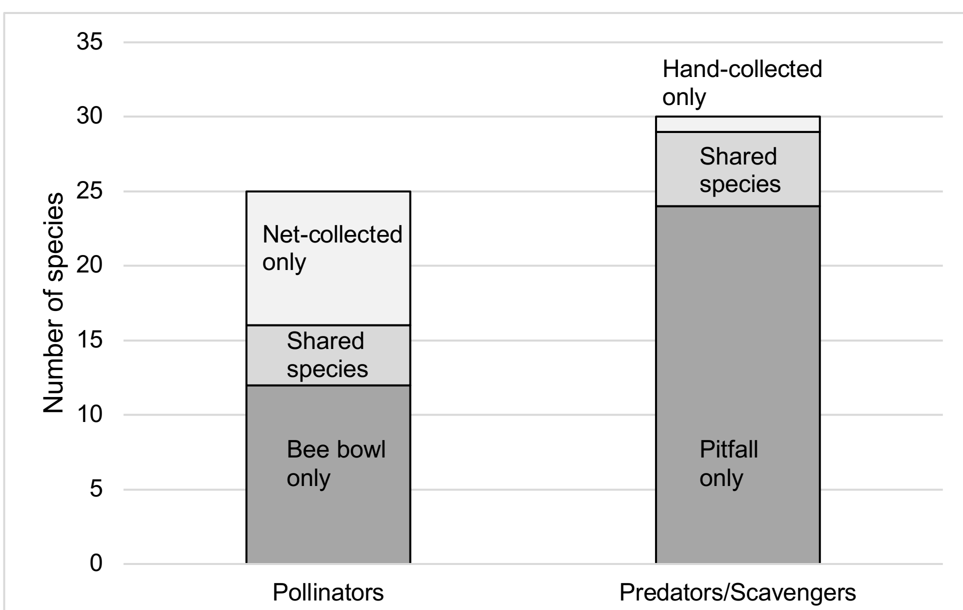

Figure 13. Number of pollinator and predators/scavenger species collected by passive trap only versus active net or hand-collecting on the Uapishka plateau in 2014.

Pitfall traps left out for 2-3 nights versus just one night collected more than 50% again as many individuals, and 25% again as many species (Fig. 14).

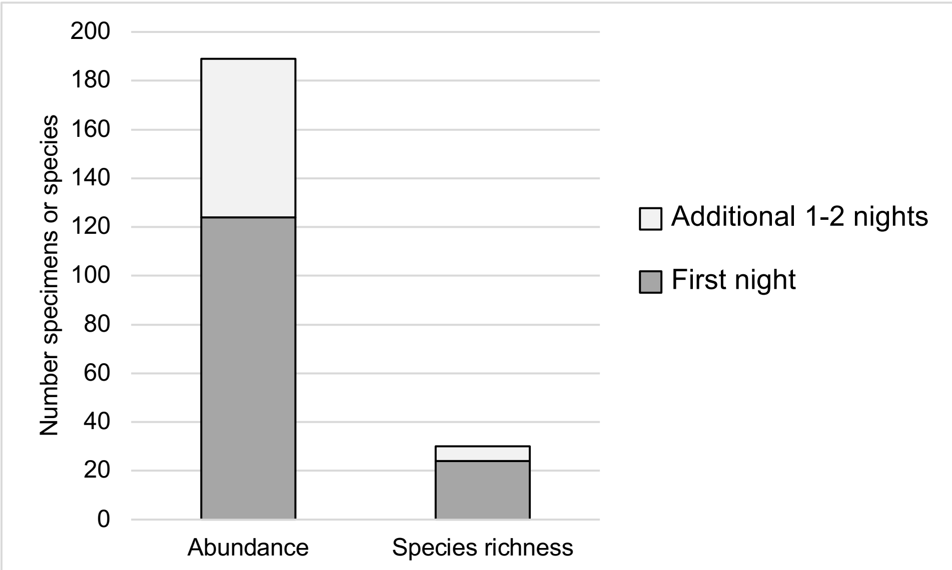

Figure 14. Gain in arthropod abundance and species richness from leaving pitfall traps open for 2-3 nights versus one night on the Uapishka plateau in 2014.

Comparison with arthropods collected in 2013

Arthropod sampling in 2013 consisted only of active net and hand-collecting for three days in early July. Of the 41 focal taxa species collected in 2013, almost half were not collected again in 2014 (Fig. 15.)

Figure 15. Numbers of arthropod species collected in 2013 in the Mont Provencher region, and/or in 2014 in the Mont Jauffret/Mont de la Tour Boissinot region on the Uapishka plateau.

Plant diversity and phenology

The following herbaceous plants were noted to be in flower at our sites during July 6-10, 2014: *Maianthemum canadense* (Canada mayflower), *Platanthera dilitata* (tall leafy white orchid), *Trientalis borealis* (starflower), *Viola* sp. (unidentified violet), *Clintonia borealis* (bluebead lily), and *Cornus canadensis* (bunchberry). Also, these shrubs: *Rubus chamaemorus* (cloudberry), *Kalmia polifolia* (bog laurel), *Phyllodoce caerulea* (mountain heath), *Vaccinium vitis-idaea* (mountain cranberry), *Rhododendron groenlandicum* (Labrador tea), *Vaccinium uliginosum* (alpine blueberry), *Harrimanella hypnoides* (moss plant), and *Salix herbacea* (dwarf willow). Narrow-leaved cottongrass (*Eriophorum angustifolium*) was also common at wetter sites. Reindeer lichens (*Cladonia stygia*, *C. rangiferina*) were a dominant component of tundra groundcover. Trees in krummholz sites were predominantly *Picea glauca* (white spruce), and dwarf birch (*Betula glandulosa*) was a common low shrub at many sites. Snowbed plots had relatively few plants in bloom.

