EARTHWATCH INSTITUTE

CLIMATE CHANGE AT THE ARCTIC'S EDGE

2014 FIELD REPORT

Climate Change at the Arctic’s Edge

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Background Information

LEAD PI: LeeAnn Fishback

REPORT COMPLETED BY: LeeAnn Fishback and Steven Mamet

PERIOD COVERED BY THIS REPORT: June 2014–March 2015

CHANGES TO:

PROJECT SCIENTISTS: Scientist Additions: Blake Hossack, United States Geologic Survey Field Staff Additions: Matthew Webb, Churchill Northern Studies Centre Kyle Kasten, Churchill Northern Studies Centre Field Staff Departures: Jackie Verstege, Churchill Northern Studies Centre Sarah Robinson, Churchill Northern Studies Centre

RESEARCH SITE: No

RESEARCH SITE LATITUDE / LONGITUDE: No

PROTECTED AREA STATUS: No

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Dear Earthwatch volunteers,

This research at Churchill, Manitoba (MB), has been underway since 1999 and in the Mackenzie Mountains, Northwest Territories (NT), since 1973. Each new season brings new insights and reinforces lessons learned. For the past 16 years at Churchill and 9 years in the Mackenzies, Earthwatch volunteers have greatly contributed to these research efforts. With several teams a year at Churchill and one in the Mackenzies, we have added significantly to the long-term record of key environmental variables. These records are unparalleled in the North; with the length of the records and the data available we have a unique data archive on environmental change at the study sites.

The project, led by Dr. LeeAnn Fishback from the Churchill Northern Studies Centre, and Dr. Steve Mamet from the Department of Biology, University of Saskatchewan, has focused on the effect of climate change on the wetlands of the subarctic near Churchill, Manitoba, and on treeline and permafrost in both Churchill and the Mackenzie Mountain area of the Northwest Territories. We are very excited to add a long list of accomplishments to our research program this year and are grateful to the generous support of all Earthwatch volunteers and funders who have aided in this project.

Our work at Churchill continues to investigate the 11 long-term monitoring sites, six treeline sites, four tree island sites, and a network of twenty wetlands from tundra through to the boreal forest. The winter work has confirmed the important role that snow plays in controlling the temperature of the ground, the health of coniferous foliage across the treeline, and as a source of water for the shallow tundra ponds. The summer wetland work has illustrated the importance of predators in the wetlands on the species that are present in these ephemeral habitats. In 2014, we conducted a third mesocosm experiment, this time in 400 L stock tanks, to investigate the effect of temperature and hydroperiod on tadpole survival. In the Mackenzie Mountains the temperature record for the permafrost reveals warming up to 1.8 °C over the last 22 years (this has brought several of the sites to within 1 °C of thawing).

The Earthwatch dataset, which continues to grow steadily each year, provides a benchmark against which future environmental change can be measured. These data have already contributed to the International Polar Year database and were used as baseline data for Parks Canada's State of the Parks report, which will guide future planning, management, and operation of the Wapusk National Park, including resource conservation. The data have also informed the North American Treeline Network (NATN) and the Global Observation Research Initiative in Alpine Environments (GLORIA) – thus contributing to global research efforts.

The 84 volunteers who participated in our project during 2014-15, including corporate volunteers and fellows (both teachers and corporate), have provided the much needed assistance to grow and develop our project (e.g. wetland mesocosm experiments) as well as conduct teams at both of our field sites (Churchill, MB and Mackenzie Mountains, NT) and in all seasons of the year. It would also not be possible for us to continue the long-term monitoring of our keystone variables (e.g. snow depth, seedling establishment, active layer development, wetland species inventory) without the generous assistance of the donors and funders who sponsor many of our Earthwatch volunteers. You should all take great pride in helping us with our many accomplishments this year and you have our heartfelt thanks.

Sincerely,

LeeAnn Fishback

Dr. LeeAnn Fishback and Dr. Steve Mamet

SECTION ONE: Scientific research achievements

TOP HIGHLIGHT FROM THE PAST SEASON

One of our more notable achievements this past year was the expansion of the experimental portion of the wetland ecology project to include thirty-six 400L stand-alone stock tanks where we created wetland environments in these tanks to examine the effect of temperature warming and drying of wetlands on the growth and behaviour of wood frog tadpoles. Our results show that tadpoles have the capacity to increase their growth in response to warmer water temperatures but do not respond to the environmental cue of decreasing hydroperiods (length of time that wetlands have open water). The lack of combined response of the tadpoles to the interaction between warming and drying indicate they are vulnerable to the threat of climate change. This mesocosm study underscores the importance for investigating how freshwater organisms at higher latitudes will respond to environmental changes occurring as a result of rapid climate change in the Subarctic.

