Impacts of Vegetation Change in the Canadian Arctic: Local and Regional Assessments

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Abstract

The tundra across the Canadian Arctic is already reacting to climate change. Northerners and scientists are observing changes, such as shrubs getting taller and more numerous. The taller shrubs catch more snow, and change the depth and pattern of snow drifting, which could affect travel and caribou migration. Increases in the cover of shrubs will also result in more sunlight being absorbed by the leaves and this will increase the temperature even further. We study these changes near Arctic communities across the North. Community members are involved in designing the studies and in conducting measurements on tundra vegetation. An important focus of the project is the measurement of changes in amounts of berries produced each year in traditional berry picking areas near the communities. Experimental studies including warming with small open-top greenhouses and altering snow deposition with snow fences have been established to determine effects on vegetation, especially berry shrubs. We also study the insects that pollinate the berry flowers, which is crucial for berry production. These studies have been incorporated into science studies in the local high schools and used to show students how traditional ecological knowledge and scientific studies can be used together. The results will be used in the communities and will contribute to national and international efforts to understand the responses of tundra ecosystems to climate variability and change.

Key Messages

- Our group continues to engage Inuit communities across the Canadian Arctic, emphasizing education and research partnerships.
- Thematic posters and a synthesis book on Inuit observations of climate change (for 8 communities) are complete and are being prepared for translation. We anticipate publication of these materials by fall 2013.
- An encyclopedic dictionary of berry ecology in Inuinnaqtun is being developed for the Kitikmeot region, Nunavut.
- Pollinators active on blueberry flowers (Vaccinium uliginosum) vary across the tundra sites studied. Bumble bees were important in Nunatsiavut but rare at Baker Lake and Alexandra Fiord. In the northern sites, flies (from the sub-order Brachycera)were the most abundant group observed on blueberry flowers.
- Antioxidant capacity was highest in berries of *Empetrum nigrum* (crowberry) followed by *Vaccinium vitis-idaea* (redberry) and *Vaccinium uliginosum* (blueberry).
- Berries from experimentally warmed plants have lower antioxidant capacity than berries in control plots. This in line with our hypothesis that berries from plants in warmer temperatures will have lower phenolic compounds (which protect against photoinhibition/photodamage) and thus lower antioxidant capacity.
- A new environmental monitoring program Avativut was established in thirteen of the fourteen communities of Nunavik in collaboration with Kativik School Board. The program involves high school students monitoring vegetation and berry shrubs and ice phenology. Forty (40) new permanent plots for vegetation and berry production (20 m X 20 m) were established.
- The Ice phenology program of Avativut is established as a pilot project in Kuujjuaq this winter and will expand to Kuujjuarapik/ Whapmagoostui in the spring.
- Video vignettes have been shot in Kangiqsujuaq to better illustrate the scientific protocols related to berry monitoring. They will be put online on the Avativut Website Winter 2013.
- Two books outlining plant identification and uses among the Inuit in Nunatsiavut have been published: one of which is now for sale to support local education efforts and to supply the tourism industry with a book on the area (e.g., Torngat Mountains National Park, Nunatsiavut).

- Nunatsiavut community leaders in Nain, Rigolet, and Goose Bay have partnered with our group work towards a community development project involving cultivation of *Rhodiola rosea* for market.

Objectives

General Objectives

- Determine changes in vegetation near Arctic communities using scientific studies and Inuit traditional knowledge (IQ) and establish permanent monitoring studies linked to communities;
- Document the ecology of the main berry species used by Inuit across the Canadian Arctic and determine their responses to experimental and observed environmental change;
- Contribute to national and international research on vegetation changes in the Arctic to better understand the effects of short-term climatic variability and long-term trends on Arctic berry plants;
- Contribute to studies of pollinating insects in the Arctic such as the NSERC CANPOLIN network;
- Generate relevant bio-climatic indicators to support vegetation studies and modelling efforts;
- Develop a network of community researchers using scientific studies and IQ to maintain a sustainable community-based environmental monitoring program assessing climate change impact on vegetation, particularly on berry productivity and shrub growth;
- Stimulate local student interest in science, math and technology and traditional knowledge (IQ) through hands-on activities and contribute to local capacity-building,
- Leave a legacy of studies in communities that will continue to be supported within the communities by local and regional organizations.