DISCUSSION

Large-scale patterns of distribution

Among the 81 species of arthropods we collected in 2013 and 2014, a large proportion have Holarctic distributions (Appendix 1), especially among the spiders, ground beetles, flower flies, and butterflies (Fig. 16). While a few of the Holarctic species have widespread distributions across North America, Europe, and Asia (e.g., the cosmopolitan syrphid fly, *Melanostoma mellinum*, which spans Alaska, Iceland, Mexico and reaches to the Indian subcontinent!), most of the Holarctic species we collected are primarily arctic and far-northern species that also occur in northern Europe and Asia. For some of these northern species, isolated populations may also be found in northern U.S. states or further south in mountain ranges. They include species with apt names such as *Arctosa alpigena*, *Pardosa hyperborea* (wolf spiders), *Amara alpina*, *Notiophilus borealis* (ground beetles), and *Boloria polaris*, the polaris fritillary, one of only a half dozen butterfly species found on Ellesmere Island! Although quite distant from the latitudinal tree line in Quebec, the alpine nature of the Uapishka plateau (i.e., above the elevational tree line) renders it suitable habitat for many otherwise arctic species.

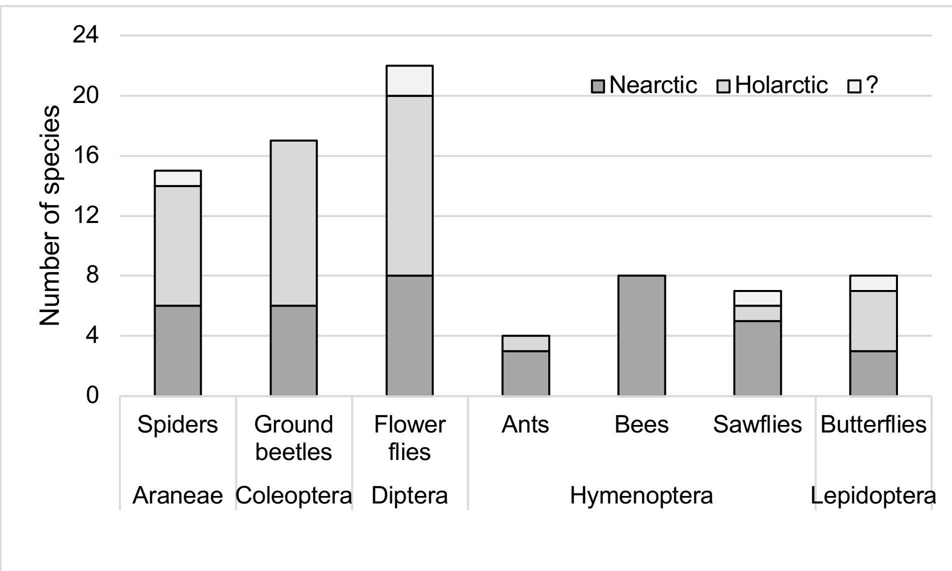

Figure 16. Number of species with Nearctic and Holarctic distributions among the focal taxa collected from the Uapishka plateau in 2013 and 2014. ? = unidentified species and/or distribution not known.

Among species we collected having a Nearctic distribution (i.e., occurring only in North America) various continental distribution patterns were represented. Many species have an exclusively northern range across Alaska and Canada, or, as with Holarctic species, may also extend into northern U.S. states or further south in mountain ranges. These include the carabid, *Pterostichus arcticola*, the wolf spiders, *Pardosa furcifera* and *P. fuscula*, the ant, *Myrmica alaskensis*, the bumble bee, *Bombus sylvicola*, and the butterflies, *Boloria chariclea and B. eunomia* (arctic and bog fritillary). Several species appear to be northeastern North American endemics: *Trechus crassiscapus*, a ground beetle; *Sericomyia bifasciata*, a syrphid fly; *Sphecodes solonis*, a cuckoo sweat bee; and *Pardosa labradorensis*, a wolf spider (also aptly named). Other species have much more widespread distributions across Canada and the U.S., including *Harpalus somnulentus*, a ground beetle which reaches south to Mississippi, and *Colias philodoce*, the clouded sulphur, which occurs throughout most of North America, but ironically, is a rare find in central Quebec. A few species have notably disjunct distributions, such as the pelidne sulphur (*Colias pelidne*) which has three widely separated populations in eastern Canada, western Canada, and the Rocky Mountains.

Notes on focal taxa and species of particular interest

Ants (Family Formicidae)

Ant diversity is low above tree line (Francoeur (1983) lists just five species in Quebec north of tree line, including three of the four species we collected on the Uapishka plateau), however, the few species that extend into the alpine zone can occur in high densities, and thus serve as an important food source for birds and mammals. All of the species we found also occur in the boreal forest where they nest in dead wood.

Camponotus herculeanus (Linneaus). Although this carpenter ant cannot venture far above tree line because it is depends on wood for nesting material, it is the most cold-tolerant ant known, able to survive temperatures below -40ºC (Ellison et al. 2012).

Bees (Family Apidae and Halictidae)

The arctic/alpine bee fauna above tree line is dominated by bumble bees (*Bombus*). We collected a northern species (*B. frigidus*) that extends south into the Rocky and Appalachian mountains, and several species that are primarily western in Canada and the U.S., but also extend to eastern provinces in Canada (*B. mixtus*, *B. melanopygus*, *B. sylvicola*). Most of the *Bombus* species were widespread across habitat types and they tend to be generalist feeders. We collected only two solitary bees, both in the halictid genus *Lasioglossum*, and also a cleptoparasitic halictid in the genus *Sphecodes*. There are undoubtedly at least a few more solitary bees and their parasites up on the plateau, but good collecting conditions (warm, calm, sunny days) were in short supply!