REPORTING AGAINST RESEARCH OBJECTIVES

Each year data are collected to quantify current environmental conditions. As this record lengthens we can be more confident that we can determine average conditions at the beginning of this 21st century. The problem we have is that we are attempting to calculate an average at a time when change is rapid and in one direction. Never-the-less we can continue to describe the state of environmental factors affecting permafrost, treeline, and wetlands with the expectation that similar studies in the future can use these data as a benchmark for comparison.

Figure 1. Two seeding (control, seeded) and two substrate (control, scarified) treatments were applied across the forest to tundra transition. Seeding treatments identify seed limitations and substrate treatments allow for the assessment of current suitability (control), and suitability following disturbance (scarified). This results in four treatment combinations: 1) control, 2) seeded, 3) scarified (ground vegetation removed), and 4) seeded and scarified.

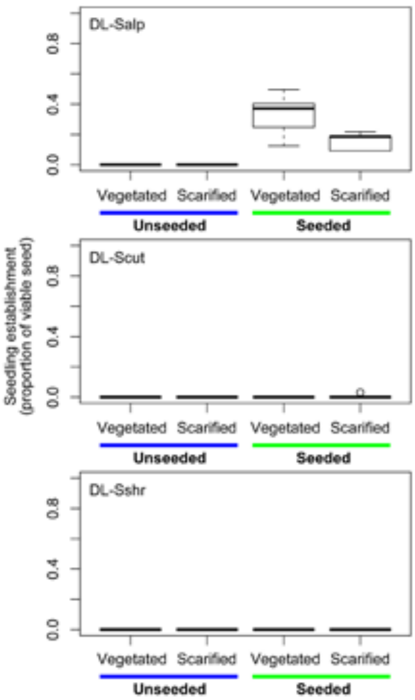

Figure 2. Establishment success in the alpine (DL-Salp) and forest-alpine transition (DL-Sshr [shrubs intact] and DL-Scut [shrubs removed]) along the Canol Heritage Trail in the western Mackenzie Mountains. Seeds were planted in August 2013. The first, second (median), and third quartiles of each data set are shown as box and whisker plots. Any values outside 1.5 units from the first or third quartiles (outside the dashed lines or "whiskers") are shown as an open circle.

The Global Treeline Range Expansion Experiment (G-TREE) is a globally distributed collaborative project aimed at testing the generality of mechanisms driving boundaries of tree distribution at the treeline. Two conditions must be met for plant species' distributions to shift as the climate of marginal environments become more favourable: i) a seed source for colonization; and ii) a suitable substrate for establishment and survival (Figs. 1 and 2). The goal of G-TREE is to disentangle substrate and seed limitations on range expansion through field experimentation. Early results suggest that seedlings could establish well-beyond treeline given a suitable seed source, though success is limited within the forest-alpine transition zone (Fig. 2). We hypothesize this paucity of seedlings is caused by granivory of sown seed by small mammals—thus biotic limitations may outweigh climatic restrictions. We aim to test this hypothesis in summer of 2016-2017.

