EARTHWATCH® INSTITUTE

Jason Learning Team in late June 2017

SCIENTIFIC TITLE: Climate Change at the Arctic's Edge

LEAD PI: LeeAnn Fishback and Steven Mamet

REPORT COMPLETED BY: LeeAnn Fishback and Steven Mamet

PERIOD COVERED BY THIS REPORT: June 2017-March 2018

LeeAnn Fishback, Scientific Coordinator, Churchill Northern Studies Centre

Steven Mamet, Department of Soil Science, University of Saskatchewan

August 2017 Churchill team

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 18 years at Churchill and 12 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.
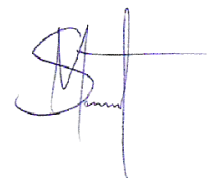
The project, led by Dr. LeeAnn Fishback from the Churchill Northern Studies Centre, and Dr. Steven Mamet from the Department of Soil Science, University of Saskatchewan, has focused on the effect of climate change on the wetlands of the Subarctic near Churchill, Manitoba, and on treeline and permafrost in both Churchill and the Mackenzie Mountains 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 for 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-three wetlands from tundra through to the boreal forest. The winter work examines the important role that snow plays in controlling the temperature of the ground, the health of coniferous foliage across the treeline, and as a water source for the shallow tundra ponds of the Hudson Bay Lowlands. The summer wetland work has illustrated the importance of predators in the wetlands on the species that are present in these ephemeral habitats. In 2017, we conducted a series of microcosm experiments on site in Churchill in 9L bins, to investigate the effect of sediment on nutrient uptake before we scale this experiment to our regular mesocosm experiments in 400L stock tanks. In the Mackenzie Mountains, the permafrost record for reveals a mean warming of 0.98 °C over the last 26 years, which has brought all of the sites to within 1 °C of thawing. This year we also completed a survey of about 100 volunteers to examine the lasting impact of our citizen science project.

The Earthwatch dataset, which continues to grow steadily each year, provides a benchmark against which future environmental change in these habitats 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), and been cited in the latest Intergovernmental Panel on Climate Change (IPCC) report – thus contributing to global research efforts.

The 96 volunteers who participated in our project during 2017-18, 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,

Drs. LeeAnn Fishback and Steven Mamet

SUMMARY

1. The flooding in the spring 2017 following unprecedented snowfalls in March led to high water levels during our wetland field work. This high snow and flooding was evidence of the extreme events that are part of the impacts of a rapidly changing climate.
2. During this year we fielded 10 Earthwatch teams, including a new to us group of volunteers with Jason Learning. With more volunteers than ever we started two new experiments associated with our wetland ecology work: terrestrial enclosures for over winter survival experiments for juvenile wood frogs and a sediment uptake of nutrients microcosm experiment.
3. Both principal investigators (Steve and LeeAnn) were present for the entire fielding of the Mackenzie Mountain team where we were able to visit all the long-term monitoring sites and re-establish the Dale Creek weather station.
4. The dynamic nature of the impacts of climate change were evident at the Churchill sites were permafrost warming at most sites with subsurface cooling occurring at one of the palsa sites.
5. The completion of our survey data collection to examine the social impacts of our place-based citizen science project meant moving forward with coding and analysis of the data collected.

GOALS, OBJECTIVES, AND RESULTS

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 challenge 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 continued and similar studies in the future can use these data as a benchmark for comparison. We continue to support undergraduate and graduate projects as part of this research and assist in the training of future scientists along with our citizen science project.

