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 absorbed by the leaves and this will cause more warming. The warmer climate will also affect the growth and production of berry shrub species. 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 research partnerships linking science and Inuit Qaujimajatuqangit (IQ) and education.
- Our community-based and inspired research has helped to establish the first environmental monitoring program in all 14 communities in Nunavik. The program, Avativut, was established in collaboration with Kativik School Board and involves high school students monitoring vegetation and berry shrubs and ice phenology and permafrost.
- Providing opportunities for youth and elders to spend time on the land together deepens their connections, and greatly enriches the appreciation of the link between scientific studies and traditional knowledge. We continue to work with communities to provide these opportunities through “land camps”, “plant walks” and outdoor school activities, and to record some of the trips on video.
- Important syntheses will be thematic posters and a book on Inuit observations of vegetation and climate change for eight communities. Manuscripts are complete and are being translated, and we anticipate publication in autumn 2014.
- A book of berry ecology with stories and recipes in Inuinnaqtun and English is under production for the Kitikmeot region, Nunavut.
- Berry production in four species has been measured in communities by community-researchers (mainly high school students) across the Canadian Arctic since 2008. We have berry and vegetation data from 22 communities and two research stations, which is the largest such network in the Arctic nations. A synthesis of these data are a high priority and will be the first to examine spatial and temporal variability in berry production.
- 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 and thus lower antioxidant capacity.
- 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).
- The potential for commercial cultivation and development of natural health products from *Rhodiola rosea* continue to be explored with Nunatsiavut community leaders in Nain, Rigolet and Goose Bay.

Objectives

General (overall objectives)

- Determine changes in vegetation near Arctic communities using scientific studies and Inuit traditional knowledge (IQ) and establish permanent monitoring studies with communities.
- Study 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 through hands-on activities in the field and contribute to local capacity-building.
- Leave a legacy of studies that will continue to be supported within the communities by local and regional organizations.

Specific objectives for 2013-2014

Nunatsiavut

- Continue monitoring of berry productivity, vegetation and experimental plots near Nain with community-based researchers and in Torngat Mountain National Park with Parks Canada staff.
- Continue to study the distribution, growth, and habitat of wild populations of *Rhodiola rosea*. in coastal ecosystems of Nunatsiavut to guide selection of appropriate cultivars for community garden trials to grow these valuable medicinal plants
- Monitor and expand community garden trials of *Rhodiola* in target communities in Nunatsiavut (Nain and Rigolet) as well as the botanical garden at Memorial University to help determine optimal local cultivars and growing conditions for cultivation of *Rhodiola.*
- Complete 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.
- 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

- Develop and submit a business plan to the Nunatsiavut government for a community-based enterprise based on cultivation, harvesting and processing of *Rhodiola rosea*.
- Complete a book chapter manuscript on *Rhodiola* in Labrador.
- Host a community open house in Nain to disseminate research results and discuss their implications for the community and region, and future directions for this research based on community needs and goals.

Nunavik

- Complete the implementation of the environmental monitoring program Avativut, on vegetation and berry production, ice phenology and permafrost in the schools throughout Nunavik with the Kativik School Board.
- Develop video and web-based resources on methods for environmental monitoring for the Avativut program.
- Produce outreach for Nunavik students from the data they collected on berry productivity.
- Explore the perceptions and experiences of the students involved in the outdoor monitoring through the Avativut program and in the context of other environmental and cultural initiatives.
- Submit scientific papers on TEK-IQ interviews on environmental changes in Nunavik.