Specific objectives for 2012-2013

Nunavik

- Submit scientific papers on TEK interviews on environmental changes in Nunavik;
- Implement the environmental monitoring program Avativut, on vegetation and berry production, with the schools throughout Nunavik and the Kativik School Board;
- Produce outreach for Nunavik students from the data they collected on berry productivity.

Nunavut

- Complete berry ecology and insect pollination analyses at Baker Lake and Alexandra Fiord;
- Conduct student-led interviews of elders in Kugluktuk about berry ecology and terminology in Inuinnaqtun to produce a “Berry Dictionary” for the region;
- Continue berry production measurements at Daring Lake, NWT, and with students at Kugluktuk as part of their environmental summer camp;
- Establish new vegetation and berry production plots in Bloody Falls Territorial Park, Nunavut, to become part of the park’s monitoring program;
- Finalize M.Sc. theses of C. Spiech and C. Lavallée;
- Continue the production of the Qarmaarjuit documentary film.

Nunatsiavut

- Gather data on the distribution, growth, and habitat of wild populations of Rhodiola spp. in coastal ecosystems of Nunatsiavut to guide selection of appropriate cultivars for community garden trials to grow these valuable medicinal plants;

- Conduct phytochemical analysis in conjunction with field trials in order to determine the effects of environmental conditions on medicinal potency, growth, and reproductive biology of Rhodiola grown in Nunatsiavut;
- Conduct field trials near target communities to determine optimal local cultivars and growing conditions for cultivation of Rhodiola;
- Collect ethnobotanical data in Nunatsiavut communities (Nain, Rigolet, and Goose Bay) through focus groups and semi-structured interviews, to inform sound collaborative development of a community-based enterprise in early 2013;
- Facilitate the planning of a future community-based enterprise based on cultivation and harvesting of *Rhodiola rosea* that is: culturally appropriate; ecologically sustainable; and economically viable;
- Organize a community workshop for Nain to present a new book on traditional uses of plants in Nunatsiavut;
- Host a community open house in Nain to disseminate research results and discuss their implications for the community and region (fall 2013). We will also discuss future directions for this research based on community needs and goals.

Nunavik-Nunavut-Nunatsiavut

- Translate and publish the booklet " What we see! Inuit talk about environmental changes in the Arctic" and associated posters;
- Compile environmental and traditional knowledge on berries from interviews conducted from 2007-2010;
- Submit a manuscript linking Inuit observations of environmental change with recent local climate records across eight communities in Arctic Canada;
- Submit manuscript on berry plant response to 2 years of experimental warming across our network of experimental warming sites;
- Submit chapters on the ethnobotany and taxonomy of *Rhodiola rosea*;
- Submit manuscript comparing ethnobotany of Nain, Nunatsiavut and Kangiqsualujjuaq, Nunavik;
- Establish community garden trials in target communities in Nunatsiavut (Nain and Rigolet) as well as the botanical garden at Memorial University.

Introduction

Our project is focussed on impacts of climate change on vegetation near Arctic communities and the responses of the four major berry shrub species found across the Arctic. Recent syntheses of warming experiments (Elmendorf et al. 2012a) and long-term changes in tundra vegetation (Elmendorf et al. 2012b) show the that warming increases the height and growth and shrubs. These field-based studies support the increased "greenness" in the tundra region found in remote sensing studies using NDVI (Bhatt et al. 2010). These changes are also being observed by residents in the communities throughout the Canadian Arctic. Many elders and other northerners report an increase in the cover and height of shrubs, and that there are more trees in areas in the forest-tundra (Henry et al. 2012). These changes are impacting travel routes of hunters and others across the landscape. The changes will also affect the forage available for important wildlife, such as caribou and muskox.