Earthwatch volunteers have collected snow depth and density data at 10 long-term monitoring sites, six treeline sites and five tree islands sites with some records beginning in 2000. In the winter of 2018, we were able to visit all of these sites to collect snowpack data with our three winter Earthwatch teams. In 2018, snow depth and density were more reflective of the average snowpack measurements (Figure 1) but still showed a declining trend for snow depth at the tree island sites (Figure 1 and 2).
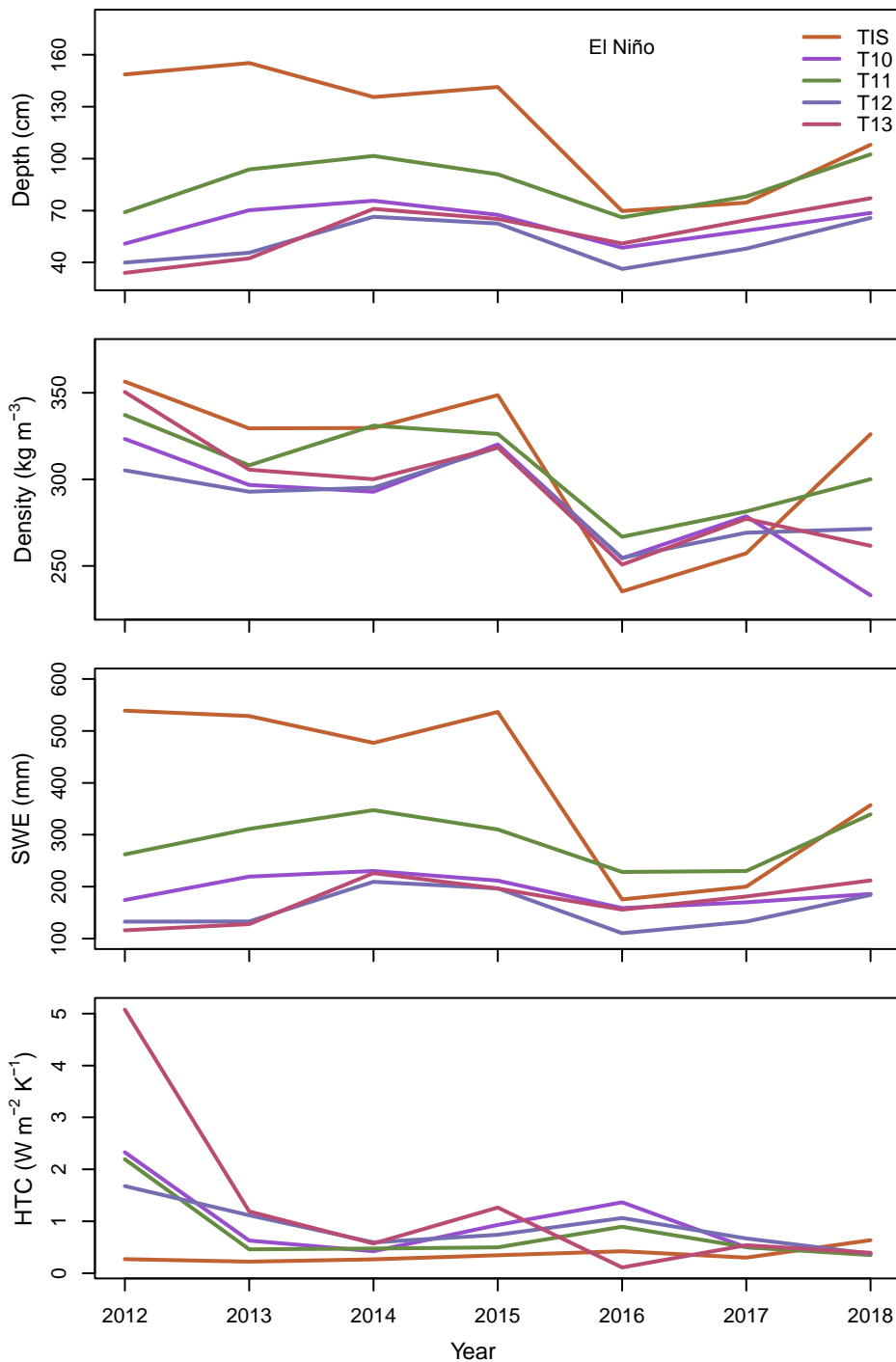
Figure 1 – Snowpack data from 2012 to 2018 for 5 tree islands. The data include depth, density, snow-water equivalent (SWE; a measure of how much water is in the snowpack), and heat transfer coefficient (HTC; a measure of convective heat transfer through the snowpack). The record-setting El Niño of 2015-2016 is indicated by the shaded region. Low wind during the El Niño winter resulted in less redistribution of snow and shallower, less dense snow within the tree islands.
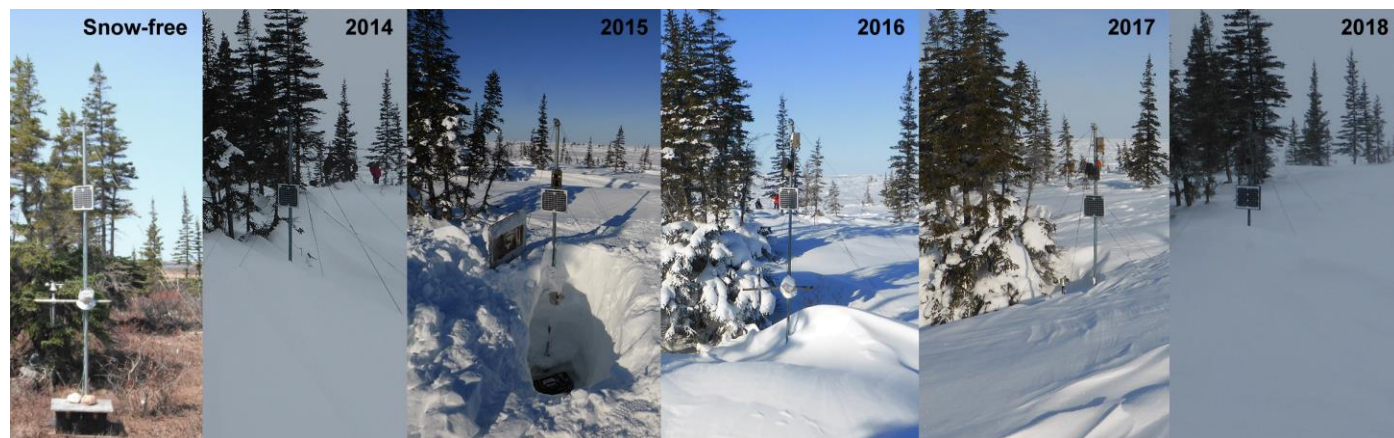
Figure 2 – Snowpack at our long-term tree island (TIS) site during the snow-free period and mid-winter (late-February). Snow depth during 2014, 2015, and 2018 were near average, whereas 2016 and 2017 were low snow years. Note solar panel on weather station mast to visually compare snow depth (compare to Figure 1 above for complete record from 2012 - 2018).

Each year we continue adding to the continuous measurements of air, ground, and sub-surface temperatures at our 10 long-term terrestrial monitoring sites in Churchill and 5 sites in Mackenzie Mountains. At Churchill, the sites with low-stature tundra vegetation (in blue in Figure 3 below) are considerably cooler at the ground surface and within the subsurface (-80 cm), relative to treed sites, burned areas, and sedge-rich wetlands. While most of the sites at Churchill are experiencing warming, there is one location where there has been subsurface cooling of about –0.4 °C per decade. This highlights the needs for continued monitoring at these sites to examine how various environments will respond to the changing climate. At the Mackenzie mountains sites at low elevations (~1200 m.a.s.l.) are warmer than sites at high elevations (~1600 m.a.s.l.,). Air temperatures at the sites have warmed only 0.1 to 0.2°C per decade, though this has translated into warming of 0.2 to 1.3°C at the ground surface and 0.1 to 0.2°C in the subsurface (-150 cm) (Figure 4). Moreover, the variation in mean annual air temperatures at Churchill and the Mackenzie Mountains illustrates the high inter-annual variability that is normal for these regions.

