20th INTERNATIONAL TUNDRA EXPERIMENT MEETING

POSTERS

01

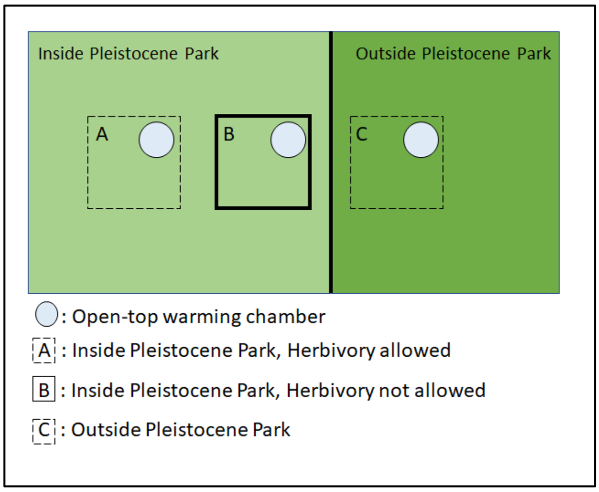
Investigating the role of large herbivores in the past, present and future of Arctic vegetation dynamics

Alessandro Mereghetti[1,2], Jacquelyn L. Gill[1,2]

[E-mail for correspondence: alessandro.mere@gmail.com]

1. University of Maine, Climate Change Institute, Bryand Global Sciences Building, Orono, ME 04469 USA
2. University of Maine, School of Biology and Ecology, 5751 Murray Hall, Orono, ME 04469 USA

Large herbivores are known to influence vegetation structure and composition by affecting nutrient cycling and interspecific interactions. Despite a growing number of studies, the scale and magnitude of these effects on Arctic vegetation are not fully understood yet. During the Late Quaternary, the Arctic was dominated by the "Mammoth Steppe" biome, a productive steppe-tundra inhabited by a rich megafaunal assemblage. One hypothesis is that this biome was maintained through the action of the megafauna on the landscape, and its disappearance led to a shift towards today's mesic tundra. To test this hypothesis, an experimental fenced area known as "Pleistocene Park" was established in 1996 in north-eastern Yakutia. There, researchers reintroduced large herbivores that disappeared from the region at the end of Pleistocene to recreate the Mammoth Steppe environment.



Our project will use this unique setting to understand how a functionally diverse and abundant herbivore community affects Arctic vegetation structure and its response to climate change.

Permanent plots will be set up inside and outside the herbivore-abundant area, with open-top chambers built following ITEX guidelines to increase temperature coherently with future regional scenarios without restricting herbivores access to vegetation. Some of the plots inside the herbivore-abundant area will be fenced to study the effect of herbivores on the trajectory of vegetation dynamics under present and warmer temperature. We will collect data on plant traits, cover, light availability and biodiversity in every plot before setting up the experiment and for at least 3 years after its beginning. Then, plots with similar environmental conditions inside and outside the Park will be compared to understand the effect of herbivores on vegetation. The results will be combined with paleoecological data obtained from sediment cores and coprolites analyses to shed light on the role of herbivores in shaping past, present and future Arctic vegetation dynamics.

02
Understanding Arctic browning from the macro to micro scale

Aurora Patchett[1], Mats Björkman[1], Louise C. Andresen[1]

[E-mail for correspondence: aurora.patchett@gu.se]