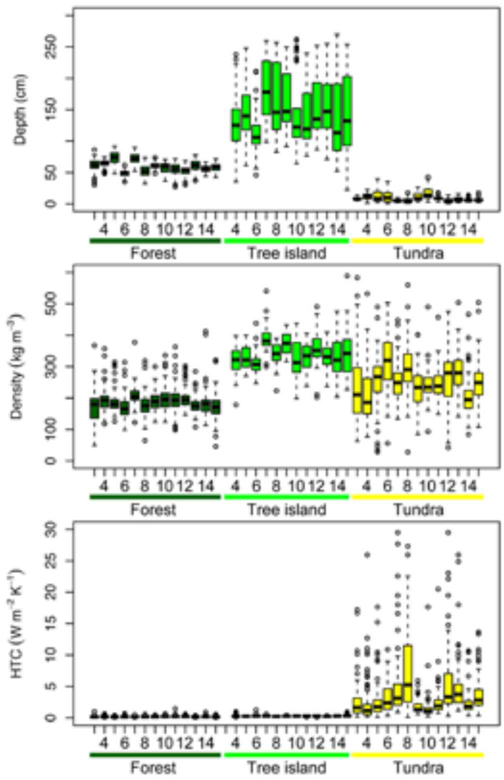

Figure 3. Mid-winter snowpack (sampled February 2003–2015) among sites along the forest to tundra transition near Churchill, Manitoba. The first, second (median), and third quartiles of each data set are shown as box and whisker plots. Any values outside 1.5 units from the first or third quartiles (outside the dashed lines or "whiskers") are shown as an open circle.

Figure 4. Snow sampling in the forest-tundra transition on a beautiful winter day in February 2015.

With regard to permafrost both the Mackenzie Mountains and the Churchill region have experienced warming over the past 20 to 35 years (respectively). Ground and aerial photography from the mid-1940's and temperature measurements from the mid-1970's provide a limited database for comparison with present-day conditions. These comparisons show loss of permafrost landforms and warming of permafrost where it persists. In the Mackenzie Mountains permafrost has warmed by as much as 1.3 °C while in the Churchill region it has risen by ~0.5 °C. In both areas the permafrost is close to 0 °C. In the Mackenzie Mountains at one research site the active layer fluctuates dramatically with annual variations in air temperature. This confirms that rapid responses can occur to variations in regional environmental conditions.

Figure 5: Title Slide from our Presentation "How citizen scientists support long-term monitoring of environmental change in a really "cool" place: Observations of arctic ecosystems in a rapidly shifting climate" at the Earthwatch Summit, November 2014.

At Churchill no trends in snowpack characteristics were apparent but inter-annual variations appear to be minimal at treed sites. Open, treeless areas offer little resistance to winter heat loss (Fig. 3, bottom panel). We continue to build this long-term monitoring of snowpack at these sites to develop a thirty year record where we can examine trends in the snowpack data in relation to temperature and precipitation patterns. Earthwatch volunteers are instrumental in collecting these data (Fig. 5). These snow data were presented in conjunction with many of the results from our project at the community outreach day of the Earthwatch Summit in November 2014 (Fig 5). A video of our complete talk is available online. (https://www.youtube.com/watch?v=oYc1bdfumTg). In March of 2015 we piloted a new method of collecting snow depth by adding camera traps at two of our sites to collect a temporal record of snow accumulation at these sites (cameras are set to take a picture each day at noon with a snow stake for depth record in each photo). We also look forward to presenting a time lapse video of snow accumulation at these sites in 2016.

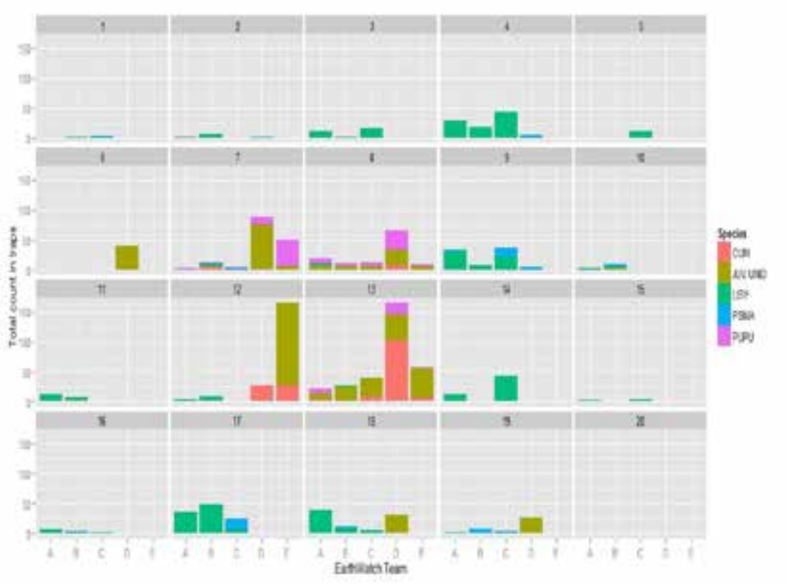

Figure 6: Preliminary results from the natural pond sampling in 2014 illustrating the total counts collected in the trapping of stickleback fish and tadpoles over the course of five teams (A through E). Of note, is the increase in unidentified fish species during teams D (August) and E (September).