Nunavut

- Continue student-led interviews of elders in Kugluktuk about berry ecology and terminology in Inuinnaqtun and gather stories and recipes to produce a bilingual "Berry Book" for the region.
- Establish new monitoring plots in Kugluk/Bloody Falls Territorial Park with the Nunavut Parks, Nunavut Dept of Environment and the Kugluktuk High School.
- Continue training high school science students in berry and vegetation measurements as part of their summer Career and Technology Studies week in Kugluktuk.
- Expand the berry shrub study plots at the Tundra Ecology Research Station at Daring Lake, NWT, and introduce the study to high school students attending the week-long summer ecology-TEK course at the station.
- Establish new experimental warming and monitoring plots for berry production and vegetation change with Nunavut Dept of Environment biologists near Igloolik.
- Search the Oral History Project database at Igloolik for interviews with Inuit Elders for information on plant use.
- Continue berry shrub ecology, production and insect pollination studies at Baker Lake, Alexandra Fiord field station and Daring Lake.
- Complete a study on the use of digital photography to monitor tundra vegetation.
- Continue the production of the Qarmaarjuit documentary film.

Nunavik-Nunavut-Nunatsiavut

- Develop methodology for using camping trips (e.g. land camps, environmental summer camps, CTS courses) with Elders and Youth in communities to provide better opportunities for transmission of knowledge
- Translate and publish the booklet " What we see! Inuit talk about environmental changes in the Arctic" and associated community posters.
- Compile environmental and traditional knowledge on berries from interviews conducted in communities from 2007-2011.
- Complete and submit a manuscript linking Inuit observations of environmental change with recent local climate records across eight communities in Arctic Canada.
- Complete data analysis and a manuscript on berry plant response to two years of experimental

warming across our network of experimental warming sites.

- Complete chapters on the ethnobotany and taxonomy of *Rhodiola rosea* throughout its range in northern Canada.
- Complete a manuscript comparing ethnobotany of Nain, Nunatsiavut and Kangiqsualujjuaq, Nunavik.
- Begin compilation and analysis of berry production in relation to climate and local environmental factors from all community-based monitoring plots across Arctic Canada.

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. Since 2008, 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 2013, 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. 2012; 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 (Cuerrier and Arnason 2008, Black et al. 2008, Hindle and Lansdowne 2007). We will 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

Nunatsiavut

- Fieldwork completed by Laura Siegwart Collier in July-August for her PhD research in Nain and Saglek. 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.
- Continued working with Parks Canada to establish vegetation monitoring plots and protocols in Torngats Mountain NP.
- Vanessa Mardone continued her PhD research in Nain and Rigolet during July-August 2013. Activities included: 1) sampling of coastal populations of Rhodiola rosea; 2) monitoring *Rhodiola* garden trials; 3) ethnobotanical interviews and community round table discussions with community members; 4) analyzing samples for medicinal constituents.
- Educational lectures and walks given to visitors (based on our research results) at the base camp for Torngat Mountains NP.
- Geo- referenced pictures taken of caterpillars and butterflies for assessing their distribution in Labrador (for eButterfly).

Nunavik

- All remaining permanent plots (20 m x 20 m) for berry production were established the last four of the 14 communities in Nunavik for the environmental monitoring program Avativut in collaboration with Kativik School Board. Snow depth poles and soil temperature data loggers were installed near the monitoring plots. A sign in Inuktitut, French and English was installed near each plot to identify them as “School plot for environmental monitoring”. We met with and consulted local authorities in all villages to determine location of the monitoring plots and devices.
- A interactive simulation of permafrost dynamics is being developed for the Permafrost monitoring unit in the Avativut program by a student in the Computer Technology Program from CEGEP de Trois-Rivières. This interactive tutorial will allow High school students to select multiple parameters (e.g. monthly mean air temperature, soil type, soil depth, ground cover, presence of infrastructure) and observe their influence on the soil temperature and the freezing front. It will also include pictures of the various permafrost features in the landscape and the related soil types and ice content in the ground. A first version will be tested by the students in fall 2014. Prof. Michel Allard (U. Laval) is acting as the expert advisor in this project.
- Fieldwork for a study of Inuit students’ perception of science, including the Avativut Program, will be initiated in Kuujjuarapik in February 2014. The study is an MSc project (Émilie Hébert-Houle).
- The implementation of the Avativut Program Ice Observation Unit was established in Kuujjuarapik and is now operating in eight communities in Nunavik, and will be incorporated into other communities over the next two years.
- Four instructional videos are in production to support the Ice Observation Unit in the Avativut program.

