Herbivory Workshop Notes, 09.04.2014

9:00-9:50 Introduction and participant presentations

Opening of Herbivory Workshop: presentation and overview of workshop goals (Isabel C Barrio)

- Presentation of the network idea, how it all got started and why organizing this workshop. Originally, the idea of the network was to focus on the interactions between plants and herbivores, but also to include external drivers, such as climate or human management, to integrate plant and animal ecologists, climate and social scientists.
- Presentation of workshop goals: the main goals of the workshop were to identify knowledge gaps, develop and discuss the need of consistent protocols for measuring herbivory, and to establish the research priorities of a network for assessing the role of herbivory in tundra ecosystems.
- Expected workshop outcomes: a workshop report (potentially turned into a publishable, multi-authored opinion paper), start an article on hotspots of herbivory in the Arctic (to be developed after the workshop by a core writing group, but to which all workshop participants are invited to contribute), the development of a common protocol for assessing herbivory, and the starting point for a collaborative research network.

Brief presentation of ongoing research questions by workshop participants

- Participants were given one minute each to present their research and study sites, based on the slides they were requested to prepare in advance of the workshop (28 slides in total).
- Slides of interested researchers that were not present that day were also presented (13 slides).

9:50-10:00 Summary of feedback on participants main research focus/interest

Key research questions and topics – setting the network's scientific strategy (Virve Ravolainen and Martin Moersdorf)

Based on the feedback provided by participants in advance of the meeting, the processes perceived to be most important in connection to herbivory were summarized. These processes could be split up into three categories, according to their focus on different responses:

- Herbivory and its effects on general processes: many processes identified by participants as relevant in their study area related to the effects of herbivory on soil nutrient turnover (~30%), the effects and interactions of climate change with biotic interactions, land use or trophic mismatches (~25%), and other processes, including trophic interactions, evolutionary adaptations and "complicated feedbacks" involving different compartments of the ecosystem.
- Herbivory and its effects on plant properties: key processes included changes in plant community structure (~25%) and dynamics, changes in plant productivity and biomass removal, and changes on characteristics of individual plants (e.g. growth, resistance and tolerance mechanisms, or reproductive traits).
- Herbivory with respect to animal populations: processes identified related to the impact of animal spatial distribution, food availability, herbivore population dynamics, interactions between herbivores and behavior and management of herbivores and predators.

The most important herbivory-related research questions for the next 10 years, based on the feedback provided by participants in advance of the meeting, were summarized. Questions are manifold, but most keywords within research questions referred to plant and animal responses; some others included the effects

of weather and climate change, and the relationship with people and human communities. Some general patterns could be deduced:

- The combined effects of climate and herbivores on plant responses
- Differential responses of plants to different herbivores
- Indirect effects of climate change on plant responses that occur through the effects of climate on herbivores

Some challenges were identified by workshop participants when trying to use these questions to set the focus of a research network. For example, some important processes were less mentioned in these questions, because the "bigger picture" questions might be more important in the future, or more relevant to be addressed by the network. Many researchers, including most workshop participants, work on specific research questions, but the network could provide opportunities to address overarching questions in a global perspective, causing a mismatch between individual researcher's questions and the research priorities of the network. Also, there might be a bias in the direction of the patterns identified, because plant ecologists were more represented among workshop participants.

10:30-11:00 Network strategy

The Herbivory Network should focus on research – it is therefore of utmost importance to identify at this point the common scientific interests. Eventually the network could help in applying for funding for a circumpolar research proposal. To define common scientific aims or main research lines for the Herbivory Network, a series of criteria were identified (summarized from participants' comments):