We have continued to maintain the reclamation sites but there was no data collection at these sites during 2014-15 year.

Churchill lies at the northern extent of the Hudson Bay Lowlands and the tundra wetland studies help us to examine the species diversity, geochemistry and physical characteristics of these ponds and how they are responding to a changing climate. Warmer summers mean shorter wet periods in these shallow tundra ponds, which compromises the reproductive cycle of species relying on wetlands for habitat. Yearly monitoring of these ponds allows us to better understand the importance of variation on pond habitats and species diversity. In 2014 we added to the long-term monitoring database of pond geochemistry by focusing on a series of 20 wetlands spread throughout different geographic units from coastal tundra to boreal forest. Each of the wetlands was sampled intensively five times during the open water season. Results for the fish and tadpole species in these wetlands vary throughout space but also vary across the seasons (Fig. 6). These data were used to extend an N-mixture model to help improve the investigation of abundance and vital rate characteristics of species (e.g. nine spine stickleback and brook stickleback) at early life stages where species are often difficult to identify (see Fig 6).

Figure 7: Wetland sampling team in September 2014 – some seeing ice on a pond for the first time in their life!

Figure 8: 2014 Mesocosm experimental setup in 400 L stock tanks in Churchill, Manitoba with early July teacher team.

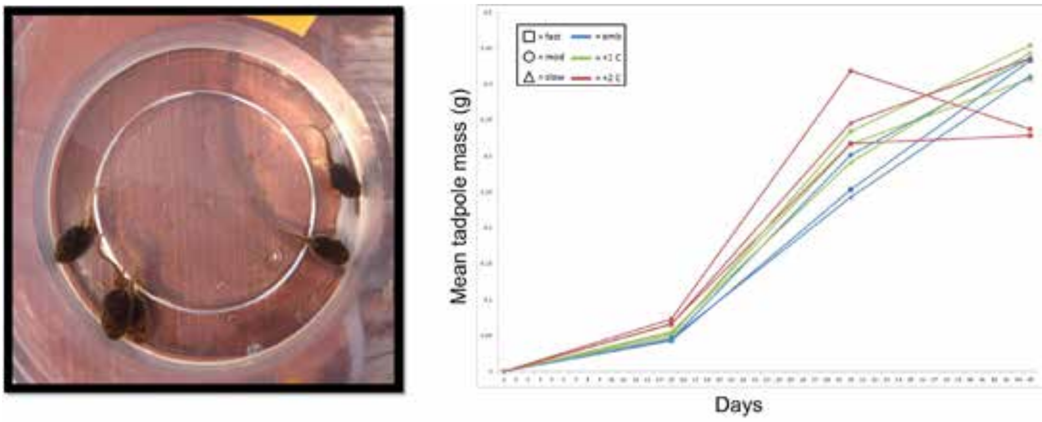

Figure 9: Preliminary results of the 2014 experimental mesocosms in Churchill, MB (a) Wood frog tadpoles at Day 45 (b) Mean mass of tadpoles (+/- 1 S.E.) by sampling date and treatment.

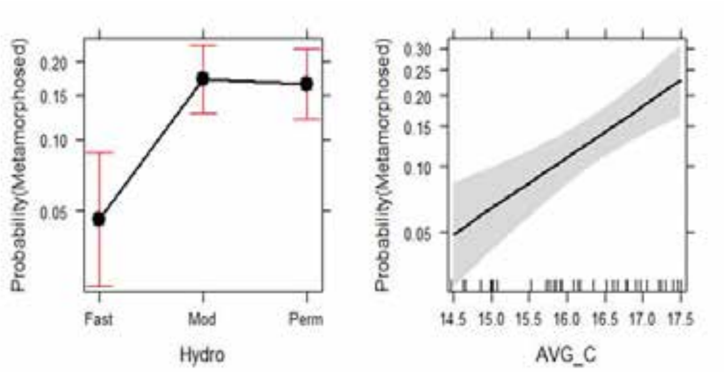

Figure 10: Mean (+ 1 S.E.) proportion of wood frogs that metamorphosed from mesocosms as a function of hydroperiod (panel A) and experimental warming (panel B).