Berry picking is an important activity in all communities and they can provide important nutritional benefits. By focussing on the berry production of four species near communities, we incorporate both scientific and traditional ecological knowledge – Inuit Qaujimajatuqangit (TEK-IQ) studies. Our project has established berry monitoring plots near 22 communities, and the monitoring is done by high school classes or by students in summer

science/TEK-IQ camps. In some communities, warming experiments are established at the berry plots to determine the impact of warming on production. The goal is to have students learn how to conduct vegetation monitoring and to learn about the changes in the vegetation and in berry production from their elders. As of fall 2012, all of the high schools in Nunavik are involved in environmental monitoring as part of their science and technology curriculum and they are using our berry monitoring protocols in this special program (Avativut: http://www.cen.ulaval.ca/avativut/en_accueil.aspx). Ultimately, we hope to have this type of environmental monitoring incorporated into the school curricula across the Arctic.

Berry production in these species depends on pollination by insects. However, we do not know which insects are the important pollinators for the shrubs (and other species) and their activity patterns. We also do not know what the impact of warming may be on the pollinating insects relative to the plants. We are conducting some of the first studies of the pollinators of these species in our research sites, connected to the CANPOLIN project across Canada.

Another potentially important species for communities in Nunatsiavut is the medicinal plant, *Rhodiola rosea*, which is native to northern Labrador. However, little is known about the basic ecology of Rhodiola populations in Labrador. The increased shading expected with the trend toward a more shrub-dominated vegetation in the Arctic (Elmendorf et al. 2012a, Myers-Smith 2011), along with the other effects of climate change, could affect plant species such as Rhodiola in unpredictable ways. The effects of climate change upon the growth and medicinal properties of Rhodiola have not been addressed (Cavalier 2009, Downing and Cuerrier 2011). Additionally, little is known about how Inuit perceive the use of their traditional knowledge within a commercial venture (Black et al. 2008, Hindle and Lansdowne 2007). Our research proposes to address these unknown aspects of the biology, medicinal properties, and response to climate change of Rhodiola in Labrador, while also investigating the attitudes towards integrating traditional knowledge with commercial enterprises in Northern Aboriginal communities.

Incorporating both scientific and TEK-IQ approaches, we aim to better understand the changes in vegetation and berry production in response to climate variability and change across the Canadian Arctic. We also hope that the set of monitoring sites in communities monitored by students will provide the long-term data required to understand the changes; and that the studies will inspire northern students to pursue careers in science.

Activities

Nunavik

- Forty (40) new permanent plots (20 m X 20 m) for berry production were established in thirteen of the fourteen communities of Nunavik for the environmental monitoring program Avativut in collaboration with Kativik School Board. These plots were characterized (slope, orientation, vegetation cover, maximum and mean height, species richness) in eleven villages. Snow depth poles and soil temperature data loggers were installed near the monitoring plots. A sign in Inuktitut, French and English has been installed near each plot to identify them as “School plot for environmental monitoring” (Figure 1). We met with local authorities in all villages to present the project and to consult about the location of the monitoring plots and devices.
- Video clips to illustrate the berry monitoring protocols for the Avativut program were shot in Kangiqsujuaq in August with the participation of Inuit students and the high school science teacher.
- The berry protocol has been now been completed by most Nunavik high schools in September-October. Where possible, maximum snow depth (in March) will also be measured on snow poles installed near the permanent plots.
- Berry abundance associated with shrub cover

increase at Umiujaq is being investigated in collaboration with vegetation mapping and permafrost degradation projects in ArcticNet.

- UQTR and INRS have been invited to the Québec Aboriginal Science Fair to be held in Kuujjuaq in March 2013. Gérin-Lajoie will discuss with Nunavik science teachers and students about the Avativut project, present hands-on scientific demos and act as a representative for the Centre d'études nordiques.
- Charlène Lavallée submitted her M.Sc. thesis, evaluations were completed, and final submission expected in the spring.

Nunavut

- Berry productivity monitoring in collaboration with J. Carpenter and Environmental Technology Program (Nunavut Arctic College) in Iqaluit has continued.
- Berries were collected around Pond Inlet by a student (Nicolas Bradette) coming out of the Bylot Island Research camp.

Figure 1. Sign posted at each of the permanent monitoring plots used in the Avativut program for high schools in Nunavik.