Mean annual subsurface (-80 cm) temperatures
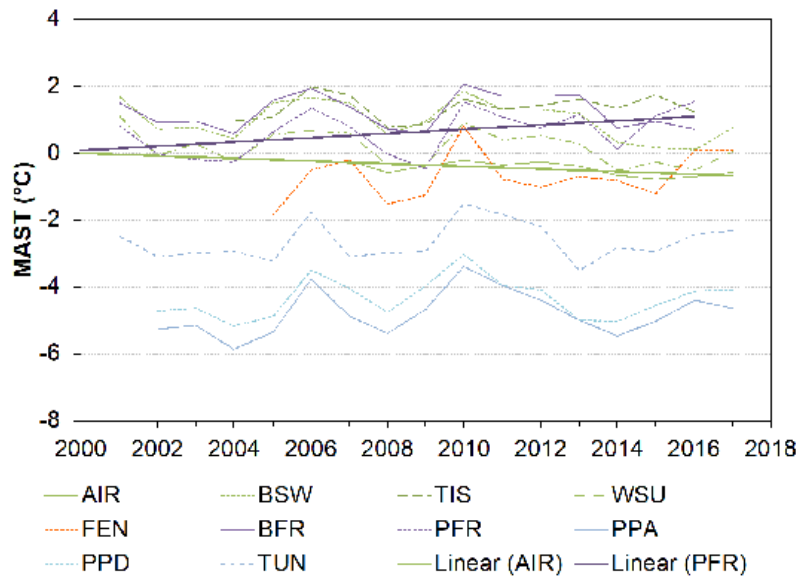
PFR: Subsurface warming at 0.7°C per decade
AIR: Subsurface cooling at 0.4°C per decade

Figure 3 – Mean annual subsurface (80 cm) temperatures at 10 long-term monitoring sites in Churchill. Note the 0.4 °C cooling at the airport site.
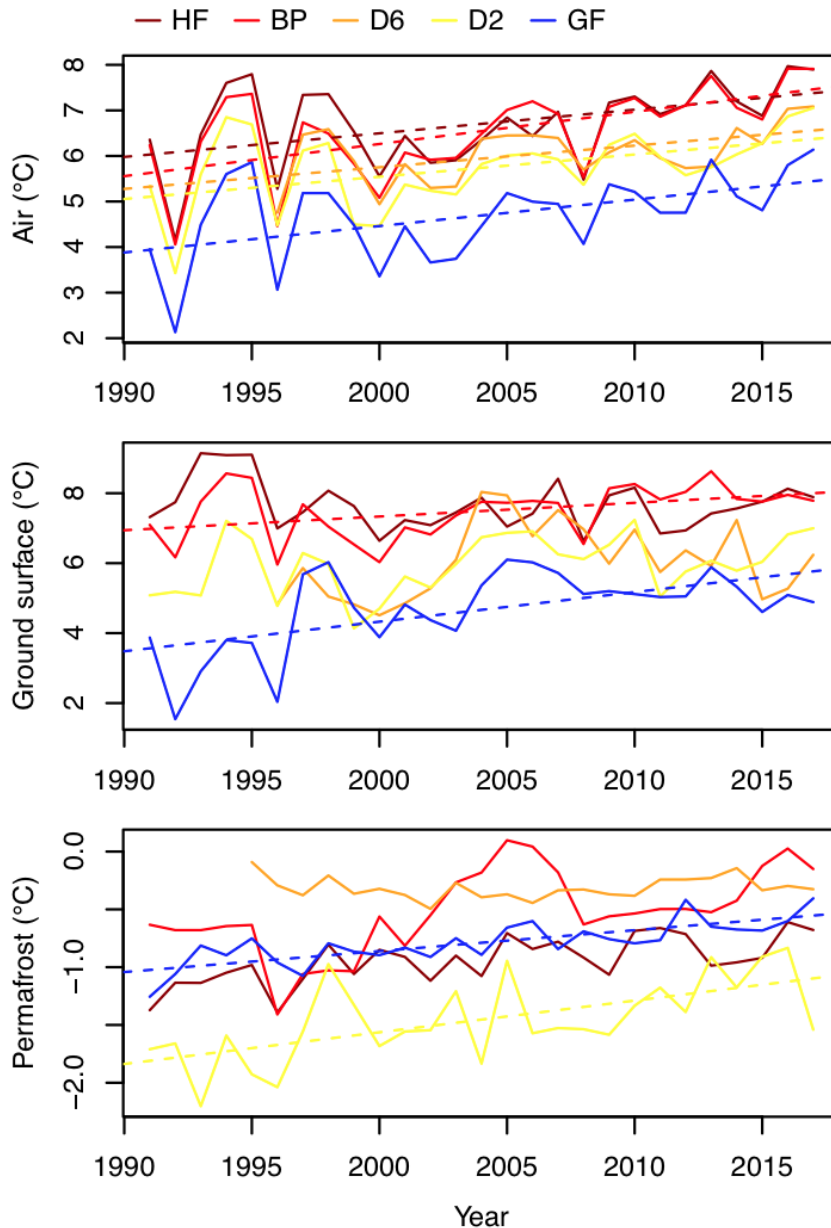
Figure 4 – Mean warm season (May–September) temperatures at 5 long-term monitoring sites in Mackenzie Mountains. Note the significant warming (dashed lines) at most sites.

Permafrost has thawed in both the Mackenzie Mountains and the Churchill over the past 20 to 35 years (respectively) and we continue the monitoring work of previous years. One of the key indicators we measure is active layer thaw depth. Each year, two of our teams dedicate several days to ensure our long-term measurements of the active layer thaw are measured and compiled. In Churchill we continue to see on average, deeper active layer depths (Figure 5). One of our monitoring sites is experiencing decreasing subsurface temperature decreases (Figure 3) and the thinner active layer depths in response can be seen in Figure 5 below. These

changing conditions are most likely due to changes in soil moisture conditions and vegetation cover as air temperatures are still warming at these locations.
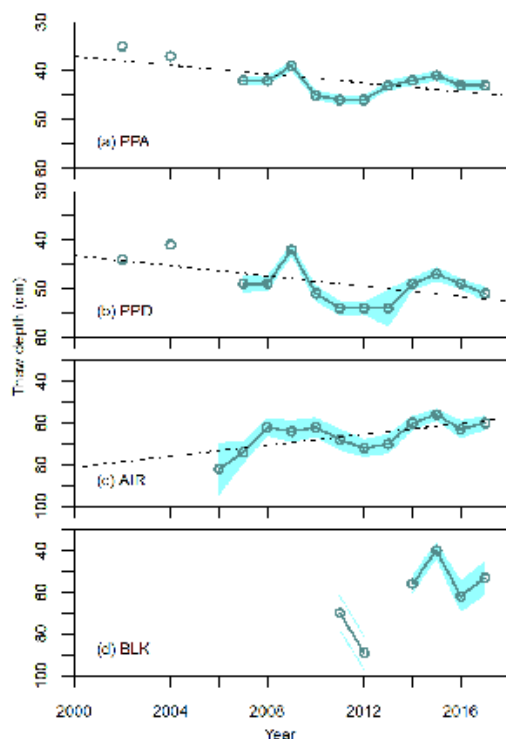
Thaw depth