In 2014 we expanded the experimental part of the wetland ecology project to include thirty-six 400L stand-alone stock tanks where we examined the effect of temperature warming and decreasing hydroperiod on the growth and behaviour of wood frog tadpoles IFIg 8). Subarctic amphibians, such as the wood frog (Lithobates sylvaticus), are excellent models as climate change impacts (i.e., pond drying) because individuals must metamorphose before a wetland dries. In this 3x3 factorial design with three warming and three hydroperiod treatments we investigated the response of tadpole growth (Fig 9) and survival (Fig 10). Our results show a lack of combined response of the tadpoles to the interaction between warming and shortening hydroperiods that indicated they are vulnerable to the threat of climate change. The wood frog tadpoles did show the capacity to respond to shortening hydroperiods or to increased temperatures, but not to the interaction of the two factors in this mesocosm experiment. Our data also show that tadpoles have the capacity to increase development (Fig 9) in response to warmer water conditions. This mesocosm study underscores the importance for investigating how freshwater organisms at higher latitudes will respond to future environmental change and future experiments will continue to investigate these particular process-based questions while continuing the long-term observation in natural wetlands.

We conducted a second mesocosm experiment in the fall (September – November 2014) to determine fish survival rates with varying sediment depths during fall ice formation. This pilot experiment demonstrated that the sediment depths used here do not drive fish survival. Indeed no fish survived the initial freezing in this experiment. To document these results we created a short video that can be viewed on the CNSC youtube channel at: https://www.youtube.com/watch?v=aVYlMyBYsGY.

CHANGES TO RESEARCH PLAN OR OBJECTIVES

We did not make any changes in our research plan or objectives.

SECTION TWO: Impacts

INCREASING SCIENTIFIC KNOWLEDGE

MoS 1.2 Peer-reviewed Publications

2015:

- Mamet, S.D., Cairns, D.M., Brook, R.K., and Kershaw, G.P. (2015). Modeling the spatial distribution of subarctic forest in northern Manitoba using GIS-based terrain and climate data. Physical Geography, 36: 93–112.
- Chambert, T., Hossack, B.R., Fishback, L.A., Davenport, J.M. submitted for review August 24, 2015. Estimating abundance in the presence of species uncertainty. Methods in Ecology and Evolution. Manuscript ID MEE-15-08-567.

2014:

- Eichel K.A., Macrae, M.M., Hall, R.I., Fishback, L.A., Wolfe, B.B. 2014. Nutrient uptake and short-term responses of phytoplankton and benthic algal communities from a subarctic pond to experimental nutrient enrichment in microcosms. Arctic, Antarctic, and Alpine Research, 46:191-205.

2013:

- Mamet, S.D. and Kershaw, G.P. Environmental influences on winter desiccation of Picea glauca foliage at treeline, and implications for treeline advance in northern Manitoba. Arctic, Antarctic and Alpine Research, 45: 219–228.
- Mamet S.D. and Kershaw G.P. Age-dependency, climate, and environmental controls of recent tree growth trends at subarctic and alpine treelines. Dendrochronologia, 31: 75–87.
- Mamet, S. D. and Kershaw, G. P. Multi-scale analysis of environmental conditions and conifer seedling distribution across the treeline ecotone of Northern Manitoba, Canada. Ecosystems, 16: 295-309.
- Davenport, J.M., Siewert, P.A., Fishback, L.A., Cash, W.B. 2013. The effects of two fish predators on Wood Frog (Lithobates sylvaticus) tadpoles in a subarctic wetland: Hudson Bay Lowlands, Canada. Canadian Journal of Zoology. 91: 866-871.

MoS 1.3 Grey Literature and Other Dissemination of Your Results

PRESENTATIONS
2014:

- Fishback, L. and Mamet, S.D. How citizen scientists support long-term monitoring of environmental change in a really "cool" place: Observations of arctic ecosystems in a rapidly shifting climate. Earthwatch Summit 2014: Citizens for Science Exposition. Nov. 6-8th, 2014. Boston, MA.
- Mamet, S.D., Harper, K.A., Pelton, J., Albertsen, E., Kershaw, G.P. and Muffly, J. (2014) Spatiotemporal patterns & processes within a latitudinal ecotone: How has the forest-tundra transition responded to climate change in northern MB? Earthwatch Summit 2014: Citizens for Science Exposition. Nov. 6-8th, 2014. Boston, MA. Poster presentation.
- Goodman, A., Fishback, L.A., Davenport, J.M., Hossack, B.R. (2014) Effects of temperature and hydroperiod on wood frog tadpoles: A mesocosm experiment in Churchill, MB. Prairie University Biology Symposium. Feb 19-21, 2015. University of Winnipeg, Winnipeg, MB, Canada. Poster presentation.