- Consultation with the Cree of Whapmagosstui and the Inuit of Kuujjuarapik was undertaken for the organization of a land camp in collaboration with the Centre d'études nordiques around the topics of northern plants uses and climate change perception.
- A five-day cross-generational and cross-cultural Land Camp was co-organized by CEN-UQTR and Whapmagoostui First Nation with a party of 18 people. The objectives were to come together, share our knowledge and learn from each other around the topics of northern plants and climate change.
- Release of the film Eeyu Cheschaaydamowin/ The Plant Gathering Project coproduced by CEN-UQTR and Whapmagoostui First Nation. The Premiere of the film was presented in Whapmagoostui in December 2013, followed by a showing at the ArcticNet Annual Science Meeting in Halfiax.
- E. Lévesque visited Kiluutaq school in Umiujaq and met with students who participated in the Avativut berry module. She presented the Avativut Program and her studies on climate change impacts, especially regarding vegetation changes such as shrub encroachment and snow-permafrost-vegetation effects.
- Observatoires Hommes-Milieux International (OHMI) (a program of Institut écologie et environment, Centre national de la recherché scientifique, France) met in Quebec City to implement an OHM in Kangiqsujuaq, as a collaboration between CNRS and CEN. Organizing a land camp in collaboration with the school and the village emerged as a central project, inspired by the Whapmagoostui experience. We are currently developing a new land camp approach to encourage traditional knowledge transmission, collaborative outdoor science and Youth expression through arts and media.
- Charlène Lavallée completed her MSc thesis : Impact de l'augmentation du couvert ligneux érigé et d'un réchauffement expérimental sur la productivité d'*Empetrum nigrum L.*, *Vaccinium uliginosum L.* et *V. vitis-idaea L.*, à Kangiqsujuaq et Kangiqsualujjuaq (Nunavik).

Nunavut:

- Discussions were held with the Nunavut Education Department for the use of Avativut Program education material. They have agreed to take charge of the transcription of the audio files from the TEK-IQ interviews we conducted across eight Arctic communities (2007-2010) in three Nunavut dialects (Baffin, Baker Lake, Inuinnaqtun).
- Berry productivity monitoring continued in collaboration with J. Carpenter and students in the Environmental Technology Program at Nunavut Arctic College in Iqaluit. José Gérin-Lajoie assisted in a poster presentation of the results of first 5 years of monitoring by the students at the ArcticNet ASM in Halifax. Three students attended the ASM.
- In collaboration with the Nunavut Department of Environment we established: 1) six new berry-monitoring plots in the vicinity of Igloolik Island, and 2) a permanent ITEX site consisting of 10 experimental warming (open-top chambers) and 10 control plots on Igloolik Island.
- The Oral History Project, a database of interviews with Inuit Elders housed in Igloolik, was searched for information on plant usage by Noémie Boulanger-Lapointe as part of her PhD research.
- Berries were harvested within permanent berry-monitoring plots at Baker Lake established in 2008, including: 20 experimental warming plots (OTCs) and 25 sub-plots in two 20 m x 20 m control plots. Harvesting in the control plots was conducted with the help of a high school science class.
- Berry productivity near Kugluktuk was measured by Sarah Desrosiers, for her MSc research, with high school students involved in a summer

environmental science/traditional knowledge camp. Sarah taught plant identification and basic vegetation monitoring as part of the summer program, and organized a camping trip with youth and elders to the Kugluk/Bloody Falls Territorial Park. Two new monitoring plots (20 m x 20 m) were established in the Park and described. There are now three plots in the Park and four plots in the vicinity of the hamlet.