1. University of Gothenburg, Department of Earth Sciences, Box 100, S-405 30, Gothenburg, Sweden

The occurrence of extreme winter warming events has increased in the sub-Arctic. The rapid temperature increases associated with these events can result in the reduction or total loss of snow cover, leading to stress responses in plants or extensive dieback of vegetation (described as a “browning event”) when temperatures return to seasonal. Shifts in the carbon and nitrogen balance are an example of the potential ecological consequences of browning events. However, few studies have connected these higher level plant responses with nonvascular plant communities and their associated belowground soil organisms; significant contributors to the C and N cycles. The occurrence of these events is predicted to increase in frequency, but it is yet unclear how resilient Arctic ecosystems are now or will be in the future. To address these gaps, we first need to understand the extent of the current browning by mapping the spatial and temporal aspects of these events; we then need to develop a model based on the biogeoclimatic data collected from these areas - highlight vulnerable regions; and then ask finer scale ecological questions through manipulative studies. In my doctoral work I will investigate the resilience of biological soil crusts (BSCs), which are made up of a community of organisms that inhabit the regions of the soil surface and subsurface. As an early successional community, these organisms are well adapted to harsh environments, contributing to the carbon and nutrient cycles, as well as having an added role in creating habitable environments for higher level organisms. However, their role in browning events remains unexplored. In situations of extensive vegetation dieback due to extreme winter warming events, it is possible that surviving BSCs can act as ecosystem stabilizers. Alternatively, if BSCs are highly sensitive to extreme winter warming, this could have potential consequences for biogeochemical cycling. Insights into BSCs level of resilience can inform us on the potential ecosystem responses of these cold regions where they contribute to species diversity.

Specific goals:

1. Map the extent of Arctic browning caused by extreme winter warming events using satellites and drones
2. Determine the impact of browning events on BSCs and the soil biogeochemical system through field monitoring and experimentally simulating extreme winter warming events

03

A recommended methodology for dendroecology analysis using common tundra shrub species

Elise Gallois[1], Greg Henry[1]

[E-mail for correspondence: elise.gallois94@gmail.com]

1. UBC Department of Geography, 1984 West Mall, Vancouver, BC V6T 1Z2

Tundra ecologists and paleoclimatologists are increasingly utilizing dendrochronology as a means to quantify annual physiological responses of tundra shrubs to air temperature, soil conditions, competition and recruitment. The methodology can be applied to a number of shrub species common across ITEX sites, including *Salix arctica*, *Cassiope tetragona*, *Dryas integrifolia* and *Betula nana*. In this poster, we will present a protocol for shrub-specific dendrochronology methods, from sample selection to analysis, using Cybis CooRecorder and CDendro image analysis software, and following classic tree ring data preparation techniques. The poster will also focus specifically on the protocol for the measurement of annual stem growth and flowering patterns of *C. tetragona*, including a specific model design incorporating both growth and reproductive indices as a means to predict annual summer air temperature variability. We will also present a brief comparison of the proxy's relationship with summer temperature at a range of ITEX sites.

04

Epigenetic and genetic responses in tundra plants to 30 years of experimental warming

Cassandra Elphinstone[1], Greg Henry[1], Marco Todesco[1], Loren Rieseberg[1], Collectors

[E-mail for correspondence: cassandra.elphinstone@shaw.ca]

1. University of British Columbia, Vancouver, BC, Canada

Understanding how species adapt to their environment will be essential to help mitigate the impacts of climate change in the future. Epigenetics is the study of gene regulation (e.g. methylation) and the heritability of this regulation. It may play an important role in passing on environmental adaptations to future generations. Epigenetic adaptations to temperature could mitigate the effects of climate change providing opportunities for species to evolve more permanent genomic adaptations. Two central questions that need to be addressed are how and over what time frame, can species adapt to the warmer temperatures associated with climate change. Is there a genomic and/or epigenetic basis to temperature adaptations in Arctic plants?

International Tundra Experiment (ITEX) sites throughout the Arctic have maintained warming open-top chambers (OTCs) on the tundra for up to 28 years. *Dryas octopetala* and *D. integrifolia* seed/leaf collection in and out of OTCs was completed at ITEX sites in Nunavut, Sweden, Svalbard and Alaska. In Nunavut, *D. integrifolia* plant traits were measured (e.g. leaf size, flowering times, seed number and size).