- Data analyses were completed for the berry project at Baker Lake. Sylvie Ferland is currently writing her thesis. Marilie Trudel completed an Honour's thesis on insect activity associated with Vaccinium uliginosum and presented her results at the ArcticNet ASM in December.
- Berry productivity near Kugluktuk was measured by Sarah Desrosiers, for her M.Sc. research, with high school students involved in a summer environmental/traditional knowledge camp. Sarah helped teach plant identification and basic vegetation monitoring as part of the summer program.
- S. Desrosiers also conducted winter field work in late January, 2013 with the high school students to measure snow conditions and surface temperatures in the berry plots at Kugluktuk.
- Three sessions were held in Kugluktuk in August where high school students learned to interview their elders to learn Inuinnaqtun terms for berry shrubs, berry phenology, flavours, uses and stories. A final session was held at the high school in late January, 2013. S. Desrosiers facilitated and recorded the sessions and the results will be published in an Inuinnaqtun/English "Berry Dictionary" for use by the community in education programs.
- Berry and vegetation data were collected in long-term monitoring plots and experimental warming plots at the Alexandra Fiord research site, Ellesmere Island, and at the Daring Lake research station, NWT.
- Pollinator activity and identification studies were conducted by Sam Robinson for his M.Sc. project at Alexandra Fiord, Ellesmere Island. Automatic cameras were established over flowers in warmed and control plots to capture visitations by insects.
- Hand pollination and pollinator exclusion experiments were conducted by S. Robinson on three plant species to determine the potential maximum seed production and the importance of insect pollinators for seed production.

- A photographic technique to measure plant phenology and cover was tested at Alexandra Fiord by Alison Beamish for her M.Sc. research. Measurements and photographs were made in the warming experiments established in four tundra plant communities.
- Gérin-Lajoie has been invited to the roundtable discussion organized by ITK on research in Inuit education that will be held in Iqaluit in Feb. 2013. She will take the opportunity to bring forward potential collaboration with Nunavut Dept. of Education for an environmental monitoring program in the high schools, similar to the Avativut program in Nunavik.
- A second shooting session was held in Pond Inlet for the Qarmaarjuit Documentary film. Fournier, the cameraman, is preparing an application to Conseil des Arts et des Lettres du Québec and le Conseil des Arts du Canada to obtain funds for the filming, editing and post-production. A third session is planned for end of March or April 2013.

Nunatsiavut

- Laura Siegwart Collier continued her Ph.D research in Nain and Saglek, Nunatsiavut in July-Au¬gust 2012. Activities included: harvesting berries, retrieving soil nutrient probes and downloading/re-launching soil temperature data loggers in experimental warming sites and long-term berry monitoring plots
- Maintenance was performed on the warming experiments using OTCs at our long-term monitoring site within Torngat Mountains National Park.
- We continued to partner with Parks Canada to establish vegetation monitoring plots in their target watershed in the McCormick Valley in July 2012.
- Vanessa Mardone started her Ph.D thesis research in Nain and Rigolet, Nunatsiavut between July-August 2012. Activities included: 1) sampling of coastal populations of *Rhodiola rosea*; 2) established Rhodiola garden trials in Nain and Rigolet; 3) initiating contact with community partners; and 4) established a multi-site common garden for Rhodiola populations in partnership with Memorial University Botanical Garden.
- Coastal populations of Rhodiola were sampled to compare above and below ground biomass of plants from the north (Nain) and south (Rigolet) of Labrador. Dry samples will undergo phytochemical analysis for medicinal constituents in 2013.

Nunavik-Nunavut-Nunatsiavut

- Texts for the booklet and posters on “Inuit observations of environmental changes across 3 regions of the Canadian Arctic” were completed. We are now actively engaged in fund raising for the translation and publication phases.
- Samples from six berry species from 15 different sites from the Canadian Arctic were harvested from 2008 to 2012. Harvests were made from warming experiments in some sites. We used the DPPH assay in order to assess antioxidant properties of a number of samples and conducted a 3-way ANOVA to determine differences in antioxidant potential among sites, years, and species.
- More assays will be performed in January 2013 and new, more robust, statistical tests will be generated to further understand the impact of climate change on berry quality and thus health of Inuit people in the Canadian Arctic.