Bombus terricola Kirby. The range of the yellow-banded bumble bee historically extended east of the Rockies across southern Canada and the northern U.S. to the Atlantic coast, and southwards in the Appalachians to North Carolina and Tennessee. Since 1999 this species has not been seen in most of its range throughout the east, perhaps because of a fungal pathogen introduced from another native *Bombus* species that was cultured in Europe and sent back to the U.S. for commercial use in greenhouse tomato production. We collected several individuals of *B. terricola* in tundra on the Uapishka plateau in both 2013 and 2014.

Lasioglossum seillean Gibbs and Packer. This small sweat bee was only recently described by Gibbs and Packer, in 2013. It is a solitary species that nests in the soil, and is limited to high latitudes, with most records coming from eastern Canada (to Newfoundland) and one U.S. record from Michigan. It is known to favor *Vaccinium* as a host (Gibbs et al. 2013).

Sphecodes solonis Graenicher. This halictid cuckoo bee is a northeastern North American endemic, ranging as far west as the Great Lakes and north to Hudson Bay. This was the only parasitic bee species collected on the Uapishka plateau. It is a “cleptoparasite” in that females lay their eggs in the nests of other solitary bee species, and the developing parasitic larvae steal all the nectar and pollen provisions intended for the host larvae. Because cleptoparasitic bees depend on healthy populations of host bees for their own success, they can serve as good indicators of the health of the broader bee community.

Butterflies and skippers (Family Lycaenidae, Nymphalidae, Pieridae, and Hesperiidae)
Although butterflies were not originally intended to be a focal group in our survey, we were very fortunate to have Maxim Larrivée at the Insectarium de Montréal offer to identify (and catalog in e-Butterfly) all the butterflies and skippers we collected in our bee bowls.

Boloria polaris (Boisduval). We collected the polaris fritillary at one tundra site. This represents the southernmost record of this species in Quebec (M. Larrivée, pers. comm.). This Holarctic species has also been found across northern Canada and in Alaska, northern Scandinavia, Greenland, and Ellesmere Island.

Boloria eunomia (Esper). The bog fritillary, not surprisingly, was strongly associated with wet habitats on the Uapishka plateau, namely, rills and wetlands.

Colias philodice (Godart). The clouded sulphur is remarkable because of its very widespread distribution. It occurs across North America, in all states and most provinces. On the Uapishka plateau, it is reaching the northern edge of its range (see range map from e-Butterfly at www.e-butterfly.org). We collected it in all habitats with the exception of krummholz.

Flower flies (Family Syrphidae)
Many adult flower flies are bee or wasp mimics, fooling predators into thinking they can sting. They are conspicuous visitors to flowers as they feed on nectar and pollen, making them potentially easy targets for predators. There are two main subfamilies: larvae of the Syrphinae are predators on aphids and other soft-bodied insects; larvae of the Eristalinae are more varied in their habits, and include feeders of dung, decaying plant material, insect remains, fungi, vascular plant parts, and rotting wood. They become increasingly important pollinators in northern and alpine areas. The genus *Parasyrphus*, of which we collected three Holarctic species, is the most northerly genus of Syrphinae in North America, extending into the U.S. only in mountain ranges (Vockeroth 1992).

Melanostoma mellinum (Linnaeus). As mentioned in the previous section, this cosmopolitan species occurs across the northern Holarctic region but also extends south to Mexico, southern Europe, and there are records from the Indian subcontinent. There is some question as to whether more than one species is represented across the range. Interestingly, adults of the species feed on pollen from wind-pollinated plants such as grasses and sedges (Proctor et al. 1996).

Sericomyia bifasciata Williston. The aquatic larvae of this northeastern species have a breathing tube that sticks up above the water surface, allowing them to live in oxygen-poor, stagnant water in bogs or other wetlands.

Volucella facialis Williston. The larvae of this fuzzy bumble bee mimic develop in the nests of yellowjacket wasp nests, scavenging for dead larvae and other debris. Adults can be quite variable in their coloring, depending on where they occur, as they tend to mimic the common local bumble bees.

Ground beetles (Family Carabidae)
Ground beetles are a very diverse family of predaceous beetles (with few exceptions) that occupy a wide range of habitats and have often been used as indicators of habitat diversity or ecosystem health (e.g., in relation to forest management practices). Not surprisingly, the suite of species we collected on the Uapishka plateau represented a predominantly northern and alpine fauna. Several species were strongly associated with either wet or dry habitats. Carabids vary in their ability to fly, with some species (or populations) having vestigial hind wings. Six of the species we collected are likely capable of flight for dispersal, an advantage in alpine biomes. A further nine species have at least some populations with functional wings, however, flight has never been observed. The two species known to be completely incapable of flight are *Pterostichus arcticola*, an arctic-alpine species, and *P. brevicornis*, a boreal species.

Amara alpina (Paykull). We know from the Quaternary fossil record that the range of this Holarctic arctic-alpine species has expanded and contracted quite rapidly in northern Europe, Asia, and North America in response to changes in climate (including glaciation) numerous times (Ashworth 1996). This has resulted in local extirpations and also in isolation of populations on mountains, but not extinction of the species. The species has functional wings, but flight has not been observed.