Earthwatch results are regularly presented as part of the "Current Research at the Churchill Northern Studies Centre" delivered by Dr. LeeAnn Fishback to visitors and clients participating in educational programming at the Centre (~ 300 people/year).

UNDERGRADUATE THESIS

- Goodman, A. 2015. Effects of temperature and hydroperiod changes on wood frog tadpoles: A mesocosm experiment in Churchill, MB. Unpublished undergraduate thesis, Department of Geography, University of Winnipeg, Winnipeg, MB, Canada, 72 pp.

MEDIA

This year we focused on media presentations and getting our results out to a wider audience while trying to stay in touch with volunteers who had been on our teams. Here are a few of our efforts:

- Climate Change at the Arctic's Edge Facebook community group - https://www.facebook.com/arcticsedge
  Here you will find many of items of interest including photos of various teams and also some of the media that may have been generated by our project staff or volunteers.
- Trees in the Tundra multimedia project with Earthwatch - http://multimedia.earthwatch.org/treesinthetundra

- Fish mesocosm: A story - https://www.youtube.com/watch?v=aVYlMyBYsGY
  This video was put together by field staff, Daniel Gibson, to report results of our experiment to the volunteers who had participated in the start of the story.
- Earthwatch summit participation – see the video of Steve and LeeAnn's presentation here - https://www.youtube.com/watch?v=oYc1bdfumTg

DEVELOPING ENVIRONMENTAL LEADERS

MoS 2.1 Education

The corporate fellows, general public volunteers, teachers and teens who have participated in our teams have benefited greatly from the lectures and additional activities they have participated in at the Centre during their time in Churchill and also in the Mackenzie Mountains. This year we also added community fellows to our March 2015 team. These fellows benefited from being able to see scientists working in the field and participate in real world data collection, even if this was well beyond the scope of their understanding or interest. They greatly enjoyed participating in the team and being able to interact daily with science field staff. In 2014, we also had the addition of teacher teams to the wetland ecology program. We used the mesocosm experiment in particular to urge the teachers to think of ways of integrating ecological experiments into their classroom experiences. Many of these teachers went home inspired having participated in real world field experiences and took back the excitement and passion of the science field staff to their classrooms. One teacher in particular was inspired to begin a graduate program in field science and outreach in 2015!

PARTNERSHIPS

MoS 2.1 Organizations Actively Engaged

One of our key partners in this research is with the Churchill Northern Studies Centre (CNSC) where Dr. Fishback is employed. The Centre also provides coordination for team logistics, gear rental, and health and safety support outside of the budgeted fees. Similar work (climate monitoring stations, snowpack surveys, tree ring analysis) is being conducted in Wapusk National Park. A small contract ($6,000) covers helicopter access to the field sites and in-kind (snowmobile, food, accommodation, field assistants) support. Partnerships with Dr. Jon Davenport, University of Southern Missouri and Dr. Blake Hossack, United States Geological Survey, provided leadership on the mesocosm wetland experiment. Dr. Ben Cash, University of Central Arkansas, was not in the field in 2014-5 but continues to provide the permitting for the collections.

CONTRIBUTIONS TO POLICIES OR MANAGEMENT PLANS

MoS 4.1 Informing Policies or Management Plans

- **International Policies or Management Plans:**
  The formation of the North American Treeline Network (NATN) in conjunction with ongoing research activities through the Global Observation Research Initiative in Alpine Environments (GLORIA; http://www.gloria.ac.at/) has allowed data collected in Churchill and the Mackenzies to be contributed to global research synthesis activities.
- **National or Regional Policies or Management Plans:**
  Our continued collaboration with Parks Canada and the expansion of the ecosystem integrity monitoring network in Wapusk National Park , which is located near our Churchill study site, provides baseline data for their State of the Park report (2011 State of the Park report - http://publications.gc.ca/collections/collection_2013/pc/R61-93-2011-eng.pdf) and regional scale monitoring efforts while placing our work into a larger context.
- **Local Policies or Management Plans:**
  None at this point