Results

Antioxidants

- Samples from six berry species from 15 different sites from the Canadian Arctic were harvested

from 2008 to 2012. Results so far have shown that Empetrum nigrum (crowberry) samples possess the highest antioxidant capacity, followed by Vaccinium vitis-idaea (redberry) and Vaccinium uliginosum (blueberry).

- A 3-way ANOVA of differences in antioxidant potential among sites, years, species indicated there was no significant difference, although years or sites alone did show significant differences. We will resume the bioassays in 2013 and finalize our analysis and results.
- Berries from warmed plots (OTCs) had lower antioxidant capacity than berries taken from control plots. This supports our hypothesis that berries from plants in warmer temperatures will have lower concentrations of phenolic compounds (which protect against photoinhibition/photodamage) and thus lower antioxidant activity. In January, 2013 more assays will be performed and new, more robust, statistical tests will be used to further understand the impact of climate change on berry quality and thus health of Inuit people in the Canadian Arctic.

Pollinators

- Insect activity in Baker Lake correlated with weather conditions with few insects observed during rainy days and when temperatures were below 10 °C. For the same sampling effort, insect activity was 7 time higher during daytime than at night (Figure 2) when temperature rarely raised above 10 °C even if the sun was present.
- An algorithm for searching through photos from automatic cameras for insect visitation to flowers was developed by Sam Robinson and is in final