- A second winter fieldwork session in late January, 2014 was conducted by S. Desrosiers with the high school students to measure snow conditions and surface temperatures in the berry plots at Kugluktuk. Presentations were made at the high school about the berry monitoring project.
- Outlines of chapters were completed for a "Berry Book" based on results from interviews of elders by students (in summer 2013) on Inuit knowledge of berry shrubs, phenology, uses and stories. Students are also writing their own stories about berries, in Inuinnaqtun, which will be included in the book.
- Berry production, vegetation, climate and soils 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. Two new monitoring plots were established at Daring Lake, and will be used in conjunction with the environmental science – TEK course for high school students that is hosted at the station each summer.
- The analysis of experiments on pollination for seed production and pollinator activity and identification studies continued by Sam Robinson for his MSc project, conducted at Alexandra Fiord, Ellesmere Island. He will analyze images from automatic cameras established over flowers in warmed and control plots to capture visitations by insects.
- Carmen Spiech completed her MSc thesis: Une caractérisation des communautés végétales et distribution des arbustes producteurs de petits fruits à Baker Lake, Nunavut.
- Sylvie Ferland completed her MSc thesis: Étude sur la pollinisation du bleuet autour de la communauté de Baker Lake (Nunavut).
- Alison Beamish completed her MSc thesis: The use of repeat colour digital photography to monitor high Arctic tundra vegetation.
- Filming was completed in Pond Inlet for the film Nallua (Qarmaarjuit/Qinniqtut Historical Project). The film is expected to be completed in late autumn 2014.

Nunatsiavut-Nunavik-Nunavut

- Texts for the booklet and posters on "Inuit observations of environmental changes across from eight communities in three regions of the Canadian Arctic" were completed. The Nunavut Education Department has agreed to take charge of the transcription of the audio files from the TEK-IQ interviews we conducted across eight Arctic communities (2007-2010) in three Nunavut dialects (Baffin, Baker Lake, Inuinnaqtun). We are now actively engaged in fund raising for translation and publication.
- Manuscript completed describing Inuit perceptions of environmental change from the interviews conducted in eight communities from 2007-2010. To be submitted in February, 2014. Analysis and writing led by Laura Siegwart Collier as part of her PhD research.
- Berry production, vegetation, climate and soils data being compiled for the first synthesis of spatial and temporal variation in berry production across the 22 communities involved in our project. The compilation, analysis and writing is led by Noémie Boulanger-Lapointe as part of her PhD research.
- The Avativut project, expanded to include sites in Nunavut and Nunatsiavut, was submitted as a entry for the Arctic Inspiration Prize, and was short-listed.

Results

Antioxidant oxidant activity in berries

- Samples from six berry species from 15 different sites from the Canadian Arctic were harvested from 2008 to 2012. Results show *Empetrum nigrum* (crowberry) samples possess the highest antioxidant capacity, followed by *Vaccinium vitis-idaea* (redberry) and *Vaccinium uliginosum* (blueberry).
- Antioxidant activity of the different berries are similar among sites and years throughout Canada.
- Berries from warmed plots (OTCs) had lower antioxidant capacity than berries from control plots. This supports our hypothesis that berries from plants in warmer temperatures will have lower concentrations of phenolic compounds and thus lower antioxidant activity. Further analyses will be completed to better understand the impact of climate change on berry quality and the potential impact on the 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 7X higher during daytime than at night when temperature rarely raised above 10°C even if the sun was present.
- 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.
- An algorithm for searching through photos from automatic cameras for insect visitation to flowers was developed by Sam Robinson (UBC) and will be tested with data from Baker Lake in the study by Sylvie Ferland (UQTR).
- Flies were also found to be the dominant group on flowers at Alexandra Fiord. Bumble bees were relatively common, although not commonly observed on blueberry flowers.
- Temporal patterns in the insect community of potential pollinators at Alexandra Fiord showed strong correlations with either early season or late season flower phenology.
- Warming experiments (OTCs) appear to reduce the number but not the diversity of potential insect pollinators.

Phenology, Vegetation and Berry Production

- Using the greenness index developed from pixel colours in digital photos of vegetation in warmed and control plots in three plant communities at Alexandra Fiord correlated very well with measured phenology and cover, and with NDVI in the same plots. This is a relatively simple and cost effective method to monitor tundra plots and could be used in school-based programs, such as Avativut. It is also possible to identify individual plants and follow their leaf and flower phenology through the season in the photographs.
- After three 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.
- Berry production data gathered by school classes in the Avativut program in Nunavik has started, but data availability (on the Avativut web site) is variable.