- **Patterns:** there are regional differences in food-web dynamics – a relevant question would be how these dynamics vary in space across the Arctic. The Network should thus focus on processes that are likely to vary regionally. In this respect, a source of variation could be the differences between island and mainland systems. The Arctic is very heterogeneous, and this provides opportunities to analyze the variability and spatial patterns.
- **Processes:** Mechanisms on plant-herbivore interactions and feedbacks with the environment are relatively well studied; however, there is little knowledge on how these processes vary throughout the Arctic. Different driving forces might have varying importance in different regions and responses might vary as well. By focusing on the spatial patterns of processes with known mechanisms, we might be able to disentangle the relative importance of different drivers.
- **Simple, replicated experiments:** ideally, a network should provide the opportunity to address the same (simple) question at different sites, covering broad gradients of variation (i.e. the spatial patterns above) and, importantly, covering the extreme ends of these gradients. Measured parameters should be comparable across sites, to facilitate synthesis.
- **Temporal changes:** a network should focus on long-term research, to allow assessment of temporal changes. The Network should provide a legacy for the future, and ensure the continuity of funding in the mid/long term if, for example, the funding is cut at some study sites, at least others can continue or support the common goal.
- **Spatial scales:** a network should bridge the gaps between research that focuses on different spatial scales. The network should have a common approach and measure parameters that can be up- and down-scaled.
- **Common theoretical model:** research within a network has to be based on a common theoretical framework and a common scientific approach. For example, in the case of herbivory, different approaches would involve an energetics perspective (mass-energy balance) or an impact perspective.

Additional points identified as relevant for the Network were:

- **Training opportunities:** a network should facilitate transnational access and exchange of research experience of people who work at different study sites.
- **Communication:** exchange of information within a network is very important. A network should promote communication among researchers with different expertise.

11:00-12:30 Developing a common conceptual model and overarching research question

Participants broke up into four discussion groups to define a common conceptual model and an overarching research question for the Herbivory Network. Conclusions of each group can be summarized:

Group A: presentation of a conceptual model that includes focus on energy fluxes, nutrient turnover and plant responses/diversity. The overarching question for the Network would be: how do herbivores modulate the responses of tundra ecosystems to rapid environmental change?

- ✓ Discussion on this proposal: Divide the Arctic into sections/regions. Research questions could include focus on differences between these geographical regions, including field and remote sensing methods for the different small and large spatial scales.

Group B: the variety of plant properties (abundance, community composition, palatability, seasonality and phenology) should be taken into account and develop a common approach to measure these. A relevant research question would be: how does the variation in herbivore composition relate to the variability of plant community composition? This group also pointed out that complex feedbacks can go both directions (from the animal or the plant side); a challenge remains on how to measure these mechanisms.

Group C: focusing on predator-herbivore-plant-soil and nutrient turnover connections. The relative importance of top-down and bottom-up mechanisms within this trophic framework might be different between regions. There are certain knowledge gaps: the importance of winter conditions, some geographic knowledge gaps (e.g. Russia), the role of island systems, or the importance of arthropod herbivory. This group also identified a different aspects of plant-herbivore interactions: eating, trampling, faeces deposition…

Group D: separate two pillars: 1) herbivores and effects on soil and nutrient cycles, and 2) herbivores and effects on species composition and functionality of plant communities. The effects on both pillars can be direct and indirect. It is important to identify what response variables can be measured and how (e.g. biomass, abundance, productivity…). Once direct and indirect effects are well known, the most important question to ask within a network would be: how does the frequency and intensity of herbivory vary in time and in space (patch - local – region)?

14:00-14:50 Presentation (and brainstorming) on the herbivore hotspots idea

Herbivore hotspots (and coldspots) in the Arctic (Isabel C Barrio)

A brief presentation introduced the idea of defining hotspots of herbivore diversity in the Arctic. So far, this analysis has only been pursued for mammals and birds, because comparable information for invertebrate herbivores at such a broad spatial scale is lacking. The immediate question is what explains the occurrence of these hotspots of herbivore species richness, and a first approach is to use the Normalized Difference Vegetation Index (NDVI) as a surrogate of plant productivity. Overall, some trends are found: herbivore species richness is related to NDVI, but this relationship is not obvious for the Subarctic. Also, these relationships are slightly different for bird and mammal herbivores.