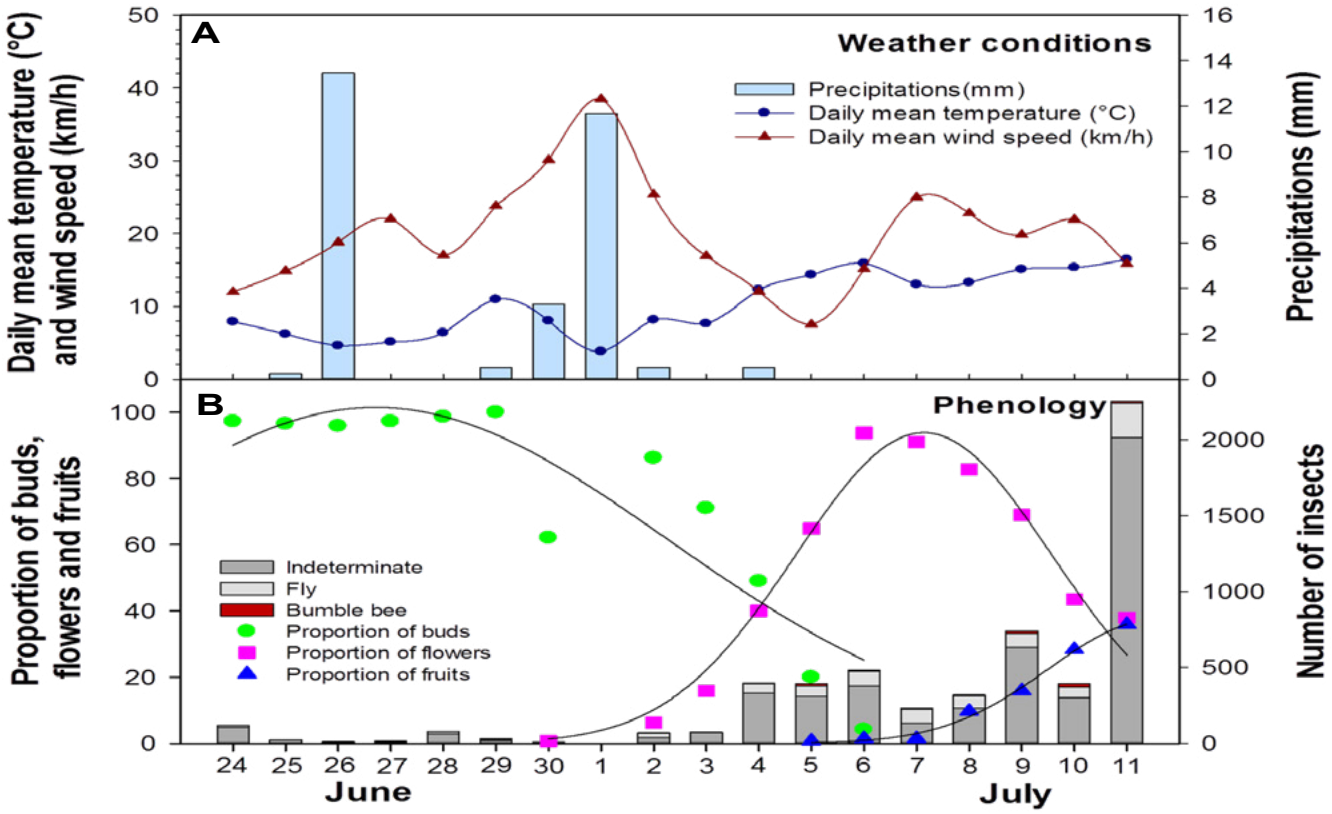

Figure 2. Weather conditions, insect visitation rates and flower phenology of Vaccinium uliginosum at Baker Lake, Nunavut in 2012.

stages of testing. The algorithm was presented at the ArcticNet ASM in Vancouver.

- In 2011, insect activity at Baker Lake coincided with blueberry flowering with a dramatic increase in the number of insects visits from ≈50 to ≈500 visits per day.
- As observed in other plots at Baker Lake, <7 % of monitored flowers produced berries. Similar proportions were found at Alexandra Fiord.
- A small proportion of insects were observed on flowers (251 out of 5187) with only one bumble bee at Baker Lake. Flies, mostly from the sub-order Brachycera, were dominant (47 %); more than half the insects remained indeterminate as they were too small to be identified on pictures. Flies are likely involved in the pollination ecology of blueberries at Bake Lake.
- Flies were also found to be the dominant group on flowers at Alexandra Fiord. Bumble bees were common, although not commonly observed on blueberry flowers.

Phenology, Vegetation and Berry Production

- A greenness index developed using pixel colours from digital photos of vegetation in warmed and control plots in three plant communities at Alexandra Fiord correlated very well with measured phenology in the same plots. The next step is to identify individual plants and follow their leaf and flower phenology through the season in the photographs.
- After two years of experimental warming in the Nunatsiavut sites, we are observing changes in deciduous shrub/berry plant structure and fruit production. Variation in fruit production with warming may be linked to increases in dwarf birch height, indicating a threshold response.

Outreach

- Posters and booklet texts on “Environmental Changes Observed by Inuit” are finished. The Nunatsiavut government has agreed to translate the appropriate booklets into Nunatsiavut Inuktitut. A grant application will be submitted to the Nunavut Dept, of Language and Culture for the Nunavut dialects (Baffin syllabic, Kitikmeot roman orthography and Inuinnaqtun). Discussions are ongoing with Avataq for the translation in Nunavik syllabic. French translations will be completed within our group.

School projects

- The Berry Learning and Evaluation Situation (LES) has been launched in all Nunavik High Schools. The Ice LES is actually tested as a pilot project in Kuujjuaq. Funding was obtained to develop new permafrost LES in collaboration with Michel Allard (U. Laval).
- Twelve video clips associated with the berry LES have been produced to better explain the protocols and abstract concepts (e.g., productivity, random sampling) for the Nunavik teachers and students. They will be posted on the Avativut Website this winter.
- The Website Avativut is fully operational and the students have begun to enter their data. The web forum has also been used by teachers when they had questions about the Berry monitoring program. http://www.cen.ulaval.ca/avativut/en_accueil.aspx
- We have been invited by Kativik School Board to attend the Quebec Aboriginal Science Fair held in Kuujjuaq in March 2013. We will discuss the Avativut project with teachers and students.
- Student led interviews with elders in Kugluktuk were completed in late January, 2013 (Figure 3). The interviews involved students learning names and words for morphology, phenological stages, uses and stories of berry shrub species in the Kugluktuk region. The interviews will be used to produce a Berry Dictionary, to be published in English and Inuinnaqtun.
- We have been identified as “someone whose experience in research and education in Inuit Nunangat can make a valuable contribution to the

roundtable discussion" organized by ITK and the Amaujaq Centre on the future of research in Inuit held in Iqaluit in Feb. 2013. José Gérin-Lajoie will attend the workshop.