- **Increasing thaw depth at PPA and PPD**
  - PPA: 4.6 cm / decade
  - PPD: 5.3 cm / decade

- **Decreasing thaw depth at AIR**
  - AIR: −13.1 cm decade

- **No trends at BLK**

Figure 5 – Active layer thaw depth at our four long-term monitoring frost probe grids in Churchill from 2006 - 2017.

One of the most common winter related tree issues is winter desiccation (also called winter drying). Winter desiccation occurs when the foliage is exposed to high winds, blowing snow, and low temperatures, which erodes the protective waxy coating (cuticule) on the individual needles. Come spring, the needles are unable to regulate water loss without this coating, resulting in drying and likely foliage mortality that reduce the health of the trees. This may be compounded by early onset of spring, where air temperatures are above zero while soil temperatures are still below zero. When the ground remains frozen, the tree is unable to replace the moisture lost from the foliage (known as frost drought). Over the past 6 years during the winter months we have collected needle samples from 20 sites to examine needle health. This work is part of our long-term monitoring of tree health. Not surprisingly, adult trees show increased epidermal conduction (essentially rates of foliage water loss) along a wind

exposure gradient from forest to tundra-adjacent (tree islands)(Figure 6). What is surprising, however, is that despite the stressful conditions surrounding tree islands, these areas represent hot spots for increased seedling establishment and possible treeline advance.
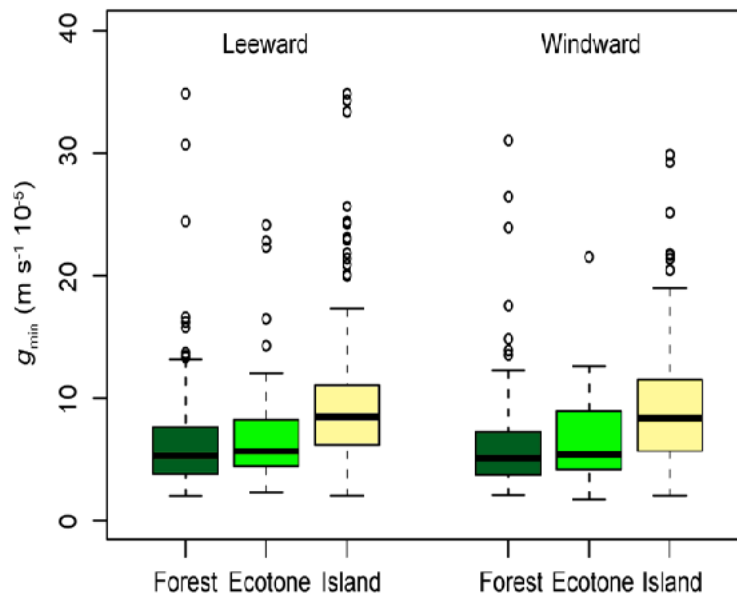

Figure 6 - Needle desiccation during winter months for white spruce trees in Churchill

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 (Brown et al. 2013). The goal of G-TREE is to disentangle substrate and seed limitations on range expansion through field experimentation. Following on our previous work where only one seedling and no seeds were found in the shrub-alpine plots in the Mackenzie Mountains, we installed exclosures at all sites (Churchill and Mackenzie Mountains) to exclude granivores from the seeded and unseeeded plots. During 2017, our assessment of the G-TREE plots found much greater seedling establishment in the exclosures (Figure 7) indicating that granivory is indeed a limiting factor on treeline expansion and is greatest in the transition zone (ecotone; see the shrub-alpine and tree island/treeline sites in Figure 7) between the forest and the alpine/tundra. With subsequent years at all our plots (Mackenzies and Churchill) we will continue to examine if and how the seedlings continue to grow and mature.
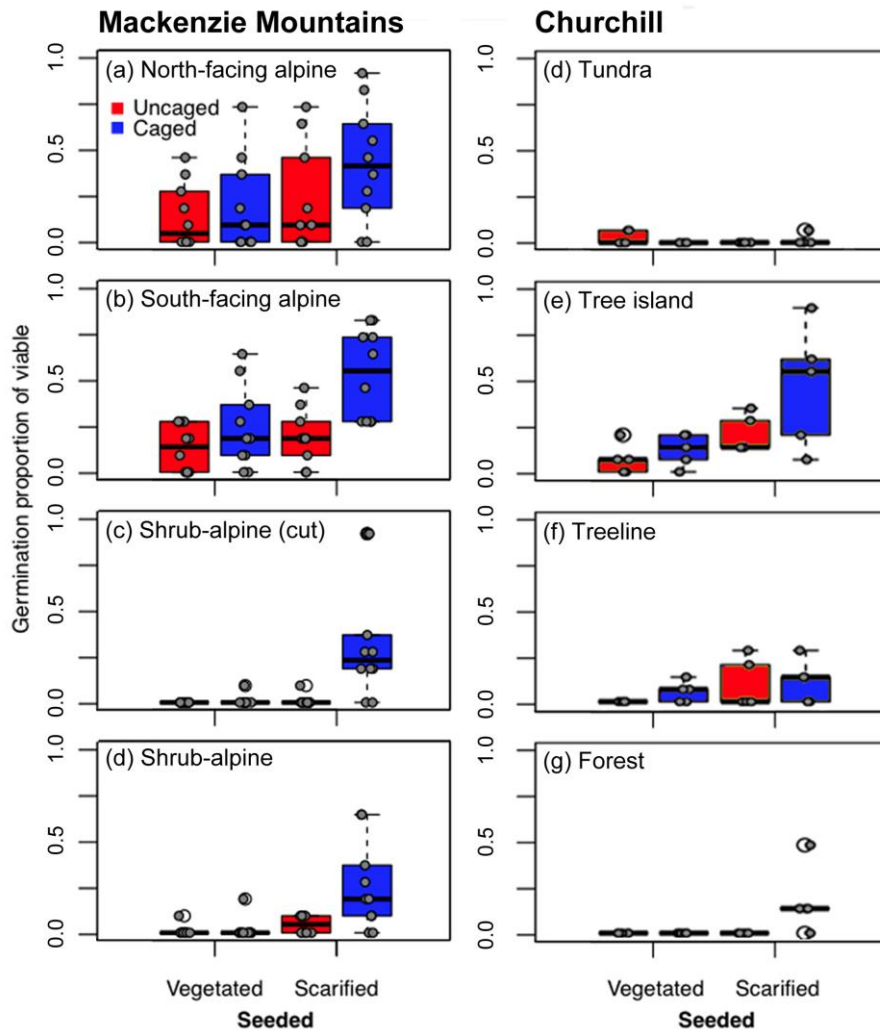
Figure 7 – G-TREE plot results in the Mackenzie Mountains and Churchill showing the results of granivore exclosures on seedling establishment in seeded plots.