Trechus crassiscapus Lindroth. This northeastern species is also known from boreal habitats, and favors wet places such as marshes and other wetlands. We found it in seven different wet habitat (i.e., rills, snowbeds, wetland edges) plots across all three sites sampled on the Uapishka plateau, making it an excellent indicator of wet habitats in northeastern alpine areas.

Sawflies (Family Tenthredinidae)
Common sawflies are a diverse and abundant group of primitive Hymenoptera, the larvae of which feed primarily on foliage. Members of the genus *Tenthredo* are predators of other insects as adults, which they often catch at flowers. Thus, they predate on pollinators, such as syrphids, but also likely consume some nectar themselves, effecting pollination as they move between flowers. Their role as pollinators has not been well studied (D. Smith, pers. comm.). Interestingly, we collected seven species (19 specimens total) of common sawflies in 2013 with our nets, and in 2014 we captured 40 individuals of just one species (*Tenthredo ungava*), all but two of which were collected in bee bowls.

Tenthredo ungava Goulet. This abundant species occurred in all five habitats, at 8 plots, but 29 of 40 specimens were collected at snowbeds. It is unknown what the larval plant host is for this species, but adults are likely generalist nectar feeders (as well as predators on small insects and other pollinators).

Spiders (Family Lycosidae and Gnaphosidae)
Wolf spiders (Lycosidae) are visual predators (i.e., they build no web) that are commonly seen during the day in open areas such as meadows, tundra, rocky outcrops, and gravel bars, although some genera are forest dwellers or subterranean to varying degrees. The genus *Pirata* is strongly associated with wet bogs and swamps (we collected it only in wetland plots). Ground spiders (Gnaphosidae) are also active hunters, but they are more secretive and mostly nocturnal, often associated with dry habitats.

Pardosa furcifera (Thorell). This was the most abundant and widespread arthropod species collected on the Uapishka plateau. We collected 40 individuals from 12 plots in all three sites, across all five habitats. This is truly a generalist species! It is reported to live below tree line in coniferous forests, as well as at and above tree line (Dondale and Redner 1990).

Pardosa labradorensis (Thorell). This Nearctic tundra-associated species ranges from Baffin Island, northern Quebec, Belcher Islands in Hudson Bay, and Labrador, to the summit of Mount Washington, NH (Dondale and Redner 1990; Koponen 1992). Thus, this species appears to be a northeastern North American endemic, unlike the other spiders we collected which are either Holarctic or range from Alaska eastwards across North America. Where this species occurs it can be quite abundant across various habitats (Koponen 1992).

Alpine arthropods as indicators of climate change

We collected several taxa that, if monitored, might serve as effective indicators of climate change. For instance, Ernst and Buddle (2015) did a structured survey of beetles across boreal, subarctic, and arctic biomes in North America and concluded that there were strong latitudinal gradients in beetle diversity and assemblage structure, and these were correlated with climatic factors such as temperature maxima and minima. They suggested that beetle communities (including ground beetles), could serve as ideal organisms for monitoring effects from climate change.

The Quaternary fossil record of one arctic/alpine ground beetle in particular, *Amara alpina* (also collected on the Uapishka plateau), has been studied to determine how ground beetles have responded to dramatic shifts in climate in the past (Ashworth 1996). Predictions based on past responses of this Holarctic species suggest that its geographic range may change quite rapidly as climate changes, and regional extirpations will likely occur in alpine areas as habitats shrink due to encroaching tree line. Additionally, more isolated populations with lower genetic diversity (e.g., in alpine areas such as the Uapishka plateau) are more likely to undergo extirpation than larger, more genetically diverse populations such as in arctic Beringia (Ashworth 1996).

Selecting known temperature-sensitive arthropod “marker species” to monitor as indicators of climate change is one of several elements suggested by Danks (1992) for long-term assessments in the arctic. In addition to arctic/alpine ground beetles, such as *Amara alpina* and *Pterostichus arcticola*, other taxonomically well-known and conspicuous arctic/alpine arthropods such as the bumble bee, *Bombus frigidus*, syrphid flies in the genus *Parasyrphus*, or wolf spiders such as *Pardosa labradorensis* would also be good candidates for marker species.

Another arthropod element that Danks (1992) includes for long-term assessments in the arctic is “limit lines” or the shift of the limits of species’ ranges, either contracting or expanding in response to climate change. Some arctic/alpine species ranges coincide with obvious environmental breaks such as tree line, for instance the carpenter ant, *Camponotus herculeanus*, is found only in very cold places around the world, but never strays far from tree line because it nests in living trees, stumps, and logs (Ellison et al. 2012). Other species may be at the northern or southern edge of their ranges due to other climatic and/or environmental cues. For instance, the polar fritillary butterfly (*Boloria polaris*) is at the southern edge of its range on the Uapishka plateau (it is also found as far north as Ellesmere Island!), while the cosmopolitan clouded sulphur (*Colias philodice*) is at the northern edge of its range. Thus, warming temperatures associated with climate change may result in northward movement of the southern limit line for *B. polaris* (i.e., range contraction) and northward movement of the northern limit line for *C. philodice* (i.e., range expansion).

In addition to spatial shifts in range, climate change may also induce temporal shifts in arthropod activity. Such shifts may result in phenological "mismatches" in interspecific dependent relationships. For instance, both pollinators and their host plants respond to temperature and other environmental cues (e.g., precipitation, snowmelt) during their development and life cycle, but it is unclear whether the timing of these cues will be affected by climate change, and if so, whether the effects will be synchronous in both plant and pollinator. Iler et al. (2103), working in the Rocky Mountains, found that at the community level, phenological synchrony was maintained between syrphid flies and their host plants even when they responded to annually variable environmental cues at different rates, however, they concluded that some individual plant species may overlap with their pollinators for fewer days under continued climate change.