MoS 4.2 Actions or activities that enhance natural and/or social capital

We encourage volunteers to be directly involved in the recycling and composting activities at the research stations in Churchill and Mackenzie Mountains. In Churchill, we engage the volunteers in a tour of the facility that highlights the sustainable features that have been incorporated into the recent station construction to reduce human activities on the natural environment. This encourages them to participate in sustainable activities, for example, to use composting toilets and reduce water consumption during their visit and perhaps into the future. We also implemented a Facebook community page for our project to continue to stay in touch with our volunteers and report to them on our research progress. We also look forward in 2015 to instituting a program assessment in collaboration with a social scientist from University of British Columbia, Dr. Mark Groulx, to determine the 'value' of placed-based learning experiences through citizen science. More to come next year!

ENHANCING NATURAL AND SOCIO-CULTURAL CAPITAL

MoS 5.1 Conservation of Taxa

Our project mostly focused on long-term monitoring of the environment in 2014.

MoS 5.2 Conservation of Habitats

Our project mostly focused on long-term monitoring for 2014. Churchill is home to thousands of migratory birds that come to the region to mate each summer. Many of these birds use the Hudson Bay Lowlands and wetlands as a source of food, water and nesting habitat during this important reproduction phase. Many species of shorebirds (Semi-palmated Plover (Charadrius semipalmatus) and Whimbrel (Numenius phaeopus) in particular have seen significant (~40%) decline in their populations in the last 30 years. Data from the monitoring network provide benchmark conditions on the wetlands and key nesting habitat.

MoS 5.3 Conservation of Ecosystem Services

The research is of a primary nature, directed at scientific inquiry and as such does not include ecosystem services support.

MoS 5.4 Conservation of Cultural Hertiage

This project does not include a conservation of cultural heritage component.

MoS 5.5 Impact Local Livelihoods

The Churchill Northern Studies Centre has full-time staff whose salaries depend on income from user fees. Earthwatch volunteers' fees help offset salaries. Some seasonal staff are local hires and all full-time staff live in the local community.

LOCAL COMMUNITY ACTIVITIES

Dr. LeeAnn Fishback, has been a member of the local community for the last 13 years as she lives full-time in Churchill, MB. The CNSC where field teams stay in the Churchill area for the duration of the team is located about 25 km from the town of Churchill. The CNSC maintains an excellent relationship with the community and all CNSC staff are also members of the local community. This makes the relationship between the project and the local community comfortable, convenient and mutually beneficial. Local people are invited to participate in any of the field teams, during all activities but particularly they are interested in interaction during day-off activities where volunteers are able to visit local dog mushers, artists, restaurants and community events to engage with the community in a setting where sharing life experiences brings added value to the volunteers and the community members.

This year we also added community fellows to our March 2015 team. These fellows benefited from being able to see scientists working in the field and participate in real world data collection, even if this was well beyond the scope of their understanding or interest. They greatly enjoyed participating in the team and being able to interact daily with science field staff.

SECTION THREE: Acknowledgements, Funding and Appendices

PROJECT FUNDING

Parks Canada (Wapusk) has provided in-kind and financial support for related research in Wapusk National Park. The Churchill Northern Studies Centre graciously provides the salary support of their Scientific Coordinator to lead this project. Funding for the salary of Dr. Steven Mamet was provided by the W. Garfield Weston Postdoctoral Fellowship in Northern Research. Other partner universities and organizations listed above also provide varying levels of support for field staff and associated research equipment.

ACKNOWLEDGEMENTS

The Churchill Northern Studies Centre provided invaluable logistical and scientific assistants to the research being conducted at Churchill. CNSC Technicians, Daniel Gibson, Jackie Verstege, Kyle Kasten, Sarah Robinson and Matthew Webb contributed many hours to team preparation and field data collection in Churchill. Dechen la' Lodge provided essential logistical support for the research in the Mackenzie Mountains. Peter Kershaw, Linda Kershaw, Geoff Kershaw, Eric Kershaw, and Jen Kershaw have been a tremendous help completing fieldwork in the Mackenzie Mountains.

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