We have continued to maintain the reclamation sites but the only data collection at these sites during 2017-18 was the small weather station that continues to run at one location.

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. In 2017 we continued to sample 23 wetlands in different habitats from coastal tundra to boreal forest. Each of these wetlands was sampled four times during the open water season and adds a fourth year of data from our long-term monitoring of these wetlands. This also parallels our sampling during the 62 days of our mesocosm experiment (see below) to capture the differences in natural ponds vs the mesocosms. Results from the laboratory analysis (nutrients, cations, chlorophyll a) of the water

samples collected during each natural pond sampling event were processed in September 2017 with the samples from the 2017 open water season but we are still awaiting the final data compilation. The results from the five years of data (2014-2018) will be analyzed to examine water chemistry, species assemblage and vegetation characteristics over time and space.

We also use mesocosm experiments to investigate how anticipated subarctic environmental changes may influence the growth and reproduction of dominant amphibious herbivores. In 2017 we crossed three warming treatments (ambient, 100W, 250W) with four different types of origin of tadpoles (from the coast to inland) in forty-five 400L stock tanks with 30 wood frog tadpoles to examine the impact of geographic location and climate change on tadpole growth. We measured survival, growth rates, and size at metamorphosis in the tadpoles at four time steps during the experiment. We predicted synergy between wetland warming and location of origin may influence the survival rates of tadpoles. Results from 2017 experiment are still being compiled but the preliminary analyses indicate that the geographic location from which the tadpoles were originally sampled (coast or inland forest) does not impact their response to warmer treatment. Basically we determined the tadpoles all appear to have similar response to the warming temperatures. Fish eat tadpoles regardless of their behavior classification and the warming treatment.

This field year we also conducted two pilot experiments to examine more detailed processes. The first pilot included designing and establishing frog enclosure for juvenile wood frogs. These enclosures allow us to examine the potential over-winter success rate of the young wood frogs that metamorphed from our mesocosm experiment (Figure 8). While the hot and dry conditions in September limited the survival rate in the fall, the enclosures themselves were robust and will be used in the following winter (with some modifications for hibernacula) to attempt to assess overwinter success. We had good success with a pilot experiment during our teen team to examine the uptake of nutrients by sediments in wetlands (Figure 9). This pilot identified the importance of sediment to our experimental design and will require follow up experiments in 2018 to determine the influence of sediment type before scaling up to the 400 L mesocosm experiment in 2019.

Figure 8 – Field team in Churchill constructing frog enclosures during the July 2017
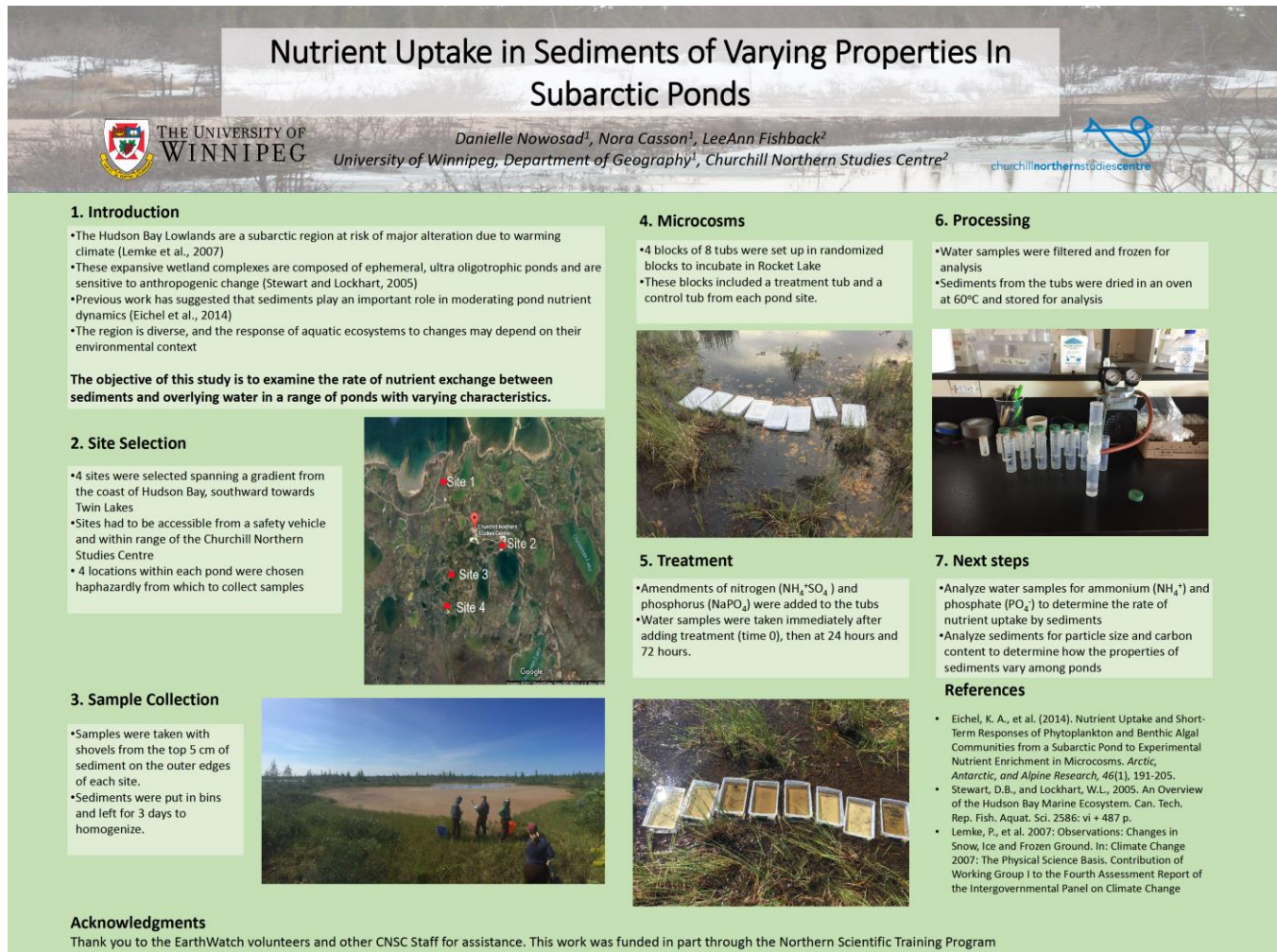
Figure 9 – Poster of the sediment uptake of nutrients experiment