Comments and input from workshop participants:

- Considering the lack of relationship between herbivore diversity and NDVI in the Subarctic – some differences in intensity of human land-use, occurrence of insect outbreaks, bedrock effects and diversity of predators could explain differences among the different regions (Subarctic vs low and high Arctic). Some of this information (e.g. bedrock types, predator diversity) might be available for the study area and the influence of some of these variables could be also tested. In general, an increase in complexity and heterogeneity can be expected for the Subarctic, which may partly explain these results.
- How are the different regions (Subarctic, Low Arctic and High Arctic) defined? The definition itself (if based on climate alone or on vegetation structure, for example) might influence the different relationships between herbivore diversity and NDVI. Also, considering ecoregions or floristic regions, the history and evolution of species can be taken into account; this may contribute to explain the variability related with dispersion, migration and adaptation of species.
- Is there an alternative measure to NDVI, or are there other predictors that can be interpreted in a more straightforward way? For example, NDVI may represent different things if shrubs are present than if we are only considering herbaceous plant species.
- It is important to consider the temporal resolution of the data and to know for what it is relevant for?
- What is the influence of human management on some of these herbivores and geographically, where is human management most important? Could this help explain the observed patterns?
- The taxonomical classification might have an important influence on the results! Probably a better approach is to define the functional diversity of herbivores (e.g. migratory vs. resident, or cyclic vs. non-cyclic herbivores), rather than species richness.
- What are our predictions on the shape of the relationship between NDVI and herbivore diversity? Is there any theoretical framework addressing this point? Could NDVI reflect the availability of niches for herbivores? What is the productivity-diversity relationship in the Arctic? How does productivity relate to diversity on another trophic level? Is this still valid with respect to theory about the productivity-diversity relationship?
- A different question: where in the landscape does herbivory take place (e.g. hilltops vs. lowlands) and when? Effects of topography and seasonality.

This idea will be developed after the workshop by a core writing group, but contributions of other workshop participants are welcome. Further contributions will be done after the workshop by e-mail.

14:50-15:30 Towards a standardized, adaptable protocol for measuring herbivory

Presentation of the summary of working group output during the morning session, to set a question for the protocol. Overall, a broad research question can be identified based on the relation of herbivory with the main external drivers: how do herbivores modulate the responses of tundra environments to rapid environmental change? More focused on herbivory itself, another question was identified: how does the (temporal and spatial) variability in plants and herbivores affect each other?

Adaptive monitoring: different approaches to long-term studies (Virve Ravolainen)

Adaptive monitoring is question-driven and can provide guidance for planning long-term studies. This approach is what we are proposing for the study designs and protocol development of the Network.

What are we already measuring? Responses to the questionnaire (C. Guillermo Bueno)

A questionnaire was sent to 35 experts on herbivory in tundra ecosystems (some of whom were participating in the workshop) in October 2013, to get their views on how to measure herbivory, how they normally do it, and what a herbivory protocol should look like. Some interesting patterns could be derived from their responses:

- Geographical locations: Within the Arctic, most studies were carried out in Subarctic areas, followed by Low Arctic and less in High Arctic, probably related to accessibility to sites. Importantly, many studies were carried out in locations considered as alpine (rather than "arctic").
- Mostly studies measure the impacts of herbivory on smaller scales (plot –cm to m-, site –hundreds of m- or landscape management units –km-), less so for the whole tundra biome. This highlights the need of synthesis work for this larger scale.
- Methods to measure herbivore presence are also scale dependent. A variety of methods are used, ranging from direct observation to recording of signs of activity. Interestingly, long time series data (>10 yrs) are frequent.
- Many methods are used as well for measuring herbivory (feeding damage). Most people use exclosures to manipulate herbivory.
- Overall recommendations: use more than one method depending on the spatial scale you are interested in; differentiate summer and winter grazing, distinguish domestic vs. induced species.
- Also some challenges for the protocol were identified: the protocol will depend on the research question being addressed. The detection limit of herbivory (time aspect), and spatial and temporal variability pose additional challenges.

The ITEX protocol as an example (Isabel C Barrio)

A draft of the protocol for measuring herbivory within the International Tundra Experiment was presented as an example. This protocol aims at assessing herbivory at ITEX sites, at 3 levels: the overall characteristics of the herbivore community, site level assessment, and plot level assessment. Different approaches are proposed for measuring herbivore presence in the area (site-level assessment), and for measuring herbivory within the ITEX experimental plots (plot-level assessment).