Whole-genome bisulfite sequencing will be used to relate individual genomic sequences and methylation patterns (epigenetics) to local adaptation. Offspring of the wild plants will be grown in a growth chamber and will have their methylation patterns sequenced. From this, we will be able to determine if the environmentally induced methylation patterns in the parents can be inherited by the offspring.

Linking plant traits with temperature is crucial if we want to improve the future survival and reproductive success of plants worldwide. Results from this study will provide guidance as to whether and how plant populations can adapt to cope with the rate of climate change, or whether interventions such as assisted migration will be necessary to ensure their survival.

05
Beyond the tundra: using OTCs in forest ecological experiments

Esther R. Frei[1], Luc Schnell[1], Yann Vitasse[1], Thomas Wohlgemuth[1], and Barbara Moser[1]

[E-mail for correspondence: esther.frei@wsl.ch]

1. Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zuercherstrasse 111, 8903 Birmensdorf, Switzerland

Besides tundra ecosystems, climate change is also increasingly affecting forest ecosystems. In this context warming experiments testing the responses of tree species to rising temperatures are urgently needed. While temperature is the main driver of temperate tree phenology in spring, growth cessation and leaf senescence in autumn depend on several other factors, photoperiod and water stress among them. As a result, leaf unfolding may be linearly related to temperature while leaf senescence is not, leading to a non-linear and species-specific correlation between temperature and growing season length. To study the effects of species-specific growing season length on juvenile growth and survival, we plan to setup in situ warming experiments with several tree species in clear-cuts of temperate forests. While Open Top Chambers (OTCs) are an established method for simulating elevated temperatures in the tundra, they have only rarely been used in forest ecosystems. Here, we present an approach to adapt the OTC method to experimentally warm plant communities in forest gaps by using large OTCs with a diameter of 5 m and a height of 2 m. As passive warming is likely to be spatially uneven in a partly shaded environment, we complemented the OTC with an active warming treatment. We present the results of a preliminary experiment, in which we compared different warming methods such as heating cables and electric heaters and checked whether homogenous warming can be achieved across large OTCs.

06
Assessing landscape-level vegetation change via remotely-sensed hyperspectral data and traditional ground-based measurements

Hana Christoffersen[1], Robert Hollister[1]

[E-mail for correspondence: christoh@mail.gvsu.edu]

1. Grand Valley State University, Department of Biology, 1 Campus Drive, Allendale, MI 49401 USA

Climate change is affecting the growth and productivity of Arctic vegetation. Vegetation monitoring studies have provided evidence of cover change at the ground level, yet advances in remote-sensing propose an alternate means to mapping, tracking, and predicting change. To better understand the efficiency and limitations of remotely sensed data in assessing vegetation change, hyperspectral indices (2017) were extracted from the National Ecological Observatory Network (NEON) Aerial Observation Platform (AOP) and correlated with vegetation cover change data (1995 – 2017) from a long-term monitoring experiment in Utqiaġvik, Alaska. Moisture Stress Index (MSI) and Normalized Difference Infrared Index (NDII) were established as the best predictors of graminoid cover change in experimentally warmed conditions at the Utqiaġvik dry site. No significant predictors were established for lichen cover change. This indicates that there may be substantial cover change if soil moisture parameters shift. Future analysis includes how hyperspectral measures may explain cover change across a latitudinal gradient of northern Alaska and explores the challenges and limitations of NEON AOP data.

07

Influence of plant-herbivore interactions and summer warming on short-term tundra plant-community nutrient levels and dynamics

Matteo Petit Bon[1,2]

[E-mail for correspondence: matteo.petitbon@unis.no]