To monitor frog populations in several wetlands, we use egg mass counts laid in particular ponds to estimate population change in the wetlands. In 2017, there was a significant decrease in the number of egg masses laid in the forest ponds, with little change in tundra ponds. We attribute this to the flooding that happened in the spring of 2017 following a record extreme snow event in March 2017. We were unable to get to the floodplain ponds due to the flooding but expect that there were no egg masses floodplain ponds (e.g. Goose Creek 2) (Figure10).
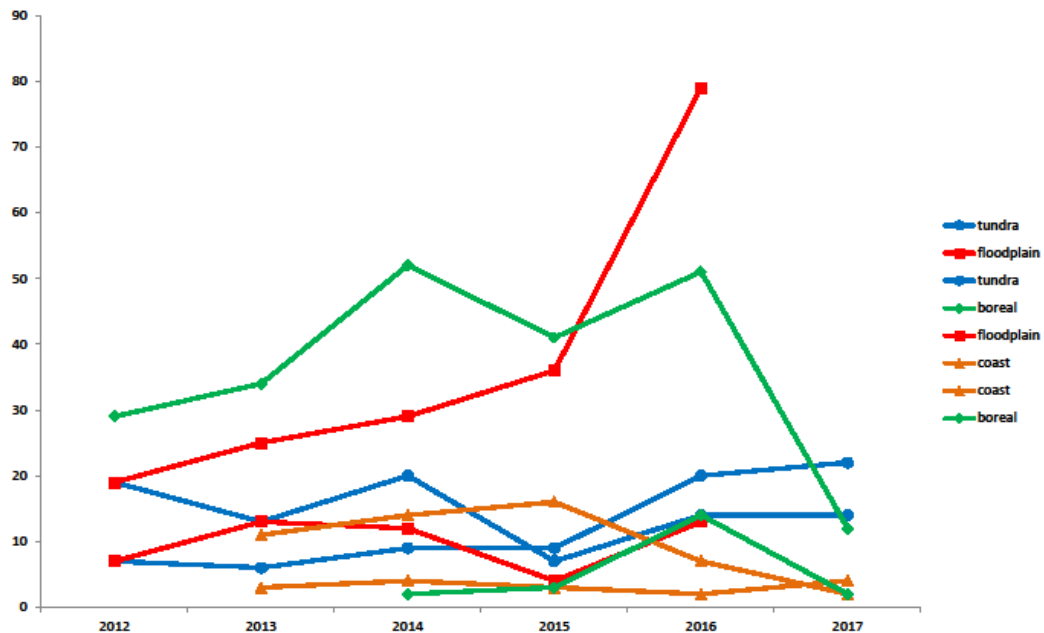
Egg Mass Counts

Figure 10 – Egg mass counts from 2012 – 2017 at 8 long-term monitoring wetlands in Churchill. Note the decline in egg masses in boreal ponds in 2017.

In 2016, we initiated a research project to examine the impact of this place-based citizen science project on the participants. Over the course of this fielding year as well we surveyed the participants to hear more about how their time on the project impacted their lives.

It is in the spirit of examining the fine-grained world where public life meets climate knowledge, policy and planning we explore what citizen science (CS) might tell us about the very public work of pursuing climate action. We examine CS precisely because rather than "informing individuals about climate science", CS positions the public as a partner in the scientific process. Within this context, we explore whether and how a climate change focused CS experience might influence climate stewardship perceptions and actions among participants, and by extension what this experience might teach us about working with the public on climate action. Using a mixture of methods including a pre-post experience survey and semi-structured interviews to we captured the impact of participants' experience. With 10 teams a year in Churchill, the opportunities for people to be engaged in CS in all seasons of the year and furthers our goal to engage the public in science beyond the role of information consumer. The program immerses participants in an intensive climate change research program for multiple

days or weeks and houses participants in an active research centre in close proximity to and contact with the surrounding tundra landscape.