Comments from workshop participants on the draft of the ITEX protocol, and general ideas:

- Surveying every year is often too much because many sites are too difficult to access.
- We also miss the winter effects with the current protocol.
- Measuring grazing marked transects, right after snowmelt. Maybe just record marks on a certain number of plant individuals per species to reduce working effort.
- Maybe try to replicate the protocol within the landscape? Agree on main response variables to record on each plant (e.g. only buds or leaves…) for certain herbivore species.
- Trampling indicators could reflect the densities of some herbivores, particularly large ungulates.
- Some unified measure would be good to make assessment comparable between sites.
- Pellet counts: How to lay out the transect (100 m)? Maybe too long to capture variation within sites? Stratification for this is important to mention in the protocol. A limitation of this approach is that faeces decomposition rates vary between locations! This could be solved removing pellets after each summer.
- Maybe using a game camera for assessment of certain herbivores within sites?

16:00-17:25 Network organization

Discussion: How should we proceed with the Network organization?

There is an upcoming funding opportunity: the Belmont forum. The call has different funding options. We could potentially write a proposal for starting up the experimental part of the network, to synthesize existing information and identify knowledge gaps. Writing the proposal is a challenge, especially at this early stage, but was supported by workshop participants; a leader for the proposal and different working groups should be identified. This proposal has to include social scientists and stakeholders. We could partner with other networks (e.g. ShrubHub, ITEX, INTERACT, Tundra Nordic Centre of Excellence, Tundra Conservation Network). This project would eventually finance a post-doc position, and maybe it would facilitate the organization of workshops to write syntheses, especially with the information we have or we could get.

Roadmap for the protocol – work (discussion led by Virve Ravolainen)

Based on the research questions defined above for the Network, there is consensus that we need a well-replicated experimental approach, over several locations throughout the Arctic (with potential expansion to other alpine sites). Overall, there was agreement on the use of exclosures to manipulate and assess the effects of herbivory (signs of herbivory and current growth, including assessment of primary productivity; an important point for the design is that exclosures should not affect the plants themselves). Other approaches were also suggested: translocation of herbivores to assess maximum carrying capacity, and fertilization experiments (e.g. translocating faeces) to evaluate the effects of herbivores on nutrient cycling (these could be potentially combined with the use ofexclosures). The experiment should focus on some (few) manipulations according to key herbivores and be replicated within the landscape. Agreeing on where to actually set up the plots in the landscape can be challenging and some guidelines need to be explicitly stated in the protocol. Broadly, locations should cover gradients (i.e. topographic entities, replicated units in comparable habitats but different habitat conditions) and choose habitat/s representative for the landscape. The location of plots could be also guided by the knowledge on preferred habitat types of the main herbivores present in the area. Some relevant measures to take, from the herbivore point of view, are palatability and plant defences. For plant diversity assessments, it is important to specify the amount of plots and pins when using the point intercept method (which will depend on the scale to cover). It is also important to assess the richness of vascular plants and mosses (i.e. create a species list). A point that was discussed, was if it would be necessary to remove or move exclosures to assess productivity, after persistence of herbivore impacts (but this might be logistically difficult!). To measure the effects of herbivory on nutrient cycling, plots need to be big enough to avoid edge effects and accessible without disturbing the plots.

To gather information on energy fluxes, meteorological stations need to be installed, at least one per site. Whenever possible, more replicates of the experimental units (including also meteorological stations) would facilitate comparisions among different habitats or vegetation types. After defining a common unit, other modules targeting specific relationships would be desirable to cover complementary processes, i.e. soil properties and processes.

17:25-17:30 Concluding remarks

Next steps: writing up the workshop report, writing a draft for the herbivore hotspots idea (Isabel will be coordinating this part; icbarrio@gmail.com), developing the protocol (Virve will be coordinating this part; virve.ravolainen@uit.no), writing a funding proposal for the network (need to look into the details for the Belmont Forum and other potential funding sources).

Follow up with the reindeer grazing workshop (ABA conference) in Trondheim in December and present the protocol.