Burkle et al. (2013) documented substantial changes in plant-pollinator relationships over the last 120 years in a site in Illinois (comparing new and historical data), and concluded that differential changes in phenology between plants and their pollinators explained at least some of the species and interaction losses they observed. Thus, current research suggests that monitoring the phenology of arthropod activity over time, in addition to documenting species occurrence and spatial distribution, is likely to contribute valuable information on the effects of climate change to ecosystem services in alpine/arctic environments.

Developing a protocol for rapid assessment

Efficiency of sampling methods

Pitfall traps and bee bowls are both tried and true methods for collecting ground-dwelling arthropods and pollinators, respectively (Spence and Niemalä 1994; Grundel et al. 2011). Because there is little sampler bias involved in deploying the traps, they ensure consistent collecting effort across sites or time periods, and thus are ideal for comparative or long-term monitoring studies. However, these passive traps do have biases of their own. For instance, arthropod size, activity level, and sex have all been shown to influence the "catchability" of individuals by pitfall traps (Topping and Sunderland 1992). Likewise, bee bowls are known to favor certain taxa over others (Roulston et al. 2007), with *Bombus* representing a taxon that is typically not well sampled with bowl traps. Active sampling by hand or with a net can be effective for capturing additional species at a site (Grundel et al. 2011); this was well-supported by our data, especially for bee bowls, where we added nine pollinator species to the overall catch with net samples. In a rapid assessment scenario, where time is limited, active collecting can present a challenge if the weather is unsuitable at the time the sampler is at the site (especially for temperature- and wind-sensitive taxa such as flying pollinators), whereas passive traps are typically deployed for one or more days, and thus have a higher probability of capturing a window of favorable conditions. We ran into the problem of not having enough time in the day for intensive hand and/or net-collecting at each site while also trying to deploy and maintain all the traps. Ideally, complementary passive and active sampling result in a higher diversity and abundance of arthropods than either one alone, but if time is limited and weather is unpredictable, then traps may suffice.

Bee bowls collect day-active insects, primarily, and are most often left open for one day or overnight (for convenience). Because they sit exposed on top of the ground, they can be quite vulnerable to disturbance such as wind gusts, rain, or curious vertebrates, as well as evaporation. Pitfall traps, by contrast, target many nocturnal species, and are sunk down into the ground and covered with a "roof." Pitfall traps are typically deployed for multiple nights, with less risk of disturbance by weather or animals. Thus our sampling design at each of the three sites was to set both the pitfall traps and the bee bowls on day 0, then collect the bee bowls on day 1, and the pitfall traps on day 3, requiring a total of three trips to the five plots at each site. With three sites, and fifteen plots total, this added up to 45 plot visits over five days, which is also why we had limited time for additional net and hand-collecting. Alternative possibilities for streamlining our protocol would be to leave the bee bowls out an additional two days, which would likely result in more trap disturbance, or shorten the pitfall trapping to just one night. Our results showed that the additional two nights of trapping with pitfalls yielded more than 50% additional specimens (compared with one night), and 25% more species, thus shortening the pitfall duration would cost us considerable loss of biodiversity data. Leaving bee bowls out for a longer period to sync with the timing of the pitfall traps may be the better option for increased efficiency in trap maintenance.

As our experience in early July made clear, seasonality and immediate weather patterns can also be very influential to collecting success, especially for flying insects and insects foraging on plants (i.e., pollinators). While we did encounter a diversity of plants in bloom, including several ericaceous species attractive to pollinators, it seemed we were too early to catch many of the plants typically associated with snowbeds, such as *Sibbaldia procumbens*, *Coptis trifolia*, *Salix herbacea*, and *Solidago macrophyllum* (Willey and Jones 2012). The snowbed habitat was thus likely undersampled for pollinators this early in the season. Most of the pollinators we collected are known to be generalist foragers (e.g., *Bombus* and many syrphids), and can forage from a wide variety of plants throughout the growing season, which is essential to their success in this harsh environment. Inclement weather (rain, cold, wind), which we experienced during the last few days of our field trip, has a much greater effect on flying insects than ground-dwelling insects. Many insects lose the ability to fly below a certain threshold body temperature, although bumble bees are quite well-adapted to flying in the cold by shivering their thoracic muscles and thus generating their own body heat. When insects aren't flying, they are extremely difficult to find and collect. At least one additional round of sampling later in the growing season would be ideal, both to catch the later-blooming plants (and their pollinators), and to increase the chances of collecting in fair weather.

The timing of sampling will also influence which arthropod species are collected with regard to their various life cycles. For instance, carabid beetles are typically either spring or autumn breeders, and this affects how active the adults will be at a given time of year. Since pitfall traps rely on high levels of activity for success, trapping at both ends of the growing season may be necessary for capturing a larger diversity of the alpine carabid community. Similarly, solitary bees are often quite seasonal in their activity, so collecting at different times may produce different results. Flight seasons for adult syrphid flies, butterflies, and skippers may also be limited to a short window during the relatively brief growing season in alpine areas. Thus, at least two samples spread out during the growing season would be ideal to capture a higher diversity of species for most of the focal taxa, or, if only one sample is taken to represent the sites, then the timing must be consistent at other sites or in future years, for comparative or monitoring studies, respectively. However, increased interannual variability in climatic cues such as snow melt and growing degree days associated with climate change may pose a challenge for consistent timing.