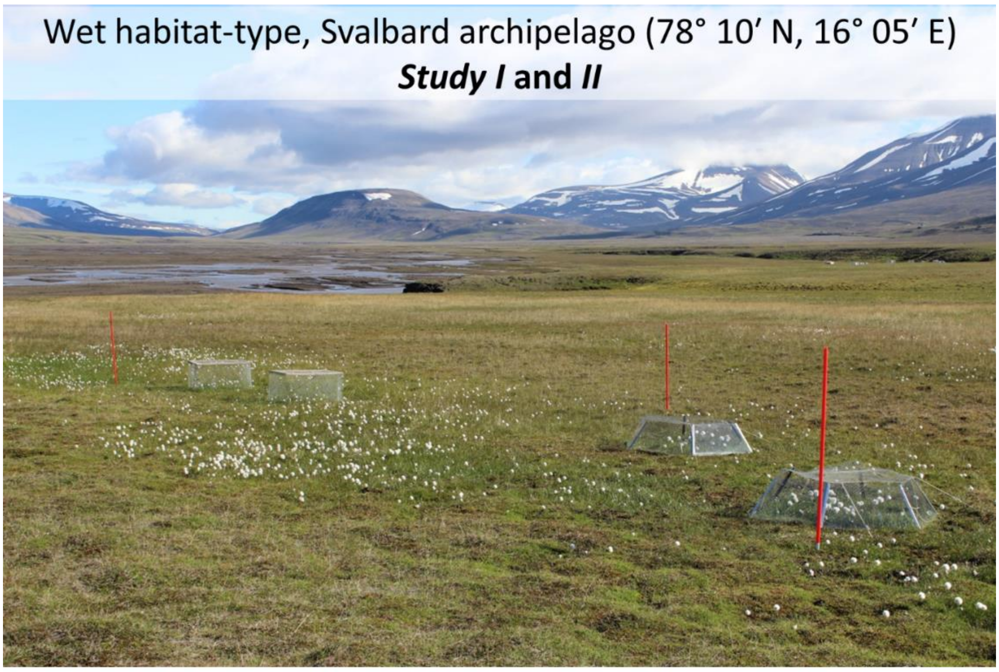
1. Department of Arctic Biology, The University Centre in Svalbard (UNIS), PO Box 156, N-9171 Longyearbyen, Norway
2. Department of Arctic and Marine Biology, Faculty of Biosciences, Fisheries, and Economics, The Arctic University of Norway (UiT), N-9037 Tromsø, Norway

Mammalian herbivores have long been recognized as fundamental drivers of energy flow and nutrient cycling in terrestrial ecosystems. More recently, global climate changes have also been identified as important modifiers of terrestrial-ecosystem process rates. In the Arctic, theories on how herbivores and climate warming influence nutrient cycling are largely tested on long-term alteration in the functional composition of plant communities, resulting in changes in quality and quantity of nutrient input through plant litter. However, to what extent plant-herbivore interactions and summer warming affect short-term tundra plant-community nutrient levels have been overlooked. The main purpose of this work was to assess how plant-herbivore interactions and summer warming affect short-term tundra plant-community nutrient levels.

Firstly, I investigated the response capacity of different ecosystem compartments (i.e. soil, mosses, and vascular plants) to herbivory and summer warming in terms of their carbon (C) and nitrogen (N) content and C:N ratio (***Study I***). In the same setting, I assessed (i) the sensitivity of diverse plant functional types (PFTs) to herbivory and summer warming in terms of their leaf N and phosphorous (P) levels and (ii) how such nutrient level changes, combined with plant biomass responses, may alter plant-community nutrient pools (***Study II***). For this purpose, I undertook a field experiment in the high-Arctic archipelago of Svalbard, in which spring goose herbivory and summer warming were simulated for two consecutive growing seasons in a range of habitat-types.

Secondly, I asked to what extent interactions between herbivores affect (i) leaf N and P seasonal dynamics of diverse PFTs (***Study III***) and, more specifically, (ii) leaf silica (Si), N, and P content (and Si:N and Si:P ratios) in grasses (***Study IV***). To achieve this purpose, I established a field experiment within tundra grasslands in northern Norway combining small-rodent winter herbivory and reindeer summer herbivory.