Outreach

- Texts and layouts for posters and the booklet on "What we see! Environmental Changes Observed by Inuit" are finished. The Nunatsiavut government has agreed to translate the appropriate booklets into Nunatsiavut Inuktitut. Nunavut Dept of Education has agreed to fund the transcription of the audio files of our interviews 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.
- Chapter outlines have been completed for all the berry species harvested near Kugluktuk, Nunavut, for a "Berry Book" based on the student-led interviews with elders facilitated as part of our project. Funding to be sought from Nunavut government agencies to publish the book in Inuinnaqtun and English.

School projects

- The Berry Learning and Evaluation Situation (LES) is now operational in all Nunavik High Schools. The Ice LES has been established in eight communities and the new Permafrost LES is underdevelopment and will be introduced to the high schools in Nunavik over the next two years.
- Video clips associated with the berry LES are available on the Avativut web site to better explain the protocols and abstract concepts (e.g. productivity, random sampling) for Nunavik teachers and students.
- The website Avativut has been fully operational for a year and the students have begun to enter their data, which can be downloaded . 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
- Student led interviews with elders in Kugluktuk were completed in late January, 2013, and follow-up discussions with elders were made in August 2013 to confirm some of the terms and stories. 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 Book, to be published in English and Inuinnaqtun. Students wrote stories about berries in their Inuinnaqtun classes, which will be included in the Berry Book.
- We were 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 for Inuit held in Iqaluit in Feb. 2013. José Gérin-Lajoie attended the workshop. The contacts made at the roundtable, especially with the Nunavut Dept of Education, have helped to advance our wish to have the Avativut program model adopted across the Canadian Arctic.

Inuit knowledge

- Multivariate analysis of interview responses from eight communities across three Inuit regions was used to examine patterns of Inuit perceptions of 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 , though not all, of the environmental changes experienced correlated strongly with recent climate change. Overall, perceptions of environmental change appear to be locally driven, as we did not detect clear east-west gradients or latitudinal patterns in community responses with respect to climate variables.

- A cross-generational and cross-cultural land camp with Cree Elders and Youth from Whapmagoostui showed the value of this approach in transmitting knowledge and deepening connections among all participants.
- The film Eeyu Cheschaaydamowin/The Plant Gathering Project, coproduced by CEN and Whapmagoostui First Nation, was released and includes scenes from the land camp.
- Elders of Kugluktuk confirmed and added to the Inuinnaqtun words to describe phenology and anatomy of berry shrub species during interviews with high school students. Stories of berries, real and fictional, were produced by students in their Inuinnaqtun classes.
- Initial examination of the archive of the Oral History Project in Igloolik contained few direct references to vegetation and berry ecology, or insights that could be used to follow up on potential changes near communities.

Rhodiola rosea

- *Rhodiola* rhizome biomass was found to be greater in southern populations (Rigolet) than northern populations (Nain), particularly in sandy and organic substrates
- Substrate was also found to have a significant effect on phytochemistry of *Rhodiola*; less tyrosol and salidroside in rocky substrates, less rosavin and rosarin in sandy soil.
- 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 some evidence of hermaphrodites among wild Rhodiola populations in Nunatsiavut.
- Several previously undocumented traditional uses of *Rhodiola* were shared during community round table discussions.
- Community members expressed strong support for a community-based herbal products enterprise during round table discussions.
- Preliminary results from the anti-diabetic bioassays showed little activity in *Rhodiola* samples from Nunatsiavut, Nunavik and Russia (grown in Alberta).

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 2013 data adds the sixth 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 and relate them to climate and soil conditions at the local scale.

New antioxidant capacity data for berry samples from across the Canadian Arctic confirmed 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. Experimentally 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 2000).

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 in the four berry producing species, were abundant in Nunatsiavut but rarely observed on blueberry

plants in Baker Lake and Alexandra Fiord (Nunavut). Our results indicate 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. Our continued research on the effects of experimental warming on the shrubs and the abundance (and diversity) of pollinating insects, shows that the OTCs appear to reduce the number of potential pollinators, but not the diversity or the temporal pattern of the insect community.