Focal taxa

We chose our focal taxa based on functional group, known diversity and abundance, and ease of sampling. Syrphid flies were a good complement to bees for the pollinator group, as their diversity is relatively high in alpine areas, while the bee fauna is limited to bumble bees (*Bombus*) and a much reduced set of solitary bees compared to lower elevations. Common sawflies (Tenthtredinidae) were also a good addition to the pollinator fauna because they were fairly abundant, widespread, and species diversity was comparable to bees if 2013 data are included. However, it may be that bee bowls are not an effective method for capturing their diversity. Butterflies and skippers were fairly abundant in the bee bowls, and provided some interesting regional information, however most lepidopterists are loathe to work with wet specimens (so we were very fortunate to find Maxim L Larrivée).

Ground beetles and wolf spiders were well-sampled with pitfalls, and for these groups there are excellent regional taxonomic keys for identification (Bousquet 2010; Dondale and Redner 1990). These two taxa also included several habitat specialists that were associated with either wet or dry habitats. We had originally intended to include rove beetles (Staphylinidae) as a focal group, but the taxonomy of these predators is extremely challenging, so they were dropped from the study. As is always the case with arthropod biodiversity surveys, reliable data depend on the availability of skilled taxonomists and/or user-friendly regional identification keys. Ants and ground spiders (Gnaphosidae) were relatively scarce in our samples, probably because they are also relatively scarce on the landscape, so these may not be ideal focal taxa for comparative or monitoring surveys.

Calypterate flies such as muscids (house flies), anthomyiids (root maggot flies), tachinids, and calliphorids (blow flies), as well as other flies, become increasingly abundant and important as pollinators in arctic and alpine habitats (Levesque and Burger 1982; Elberling and Olesen 1999). Although individual flies may carry less pollen between plants than bees or syrphids, their sheer numbers and their ability to fly in cooler, cloudier conditions make their collective contribution to pollination in harsh climates considerable. The greatest obstacle to using these groups as focal taxa in rapid assessment surveys is their extremely challenging taxonomy, and the scarcity of taxonomists with the skills (and time) needed to identify them.

Habitats

The five habitats we selected for sampling included the most common terrestrial and riparian habitats on the Uapishka plateau, with the exception of rocky substrate and cliffs, which would not be suitable for pitfall traps. Aquatic habitats such as ponds, lakes, wetlands, and streams would be another obvious component of the landscape to survey and monitor for arthropod biodiversity, however, different sampling techniques would need to be employed, and additional feeding guilds would likely be added to the focal taxa.

The five terrestrial habitats we selected varied in both mean abundance and species richness of arthropods, with krummholz yielding consistently low abundance and diversity, in part because this habitat received almost no active sampling (i.e., net and hand collecting). However, wetlands were sampled similarly sparsely and had notably higher arthropod abundance and species richness. The variance between the three plots sampled for each habitat was quite high for rill, tundra, and wetland habitats. Some of this variance was also likely due to sampling artifacts, for example, tundra habitats are prone to wind, and wind strength is highly variable day to day. Bee bowls collect very little on windy days because most flying insects (including pollinators) hunker down during these conditions. Our sampling design required us to visit tundra plots in the three sites on different days, and there was no way to control for differences in wind strength on the day that a tundra plot was sampled. These sampling protocols together with vagaries of the weather affected the success of our collecting in other habitats also. For example, the weather became so poor (wind, rain, and cold) during the end of our sampling period, that all Mont Jauffret-west (JAW) pitfall traps were closed a day early.

Our rapid assessment approach to documenting arthropod biodiversity on the Uapishka plateau was not expected to produce a complete list of arthropods occupying these five habitats. However, it is worth noting from the rarefaction curves that habitats with more samples (i.e., additional active net and hand collecting) yielded higher numbers of species, and there are many more species to be found with more sampling in *all* of the habitats, including in snowbeds and tundra. Among arthropods collected only in bee bowls and/or pitfall traps, the highest species richness was found among the ground-dwelling predators and scavengers (versus pollinators), especially in rill plots. Riparian specialists that hunt next to streams are generally a diverse guild, and at these plots included the carabid beetles, *Agonum affine*, *Trechus crassiscapus*, and *Patrobus septentrionis*, as well as the wolf spiders, *Pirata bryantae* and *Pardosa xerampelina*, all of which prefer stream edges and wet places. Wetland habitats had proportionally more pollinator species in addition to riparian ground-dwelling species.

Low turnover in species composition between pairs of habitats might suggest that including both habitats in the rapid assessment survey protocol provides redundant information. The highest similarity in species composition was between snowbed and rill habitats, which shared 13 species. All three wet habitats (rill, wetland, snowbed) were more similar to each other than to tundra or krummholz habitats, suggesting the occurrence of wet habitat specialists. The lowest community similarity was between krummholz and any other site, but this is, in part, because krummholz had so few species overall. Relatively low similarity scores for pairs of habitats overall refuted the idea that any single habitat should be dropped because of redundancy in species.

CONCLUSIONS AND RECOMMENDATIONS

- The Uapishka plateau has a high proportion of arctic/alpine species which are rarely seen further south, except perhaps in isolated alpine areas like Mount Washington in New Hampshire, but are more commonly seen further north, above the latitudinal tree line. Many of these species have Holarctic distributions, also occurring in northern Europe and/or Siberia and other parts of Asia. As so little information currently exists about the diversity and distribution of arthropods in most alpine areas of northeastern North America, these results will make a valuable contribution to establishing baseline databases.

- We did not detect any truly endemic species to the Uapishka plateau among our focal taxa, however, rarefaction analyses suggest that we have many more species yet to discover in the region. Additional sampling, especially later in the growing season, will substantially increase the known diversity.