One of the most powerful aspects of CS is its capacity to provide members of the public an architecture to enact stronger democratic control over the questions we ask about climate change and our communities. The results of our study showed that the philosophy of knowledge co-production holds a broader lesson for climate action work. Specifically, the lesson from the Arctic's Edge program seems to be that climate action work can be both more effective and more meaningful when professionals approach the relationships they build with the public in the same spirit that CS approaches the democratization of scientific knowledge. Ultimately, what left a mark on participants in the Arctic's Edge program was not simply the opportunity to take part in the scientific process, but the opportunity to be invited into the craftwork of each CNSC scientist. It seems clear that this craftwork conveyed information about science and climate change, but was far more impactful as an invitation to experience the dedication and passion of individuals working in a profession that is often distant from public life. Clearly, not all climate action work is the work of scientists; but behind all successful climate action work is at least one dedicated and passionate person, and a reminder that sharing who we are and why we persist is at least as important as sharing what we know.

PROJECT IMPACTS

1. Increasing Scientific Knowledge

a) Total citizen science research hours

We spend an average of 7-12 hours/day/team collecting data, being trained to collect data in the field and performing data.

b) Peer-reviewed publications

Mamet, S.D., Chun, K.P., Kershaw, G.G.L., Loranty, M.M., & Kershaw, G.P. (2017) Recent increases in permafrost thaw rates and areal loss of palsas in the western Northwest Territories, Canada. *Permafrost and Periglacial Processes*. 619–633. doi:10.1002/ppp.1951.

Groulx, M., Brisbois, M.C., Lemieux, C.J., Winegardner, A., **Fishback, L.A.** 2017. A role for nature-based citizen science in promoting individual and collective climate change action? A systematic review of learning outcomes. *Science Communication*, 39 (1), 45-76

Morison, M., Macrae, M., Petrone, R., **Fishback, L.A.** 2017. Capturing temporal and spatial variability in the chemistry of shallow permafrost ponds. *Biogeosciences*. DOI: 10.5194/bg-14-5471-2017.

Morison, M., Macrae, M., Petrone, R., **Fishback, L.A.** 2017. Hydrology drives chemical synchronicity in subarctic tundra ponds. *Biogeosciences Discussions*. 1-28.

c) Non-peer reviewed publications:

Technical reports, white papers, articles, sponsored or personal blogs

MAMET, S.D. & FISHBACK, L.A. (2017) Microclimate, snowpack, treeline dynamics, and permafrost degradation in Wapusk National Park, Manitoba. Report on Research and Monitoring in Wapusk National Park 2016-2017. 2 pp.

Please visit Dr. Steven Mamet's personal webpage for more details on his contributions to the research project: http://www.stevenmamet.com/

We continue to maintain a community Facebook page for the project. **https://www.facebook.com/arcticsedge**

d) Books and book chapters

e) Presentations:

Indicate if this was an invited paper, panel presentation, keynote speech, plenary address, or other.

Kershaw, G.G.L., Quinton, W., Mamet, S.D., & Kershaw, G.P. (2017) A remote assessment of ice-rich permafrost loss across a ~500m elevation gradient in the Mackenzie and Selwyn Mountains, Canada. 21st International Northern Research Basins Symposium and Workshop, Yakutsk, Russia, August 5–12, 2017. Oral presentation.

Kershaw, G.G.L., Mamet, S.D.& Kershaw, G.P. (2016) Treeline expansion along the Canol Heritage Trail, NWT, Canada: >70 years post-disturbance. 2016 Canadian Association of Geographers of Ontario Conference (CAGONT). Waterloo, ON. 28–29 October 2016. Oral presentation.

Kropp, H., Loranty, M.M., Natali, S., Kholodov, A.L., Abbott, B.W., Abermann, J., Blanc-Betes, E., Blok, D., Blume-Werry, G., Boike, J., Cahoon, S.M.P., Christiansen, C.T., Euskirchen, E.S., Frost Jr, G.V., Goeckede, M., Gough, L., Hjort, J., Hoye, T.T., Jones, B.M., Jorgenson, T., Juszak, I., Kokelj, S., Lund, M., Lafleur, P., Mamet, S.D., Mauritz, M., Michelsen, A., Myers-Smith, I.H., O'Donnell, J., Olefeldt, D., Phoenix, G.K., Rocha, A.V., Sannel, B., Schaepman-Strub, G., Sonnentag, O., Tape, K.D., Torn, M.S., Vaughn, L.S., Sorensen, M., Williams, M.D., & Wilson, C.J. (2016) Impacts of vegetation on the decoupling between air and soil temperatures across the Arctic. AGU Fall Meeting. San Francisco, CA. 12–16 December 2016. Oral presentation.

Mamet, S.D. (2017) Citizen Science and Ecological Change in the Mackenzie Mountains. Canadian Mountain Network, International Mountain Day Livestream. Dec. 11th, 2017. Webinar.

Mamet, S.D. (2017) In Defense of Climate Science in an Era of Alternative Facts: Q&A with Dr. Steve Mamet. Earthwatch International Webinar. Feb. 15th, 2017. Webinar.

Fishback, L.A. 2017. Outreach citizen science event for a two day all school workshop at FW Parker School in Chicago, October 25 and 26, 2017.

Mamet, S.D., BROWN, C.D., TRANT, A.J., JOHNSTONE, J.F., CONWAY, A.J., BERNARD, J., FISHBACK, L.A., KERSHAW, G.G.L., & KERSHAW, G.P. (2018) Non-climatic constraints on treeline advance in western Canada. 48th International Arctic Workshop. Apr. 5–6, 2018. Boulder, CO. *Oral Presentation*.

2. Mentoring

a) Graduate students

List graduate students doing thesis work on the project and include student CVs and their research proposal on file with the university as an attachment when you submit your annual report

Student Name	Graduate Degree	Project Title	Anticipated Year of Completion
Stephanie Bishir	MSc	Wood frog movements and habitat selection across arctic–subarctic ecotones	2017
Hilary White	PhD	Contemporary and paleolimnological approaches for assessing the hydrological and limnological susceptibility of shallow subarctic lakes in Wapusk National Park, Manitoba to climate change and Lesser Snow Goose population expansion	2018

b) Community outreach

Provide details on how you have supported the development of environmental leaders in the community in which you work.