We have been very successful in achieving one of our original objectives to have the community-based monitoring studies included in the curriculum of local schools. The Avativut program involves monitoring berry production, vegetation phenology, snow, ice phenology, and permafrost, and is a part of the new field-based science curriculum of the Kativik School Board. Observations of these environmental variables are being collected with standard protocols in high school science classes in all 14 communities in Nunavik. The berry monitoring program in Avativut has now been implemented in all of the 14 communities and the ice phenology is now in eight communities as of the 2013-2014 school year, and TEK-IQ data such as observations on characteristics of the seasons, berry production and ice characteristics are included in the monitoring. Permafrost monitoring will be included in the program over the next 2 years, beginning with the implementation of a simulation for students to understand factors that affect permafrost. 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). Students have already uploaded data on berry production to the site. 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 en¬vironment 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 Inuit in the monitoring of their environment. We hope to stimulate interest of Inuit Youth in environmental sciences and TEK-IQ. This is exactly the type of legacy we hoped for in our project.

However, even if the Avativut Program is well established in Nunavik, its long term sustainability is still at risk. For example, because the Kativik School Board is chronically short of staff and resources, it is difficult to have a stable contact person for this project. This context forces us to take on more initiatives and use more resources on our side. We consider the land camp approach as a complementary tool for the Avativut Program, and for our project in general, as one of the main objectives is to have Northerners actively involved in data collection and management. It is another way to link science and TEK-IQ, and we have seen how successful these camping events can be with the Cree in Whapmagoostui and in both summer and winter trips in Kugluktuk. These two approaches can reinforce each other and contribute to spark student interest in science. Having a variety of methods to achieve this link may make it easier to get support from northern institutions and industries.

In the future, we would like to develop our community science workshops using approaches that will benefit both the students and the researchers. The use of a recently acquired satellite image of the local area will be central to these workshops. We will be able to look at the different scales in the landscape, and students will be engaged in ground-truthing and interpretation of the satellite image and will learn state of the art techniques and tools. They can then use similar techniques in analysis of digital photos of their plots. We also introduce the use of arts (Land Art) and media (participatory photography) in the land camps as a complementary approach to connect with the Youth and to help them to express themselves. Science will

be embedded in the local and traditional knowledge, culture and language instead of the opposite. In this regard we have initiated discussions with the Kativik School Board to have these land camps recognized for school credits.

Results to date from on our field, lab and community TEK-IQ research results, indicate there is strong potential to establish a small-scale enterprise in Nunatsiavut (and parts of Nunavik) producing and manufacturing medicinal plant products from *Rhodiola rosea*. We are developing a business plan with community agencies to be submitted to the Nunatsiavut government and evaluated. If demonstration projects are approved, we will be well-placed to continue to assist the community-based enterprises. This would be another avenue developed from our research project in ArcticNet.

Conclusion

Inuit perceptions of environmental change vary according to the scale of the variable of interest, and appear to depend more strongly on local factors. General conclusions of the magnitude and direction of change varies among communities, and to some degree, within communities.

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 allows us to better understand the potential effects of climate change on both the shrub and important insect pollinator species.

Using image analysis techniques on digital photos of plots can provide a simple means for monitoring tundra plant response variation in time and space.

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 continue our studies on the medicinal plant *Rhodiola rosea* and its responses to environmental change in Labrador/Nunatsiavut. The species appears to have potential for cultivation and could form the basis of a small, sustainable industry for Nunatsiavut communities.

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 Avativut program was developed and Kativik School Board for Nunavik has adopted our methods and project ideas for monitoring berry production, snow, ice and permafrost. We hope to expand this type of program to the other Inuit territories, beginning with Nunavut.

Through our growing experiences, enhancing opportunities for Youth and Elders in northern communities to spend time on the land together, either through camping excursions or day trips to important sites, can stimulate and enhance knowledge transfer and deepen connections between generations.

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