- The focal taxa we chose to examine were sufficiently abundant and diverse to provide a "snapshot" of arthropod diversity on the Uapishka plateau. Among pollinators, it was apparent that syrphid flies were much more diverse than bees in this alpine system. Calypterate flies (i.e., black, "house fly" type flies), which were *not* included among the focal taxa, were also abundant in our samples, and it is has been observed that flies comprise an increasingly important component of the pollinator fauna in arctic and alpine systems. If it were possible to find taxonomists to identify calypterate flies, the additional data would significantly increase our understanding of eastern alpine pollinators. Likewise, we collected approximately 60 specimens of predaceous rove beetles (Staphylinidae), but lacked the expertise to identify them. This diverse group would also add valuable information to the survey.

- Pitfall traps and bee bowls proved adequate for sampling a diversity of predators/scavengers and pollinators, respectively, but net and hand-collecting were effective complementary techniques for collecting a higher diversity of species, especially larger and conspicuous species (like bumble bees, a dominant pollinator in alpine areas).

- The five habitats we sampled: krummholz, snowbed, rill/stream, wetland edge, and dry tundra had relatively little overlap of species, with the wet habitats sharing the most species. In combination, they appeared to provide a good representation of the terrestrial ecosystem in the northeastern portion of the Uapishka plateau. Sampling in these same habitats in other parts of the plateau will help elucidate if the patterns we observed are also representative of the broader alpine system.

- Because there are so many aquatic features (i.e., ponds, lakes, streams) on the Uapishka plateau (see Fig. 1), and aquatic insects are well-known taxonomically, fairly easy to sample, and already used as indicators of water quality, an aquatic insect survey would be a valuable addition to our terrestrial arthropod work.

- The sampling design we used was fairly labor intensive, requiring three visits to each of the 15 plots. One way to streamline the protocol would be to leave the bee bowls and pitfall traps out for the same number of days. Because pitfall traps collected notably more organisms over three nights than one night, it would be best to leave all traps out for three nights, even though this leaves the bee bowls, which are less protected than pitfall traps, more vulnerable to disturbance.

- Intense snowfall the previous winter likely influenced the delayed timing of flowering for snowbed plant communities on the Uapishka plateau in 2014, and points to the fact that it is difficult to predict what the seasonal climatic conditions will be like in a remote place like the Uapishka plateau, even as they are critical to predicting the phenology of the flora and fauna. Daily weather is also difficult to forecast, and has a large influence on arthropod activity. Being able to leave traps installed in the plots for a longer window of time would help mitigate the timing problem, but is impractical given the remote location. A second "snapshot" sample later in the season would certainly add more species to the database, and provide another chance to collect if the early-season sample encountered foul weather.

- The relatively few specimens of each arthropod species collected overall in such a short period of time will make it difficult to statistically differentiate "noise" (due to natural interannual variability) from actual trends related to anthropogenic disturbance (such as climate change) in a monitoring program. However, some suggestions for possible metrics to monitor or to use in comparative studies include: presence/absence or abundance of species known to be at the edge of their range (e.g., butterflies *Boloria polaris, Colias philodoce*) or known to have primarily arctic/northern distributions with isolated alpine populations further south (e.g., wolf spider *Pardosa labradorensis*, ground beetle *Pterostichus arcticola*, syrphid flies in the genus P*arasyrphus*); the proportion of pollinating flies to bees (bee diversity should increase overall with warmer temperatures); the proportion of species within any of the focal taxa that have primarily northern versus more transcontinental distributions; presence/absence of non-native species (we documented none in 2013 or 2014); and, if possible, the phenology of arthropod activity at the beginning and end of the growing season.

- As we develop the protocol for the rapid assessment of arthropod diversity in eastern alpine areas, it will be beneficial to collaborate with established long-term alpine monitoring programs such as GLORIA, so that arthropod sampling can be incorporated into alpine survey and monitoring protocols on a global scale.

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Appendix 1. Number of specimens, local habitat distribution, and global/North American distribution of focal arthropod taxa collected on the Uapishka plateau in July 2013 and July 2014. Habitats: K=krummholz; R=rill; S=snowbed; T=tundra; W=wetland; ?=not noted (all 2013 samples). Global distribution: HOL=Holarctic; NEA=Nearctic. North American distribution: Trans=transcontinental, including central and/or southern U.S.; N=across Canada and northern U.S. states; E=eastern North America; NE=eastern Canada and northeastern U.S.

Family Gnaphosidae (Ground spiders)											
Gnaphosa parvula	Banks	1							x	NEA	Trans
Gnaphosa orites	Chamberlin		7				x			HOL	N
Family Lycosidae (Wolf spiders)											
Alopecosa aculeata	(Clerck)		1					x		HOL	Trans
Arctosa alpigena	(Doleschall)	1							x	HOL	Trans
Arctosa insignita	(Thorell)		4				x	x		HOL	N
Arctosa raptor	(Kulczyński)		1			x				HOL	N
Pardosa furcifera	(Thorell)	4	40	x	x	x	x	x	x	HOL	N
Pardosa fuscula	(Thorell)	8	32		x	x		x	x	NEA	Trans
Pardosa hyperborea	(Thorell)	2	11		x		x	x	x	HOL	N
Pardosa labradorensis	(Thorell)		7				x			NEA	NE
Pardosa moesta	Banks		1				x			NEA	Trans
Pardosa sp.			1		x					?	?
Pardosa xerampelina	(Keyserling)		1		x					NEA	Trans
Pirata bryantae	Kurata		1		x					NEA	N
Pirata piraticus	(Clerck)	2	11					x	x	HOL	N
ORDER COLEOPTERA (BEETLES)											
Family Carabidae (Ground beetles)											
Agonum affine	Kirby	1	7		x	x		x	x	NEA	Trans
Agonum retractum	LeConte	1							x	NEA	N
Amara alpina	(Paykull)	3	4				x		x	HOL	N
Amara hyperborea	Dejean		5				x			HOL	N
Amara musculis	(Say)		2				x			NEA	Trans
Elaphrus lapponicus lapponicus	Gyllenhal		20	x		x				HOL	N
Harpalus nigritarsis	C. Sahlberg		2		x					HOL	N
Harpalus somnulentus	Dejean		1			x				NEA	Trans
Nebria gyllenhali castanipes	(Kirby)		1			x				HOL	Trans
Notiophilus borealis	T. Harris	1	1				x		x	HOL	N
Patrobus foveocollis	(Eschscholtz)		5		x	x				HOL	N
Patrobus septentrionis	Dejean		11		x	x				HOL	N
Platynus mannerheimii	(Dejean)	1							x	HOL	N
Pterostichus arcticola	(Chaudoir)	3	1				x		x	NEA	N
Pterostichus brevicornis	(Kirby)		2	x			x			HOL	N
Stereocerus haematopus	(Dejean)	2	6			x	x	x	x	HOL	N
Trechus crassiscapus	Lindroth		12	x	x	x		x		NEA	NE