Figure 3. A group of elders and high school students in the Kugluktuk high school during the student-led interviews in August, 2012 to learn Inuinnaqtun terms/words for berry plants, their morphology, the phenology of flowers, leaves and berries, and stories and songs about berry picking. (Photo by S. Desrosiers).

Inuit knowledge

- Multivariate analysis of interview responses was used to examine patterns of Inuit experience with recent environmental change. Consensus on observations within and among communities' ranged from strong to weak, depending on the type of natural resource considered. Direction of change in recent climate was similar for many communities, however the magnitude was different. Many of the environmental changes experienced correlated strongly with recent (1, 5 and 10 years before interviews) climate change. Overall, environmental change appears to be locally driven, as we did not detect clear east-west gradients or latitudinal patterns in community responses with respect to climate variables.
- Although Inuit of Nain and Kangiqsualujjuaq use similar range of plant species (43 species), they use the same plants for different purposes.
- Ethnoecology has provided over 1400 entries of words used to depict and describe Inuit environment. Many words are intimately connected to Inuit traditional activities.
- Elders of Kugluktuk worked together to recall Inuinnaqtun words to describe phenology and anatomy of berry shrub species during interviews with high school students.

Rhodiola rosea

- Rhodiola rhizome biomass was found to be greater in southern populations (Rigolet) than northern populations (Nain), particularly in sandy and organic substrates.
- Rhodiola rhizomes in coastal Nunatsiavut populations show new evidence of weevil infestation (*Dryocoetes krivolutzkajae*) and some infestation by eriophyoid bud mites (*Aceria rhodiolae*).
- There is evidence of hermaphrodites among wild Rhodiola populations in Nunatsiavut.

Discussion

Our berry ecology studies continue to show the importance of local environmental factors on berry productivity (Tolvanen 1995, Krebs et al. 2009, Henry et al. 2012). We have found important variability in the productivity of the four focus species among the sites and between years (Henry et al. 2012). The variability in production in both space and time will require long-term data, and our 2012 data adds the fifth year for some sites in a growing data set from communities and other research sites across the Canadian Arctic. Our planned synthesis of the production data will examine patterns in more detail.

New antioxidant capacity data for berry samples from across the Canadian Arctic showed that *Empetrum*

nigrum (Blackberry) had the highest capacity among the four species, but there was little difference among sites and years for all species, indicating that people can count on the nutritional value of these berries. Warmed plants had lower antioxidant capacities, which we expect is due to the lower production of phenols and other secondary compounds by these species under ameliorated conditions (e.g. Tolvanen and Henry 2001).

One of the important factors in berry production is the availability and success of pollinators (Usui et al. 2005), yet which insect species act as pollinators varies greatly among sites. Bumble bees, known to be good pollinators of bell-shaped flowers such as those of the four berry producing species, were abundant in Nunatsiavut but rarely observed on blueberry plants in Baker Lake and Alexandra Fiord (Nunavut). Our results are showing that smaller flies are important as pollinators, at least for blueberry (*Vaccinium uliginosum*), and that there may be a shift to greater reliance on flies with latitude. The low ratio of berries to flowers for blueberry is likely due to the lack of pollinators, and we are investigating this in the other species. Our admittedly restricted data shows no mismatch between flowering phenology in blueberry and temporal dynamics of the insects. We are continuing this research and determining the effect of experimental warming on both the shrubs and the abundance and diversity of pollinating insects.