Name of school, organization, or group	Education level	Participants local or non-local	Details on contributions/ activities
ISAMR and Junior Rangers	High school	Local and non-local	Led snowpack sampling in Wapusk National Park with Junior Rangers
CNSC staff	university	local	CNSC staff reside and are part of the local community and provide connection with the community particularly during showcase events like the CNSC Community Day.
Duke of Marlborough School - Churchill	High school	local	Lead PI visited with several classes at the local school, CNSC teaches full credit science course in June 2017 and several of the EW field staff helped 10 students collect field data for our project

3. Partnerships

List your current active professional partnerships that contribute to your project and indicate the type of support these partners provide

Partner	Support Type(s)[1]	Years of Association (e.g. 2006-present)
Churchill Northern Studies Centre	Team logistics, gear rental, health and safety support, research and administrative staff time	1999 – present
Wapusk National Park	Funding, logistics, collaboration	2006 - present
University of Saskatchewan	Academic support, technical support	2012 – present
Southeast Missouri State University	Collaboration, permits, funding, academic support	2013 - 2018
United States Geological Survey - Aldo Leopold Wilderness Research Institute	Collaboration, data, academic support, funding	2014 – present

[1.] Support type options: funding, data, logistics, permits, technical support, collaboration, academic support, cultural support, other (define)

4. Contributions to management plans or policies

List the management plans/policies to which your project contributed this year

Plan/Policy Name	Type[2]	Level of Impact[3]	New or Existing?	Primary goal of plan/policy[4]	Stage of plan/policy[5]	Description of Contribution
Wapusk National Park Management Plan	Management Plan	regional	existing	Natural resource conservation	In place	Ecosystem integrity monitoring
North American	Other – policy development	International	development	Natural resource	In progress	Experimental results to

				conservation		broaden geographic coverage
Treeline Network (NATN) through Global Observation Research Initiative in Alpine Environments (GLORIA)						

[2] Type options: agenda, convention, development plan, management plan, policy, or other (define)

[3] Level of impact options: local, regional, national, international

[4] Primary goal options: cultural conservation, land conservation, species conservation, natural resource conservation, other

[5] Stage of plan/policy options: proposed, in progress, adopted, other (define)

5. Conserving natural and sociocultural capital

a) Conservation of taxa

    i.   List any focal species that you did not list in your most recent proposal

Species	Common name	IUCN Red List category	Local/regional conservation status	Local/regional conservation status source
Pseudacris maculata	**Boreal chorus frog**	**Least concern**		
Lithobates sylvaticus	**Wood frog**	**Least concern**		
Culaea inconstans	**Brook stickleback**	**Least concern**		
Pungitius pungituis	**Ninespine stickleback**	**Least concern**		
Picea glauca	**White spruce**	**Least concern**		
Picea mariana	**Black spruce**	**Least concern**		
Larix laricina	**Tamarack/larch**	**Least concern**		

    ii.   In the past year, has your project helped conserve or restore populations of species of conservation significance? If so, please describe below.

Species	IUCN Red List category	Local/regional conservation status	Local/regional conservation status source	Description of contribution	Resulting effect[6]

[6] Resulting effect options: decreased competition, improved habitat for species, range increased, population increase, improved population structure, increased breeding success, maintained/enhanced genetic diversity, other

b) Conservation of ecosystems

In the past year, has your project helped conserve or restore habitats? If so, please describe below.

Habitat type	Habitat significance[7]	Description of contribution	Resulting effect[8]
Arctic tundra	All	Baseline data collection of key environmental variables	Extent maintained
Boreal forest	All	Baseline data collection of key environmental variables	Extent maintained
Arctic treeline	All	Baseline data collection of key environmental variables	Extent maintained

[7.] Habitat significance options: nursery, breeding ground, feeding site, corridor, migration path, refuge, winter range, summer range, spring range, fall range or other (define)

[8.] Resulting effect options: extent maintained, condition achieved, restored, expanded, improved connectivity or resilience

c) Ecosystem services

Indicate which ecosystem service categories you are **directly studying** in your Earthwatch research and provide further details in the box below.

☒Food and water

☐Flood and disease control

☐Spiritual, recreational, and cultural benefits

☒Nutrient cycling

Details:

> The research is of a primary nature, directed at scientific inquiry and as such does not include ecosystem services support. Our project provides information on nutrient cycling in naturally occurring tundra ponds. In 2017-18 we will conduct a synthesis of these results and present them to the community and also as an academic publication.

d) Conservation of cultural heritage

Provide details on intangible or tangible cultural heritage components that your project has conserved or restored in the past year.

Cultural heritage component[9]	Description of contribution	Resulting effect
None in this project		

[9.] Cultural heritage component options: traditional agriculture, artifacts, building(s), hunting ground or kill site, traditional ecological knowledge and practices, monument(s), oral traditions and history, spiritual site, traditional subsistence living

RESEARCH PLAN UPDATES

Report any changes in your research since your last proposal/annual report. For any 'yes' answers, provide details on the change in the 'Details' box. This section will not be published online.

1) Have you added a new research site or has your research site location changed? ☐**Yes** ☒**No**
2) Has the protected area status of your research site changed? ☐**Yes** ☒**No**
3) Has the conservation status of a species you study changed? ☐**Yes** ☒**No**
4) Have there been any changes in project scientists or field crew? ☒**Yes** ☐**No**

Details – provide more information for any 'yes' answers

We have added new summer and seasonal field staff at the Churchill site for 2017 – Tomas Taylor, Kenzi Stemp, Dani Nowosad, Alexandra Windsor, Evan Roberts. Continuing field staff were Jon Davenport, Blake Hossack, Stephanie Bishir, Hilary White, Fiona LeTaro and Geoff Kershaw.

5) Provide details on any changes to your objectives, volunteer tasks, or methods, include reason for the change.

There are no substantive changes to our objectives, volunteer tasks, or methods for the 2015 season.

ACKNOWLEDGEMENTS

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ANYTHING ELSE

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