By using Near Infrared Reflectance Spectroscopy (NIRS) methodology, which allowed me to process a large amount of samples, thus working at the plant-community level, but still be able to assess nutrient content in single leaves, this work demonstrated a breakthrough in the assessment of short-term tundra plant-community nutrient responses to herbivores and summer warming. Implications for tundra-ecosystem process rates and how my findings align with long-term herbivore- and warming-driven changes in tundra-ecosystem nutrient cycling are discussed.



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08
Functional traits of arctic plants offspring

Lucie Smržová[1], Petr Macek[1]

[E-mail for correspondence: lucka.low@gmail.com]

1. Centre for Polar Ecology, Faculty of Science, University of South Bohemia, Branišovská 1760, CZ-370 05 České Budějovice, Czech Republic

Arctic plants frequently reproduce by vegetative means, yet with ongoing climatic changes driven largely by rising temperatures a balance between sexual and vegetative reproduction is shifting. Warming experiments indicate positive effects on arctic plant reproductive traits, i.e. greater reproductive effort and especially reproductive output, which can be crucial in the life of plants and would probably determine survival and migration possibilities for many species in the near future.

In a recently started PhD project we plan to examine existing reproductive traits of plant species naturally occurring in central Svalbard as well as of those growing under experimentally warmed conditions. We ask on a versatility of (vegetative and) reproductive traits using traits of F1 generation plants from both controlled and warmed conditions.

Greater reproductive effort under warmer climate may also lead to changes in tundra community composition due to migration of new species. We hence ask on a relative importance of dispersal limitation and habitat quality for species occurring in naturally warmer locations neighbouring warmed experimental plots.

Finally, reproductive output of plants grown at warmer conditions is also driven by survival in future environmental conditions. Therefore, ecophysiological limits of plants germinating from seeds formed under warmer conditions will be assessed.

A set of both field and laboratory manipulative experiments (reciprocal transplants, common garden) to approach these goals will be presented.

09
Ecosystem carbon budgets across a permafrost thaw gradient in Northern Norway

Casper T. Christiansen[1], Hanna Lee[1]

[E-mail for correspondence: cach@norceresearch.no]

1. NORCE Climate, Norwegian Research Centre, Bjerknes Centre for Climate Research, Bergen, Norway

Permafrost soils store approximately twice the amount of carbon (C) relative to the atmosphere. Climate warming leads to permafrost thaw and the potential release of large amounts of permafrost C to the atmosphere as CO_2 and CH_4, further accelerating climate change in a positive feedback. However, uncertainty in the mechanisms controlling C mineralization is compounded by concurrent changes in soil hydrology associated with permafrost thaw. Thawing permafrost can lead to subsidence and surface water accumulation in some areas and soil drying in other areas where permafrost thaw opens up new channels of water to flow through. The complexity of the hydrologic response to permafrost thaw increases the challenge in generating reliable estimates of the permafrost carbon-climate feedback. Another complication is the fact that limited observational data exist to quantify the effects of permafrost thaw on net tundra carbon budgets, let alone to constrain the underlying processes governing C release under aerobic and anaerobic conditions.

We established a field gradient study in northern Norway (Iskorasfjellet; 69° N) where recent degradation of permafrost created thaw ponds in a palsa-mire wetland. Our objectives are to improve our process understanding of how changes in local hydrology affect annual CO_2 and CH_4 release from thawing permafrost soils. We use a natural gradient of permafrost thaw, corresponding to a local hydrological gradient, going from dry palsa with intact permafrost over seasonally inundated thaw slumps and into thaw ponds without permafrost. Since 2017, we have used a range of manual and automated techniques to measure changes in vegetation, soil and water microclimate, biogeochemistry, and greenhouse gas exchange across plot and catchment scales, and using open-top-chambers.

Our preliminary observations, and modelling results, suggest that permafrost thaw and landscape subsidence – both intermediate slumping and pond formation – currently increases net annual carbon loss in this widespread subarctic wetland type.