One of our original objectives was to have the community-based monitoring studies included in the curriculum of the local schools. As a result of our work with Nunavik communities, community-based environmental and TEK-IQ data (berries, snow, ice and climate) will now be collected over the long-term with standard protocols through high schools of all 14 communities in Nunavik with the collaboration of the Kativik School Board. The environmental monitoring program (Avativut) has been implemented in 11 of the 14 communities during the 2012-2013 school year. Berry production and vegetation monitoring has been established and will be followed by monitoring of snow depth and phenology next year, and a program on permafrost is in development. TEK-IQ data such as observations on seasonal characteristics, berry production and ice characteristics are included in the monitoring. All these data will be stored in a validated database on a specifically designed web site for the Avativut program (http://www.cen.ulaval.ca/avativut/en_accueil.aspx). We received funds (January 2012) from the PromoScience Program (NSERC) in a joint application with INRS-ETE to continue the development of the website and build the database. Once fully operational, the web site will allow teachers and students to access the data from across the communities to use in science and TEK-IQ studies, and to see the variability in the environment across Nunavik. The government of Nunavut has also approached us to show how the program will work in Nunavik, and we are hopeful a similar program will be created for Nunavut. The berry monitoring protocols for the Avativut program in Nunavik and the tutorial video clips and the Avativut Website constitute major realizations aiming to better involve the Inuit in the monitoring of their environment. We hope to contribute to the interest of Inuit Youth for environmental sciences and TEK-IQ. This is exactly the type of legacy we hoped for in our project.

Conclusion

Our research to date has shown the importance of local factors in the productivity of berry shrub species across the Arctic. Bumblebees are important pollinators of the shrub species in the southern sites (Nunatsiavut) but are replaced by small flies in the northern sites. Linking these studies to experimental warming studies will allow us to better understand the potential effects of climate change on both the shrub and important insect pollinator species.

The nutritional quality (antioxidant capacity) of the berries varied among species, but not among sites or years. Warming appears to reduce the antioxidant capacity.

We will expand our studies to include the medicinal plant *Rhodiola rosea* and its responses to

environmental change in Labrador/Nunatsiavut. The species may have potential to be cultivated and could form the basis of a small, sustainable industry for Nunatsiavut communties.

Involving students in communities in environmental monitoring was one of our most important objectives, as this is seen to be an effective method for developing an interest in science and the link to TEK-IQ among northern youth. As a result of our work, the Kativik School Board for Nunavik has adopted our methods and project ideas and established a new envi¬ronmental monitoring section in the school curriculum that started in autumn 2012. We hope to expand this type of program to the other Inuit territories, starting with Nunavut.

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Inuit and Northern Governments and Organizations:

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- Institut culturel Avataq
- Northern Village of Kangirsujuaq
- Kangirsujuaq Land Holding Committee
- Northern Village of Quaqtaq
- Northern Village of Kangirsualujjuaq
- Northern Village of Umiujaq
- Hamlet of Pangnirtung
- Hamlet of Pond Inlet
- Nunatsiavut Government
- Nain Inuit Community Government
- kANGIDLUASUk Student Intern Program
- Labrador Inuit Development Corporation
- Nunavut Department of Education
- Nunavut Department of Environment
- Nunavut Department of Culture, Language, Elders and Youth
- Nunavut Inuit Heritage Trust
- Hamlet of Baker Lake
- Hamlet of Kugluktuk

Academic Institutions:

- Arctic College in Iqaluit (Nunavut)
- Nunavut Research Institute
- Memorial University of Newfoundland; Labrador Institute
- Université de Montréal
- Jardin Botanique de Montréal/ Institut de recherche en biologie végétale
- Université du Québec à Trois-Rivières
- University of British Columbia
- Centre d'études nordiques
- Institut national de la recherche scientifique, Centre Eau, Terre Environnement
- Université Laval

Government Agencies and Funding Bodies

- ArcticNet NCE
- Parks Canada Agency (Torngat Mountains National
- Park; Sirmilik National Park)
- Health Canada
- Aboriginal Affairs and Northern Development Canada (NSTP)
- NSERC

- FQRNT
- CANPOLIN
- Natural Resources Canada (Polar Continental Shelf Program)
- NovaScience (MDEIE, Gouv. Québec)
- Agence spatiale canadienne (Gouv. Canada)
- Ministère du Développement économique, de
- l'Innovation et de l'Exportation du Québec (Programme NovaScience)

Industrial Partners

- First Air
- Agnico-Eagle Mines

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