Taxon	Authority	No. specimens 2013	2014	Habitat K	R	S	T	W	?	Distribution Global	N.Am.
ORDER DIPTERA (FLIES)											
Family Syrphidae (Hover or Flower flies)											
Cheilosia orilliaensis	(Curran)	4	2		x		x		x	NEA	N
Chrysosyrphus frontosus	(Bigot)		1				x			NEA	Trans
Chrysotoxum flavifrons	Macquart	1							x	NEA	Trans
Dasysyrphus intrudens	(Osten Sacken)	1							x	HOL	Trans
Dasysyrphus venustus	(Meigen)	1							x	HOL	Trans
Eristalis anthophorina	(Fallén)	1							x	HOL	Trans
Eristalis flavipes	Walker		1			x				NEA	Trans
Lapposyrphus lapponicus	(Zetterstedt)		4		x	x	x			HOL	Trans
Melangyna arctica	(Zetterstedt)	1							x	HOL	Trans
Melangyna labiatarum	(Verrall)		1							HOL	N
Melanostoma mellinum	(Linnaeus)	3	2				x		x	HOL	Trans
Parasyrphus nigritarsis	(Zetterstedt)		1			x				HOL	N
Parasyrphus relictus	(Zetterstedt)	3							x	HOL	N
Parasyrphus tarsatus	(Zetterstedt)	6	3			x	x		x	HOL	N
Platycheirus parmatus	Rondani	1							x	HOL	Trans
Platycheirus sp.		1	1				x		x	?	?
Platycheirus thylax	Hull		1							NEA	Trans
Sericomyia bifasciata	Williston	1	4	x			x	x	x	NEA	NE
Sphaerophoria sp.		1							x	?	?
Syrphus torvus	Osten Sacken	3							x	HOL	Trans
Trichopsomyia apisaon	Walker		1					x		NEA	Trans
Volucella facialis	Williston		3	x	x		x			NEA	?
ORDER HYMENOPTERA (WASPS, BEES & RELATIVES)											
Family Apidae (Bumble bees and relatives)											
Bombus frigidus	Smith	13	6		x	x	x		x	NEA	N
Bombus melanopygus	Nylander		6		x	x	x			NEA	Trans
Bombus mixtus	Cresson	1	11		x	x	x	x	x	NEA	Trans
Bombus sylvicola	Kirby	18	31	x	x	x	x		x	NEA	Trans
Bombus terricola	Kirby	3	1				x		x	NEA	E
Family Formicidae (Ants)											
Camponotus herculeanus	(Linneaus)	4							x	HOL	Trans
Formica neorufibarbis	Emery	7							x	NEA	Trans
Myrmica alaskensis	Wheeler		100's					x		NEA	N
Myrmica detrinodis	Wheeler		3		x					NEA	Trans
Family Halictidae (Sweat bees and parasites)											
Lasioglossum inconditum	(Cockerell)		1			x				NEA	Trans
Lasioglossum seillean	Gibbs & Packer	1							x	NEA	Trans

Taxon	Authority	2013	2014	K	R	S	T	W	?	Global	N.Am.
Family Tenthredinidae (Common sawflies)											
Arge cyra	(W.F. Kirby)	1							x	NEA	Trans
Pachynematus corniger	(Norton)	1							x	NEA	E
Pristiphora cincta	Newman	1							x	HOL	Trans
Tenthredo leucostoma	Kirby	1							x	NEA	Trans
Tenthredo originalis	(Norton)	6							x	NEA	N
Tenthredo sp.		2							x	?	?
Tenthredo ungava	Goulet	7	35	x	x	x		x	x	NEA	N
ORDER LEPIDOPTERA (BUTTERFLIES AND MOTHS)											
Family Hesperiidae (Skippers)											
Pyrgus centaureae	(Rambur)		10			x	x	x		HOL	N
Family Lycaenidae (Blues, coppers, and relatives)											
Plebejus glandon	(de Prunner)		2				x			HOL	Trans
Family Nymphalidae (Brushfooted butterflies)											
Boloria chariclea	(Schneider)		1					x		HOL	N
Boloria eunomia	(Esper)		3		x			x		NEA	N
Boloria polaris	(Boisduval)		1				x			HOL	N
Family Pieridae (Whites, sulphurs, yellows)											
Colias pelidne	(Boisduval & LeConte)		23		x	x	x	x		NEA	N
Colias philodice	(Godart)		1					x		NEA	Trans
Colias sp.			2				x			?	?