HERBIVORE INFLUENCES ON ECOSYSTEM FUNCTIONING

Establishment of musk ox exclosures at Zackenberg

Technical Report from DCE – Danish Centre for Environment and Energy No. 2 2011

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Data sheet

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Abstract: This report provides a detailed description of the musk ox exclosures established at Zackenberg in summer 2010. Apart from the exclosure and the unfenced control, we also established snow-control plots to examine the potential effect of the fence itself on the snow accumulation in the plots. Available baseline data include data on plant biodiversity, leaf area index and NDVI, soil fauna biodiversity and food web structure. Also, data on a number of abiotic parameters have been collected.

Keywords: Biodiversity, Plant-herbivore interactions, Soil fauna

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Contents

Preface

The present report describes the establishment of musk ox exclosures at Zackenberg, Northeast Greenland, in summer 2010. The main aim of the report is to describe the methods and materials used during the establishment of the exclosures and during the collection of baseline data in the plots, thereby serving as a detailed reference manual for future analyses to be conducted in the exclosures. In addition to this, some preliminary results from the year of exclosure establishment are presented.

The establishment of the musk ox exclosures as well as the initial data collection was funded by the Danish Environmental Protection Agency (DANCEA; j.no. MST-112-00240). Permissions to establish the exclosures, and to collect and export soil and plant samples were granted by the Greenland Government (j.nos. 26.52/22+A00049 and 2010-027384).

Acknowledgements

The authors are indebted to Christian Bay and Ditte K. Kristensen for their assistance with the botanical work while in Zackenberg, and Zdenek Gavor and Elin Jørgensen for identification of collembolans with support from collembolan taxonomist Dr. Arne Fjellberg, Tjøme, Norway. GEM secretariat, Aarhus University, is thanked for providing access to and logistics at Zackenberg.

Summary

In July 2010 we established permanent musk ox exclosures in the large fen area Rylekærene at Zackenberg, Northeast Greenland. The set-up consists of two treatments, exclosure (EX) and snow-control (SC), and one control (C). The EX plots inhibit musk ox grazing, while the SC plots serve as controls for the potential effects of the fence itself, whilst still allowing musk oxen to graze the plot. The C plots are unmanipulated controls. A randomized complete blocks design (RCBD) was established with three plots per each of 5 blocks, including the treatments EX, SC and C. Each plot measures 10x10m, and are positioned facing NNW, which is the dominating wind direction during winter. The EX plots are fenced on all four sides, while SC has a fence towards NNW only, thereby making the potential snowfence-effect in SC and EX plots comparable. The C plots are marked by iron posts only.

In connection with the establishment of the exclosures, a suite of baseline data were collected. These include data on plant diversity and species composition (frequency analysis), estimates of plant biomass, leaf area index and NDVI. Soil fauna species biodiversity and species composition, as well as their food web structure derived from natural abundances of ^{13}C and ^{15}N, were examined treatment-wise across plot replicates. In all plots we also placed soil temperature loggers to allow for detection of changes sin soil temperature, nutrient probes to examine the level of nutrients, and litter-bags to examine decomposition rates in the various treatments. Additional data collected were soil characteristics and depth of the active layer.

Sammendrag

I juli 2010 etablerede vi permanente moskusokse-exclosures i et stort kærområde i Zackenbergdalen, Nordøstgrønland. Forsøgsdesignet inkluderer to behandlinger, et exclosure (EX) og en sne-kontrol (SC), samt et kontrolplot (C). EX behandlingen forhindrer moskusgræsning, mens SC behandlingen tillader moskusgræsning, samtidig med at den fungerer som kontrol for en mulig hegns-effekt på sneaflejringen i feltet. C behandlingen er umanipuleret. Alle 25 felter er opsat i et randomiseret blok-design med 5 replikater af hver behandling. Hvert felt måler 10x10m, og vender mod NNW, som er den dominerende vindretning om vinteren. EX-felter har hegn på alle sider, mens SC-felterne kun har hegn mod NNW, hvorved en eventuel snehegns-effekt i EX og SC bliver sammenlignelig. C-felterne er udelukkende markeret med små stolper.

I forbindelse med etableringen af exclosures indsamlede vi en række base-line data, herunder data på biodiversitet af planter, biomasse og NDVI. Desuden indsamlede vi data på biodiversiteten af jordbundsdyr, fødekædestrukturen i jorden vha. stabile isotoper, og jordbundsforhold. Endelig udlagde vi udstyr til måling af jordtemperatur, næringsstoftilgængelighed og nedbrydningsrater i alle felter, samt målte tykkelsen af aktivlaget.

1 Introduction

Biodiversity and its development over time is a corner stone in ecosystem functioning, and biodiversity is therefore also a central issue in management and conservation across biomes. Biodiversity in a given area is the product of the area and the history of the area. For instance, the biodiversity of vascular plants in Greenland is the product of local geology, local weather, regional climate, human disturbance, and not the least, the product of the interactions between local organisms on the various trophic levels, such as the interaction between vascular plants and herbivore animals. From the low arctic, we know that herbivores do affect the vegetation, not only in terms of biomass removal, but also the species composition of the vegetation (Post & Pedersen 2008). Hence, herbivores can potentially enhance or buffer changes in biodiversity induced by e.g. climatic changes. Whether these results from the low arctic can be transferred to a high arctic setting is, however, uncertain, among other things due to the lower biodiversity and lower productivity there. The present project therefore aims at quantifying the long-term effects of the largest herbivore in high arctic Greenland, the musk ox (*Ovibos moschatus*), on the biodiversity of organisms on two trophic levels, i.e. vascular plants and soil fauna, in Zackenbergdalen. Specifically, the project will establish fenced plots, control plots, and snow-control plots in a fen/grassland area in Zackenbergdalen, thereby allowing for the assessment of the large herbivore impacts on the vegetation and soil fauna, as well as the potential effect of the fence itself. In addition to establishing the plots, the project will provide baseline data on a number of ecosystem parameters, which will form the basis for future examinations of the effects of musk oxen on the high arctic vegetation and soil.

2 Experimental design

All plots are placed in Rylekærene, Zackenberg, NE Greenland (Figure 1). Plots were established in the period 14 July to 23 July 2010 by Niels M. Schmidt and Mads C. Forchhammer.

The set-up consists of two treatments (exclosure (EX) and snow-control (SC)) and one control (C). The EX plots inhibit musk ox grazing, while the SC plots serve as controls for the potential effects of the fence itself. The C plots are unmanipulated controls. Plots are placed in 5 replicate blocks, each with EX, SC and C (Figure 1). Each plot measures 10x10m, and are positioned facing NNW, which is the dominating wind direction during winter (340 degrees N; Hansen *et al.* 2008). The EX plots are fenced on all four sides, while SC only has fence towards NNW only, thereby making the potential snow-fence-effect in SC and EX plots comparable. The C plots are marked by iron posts only.

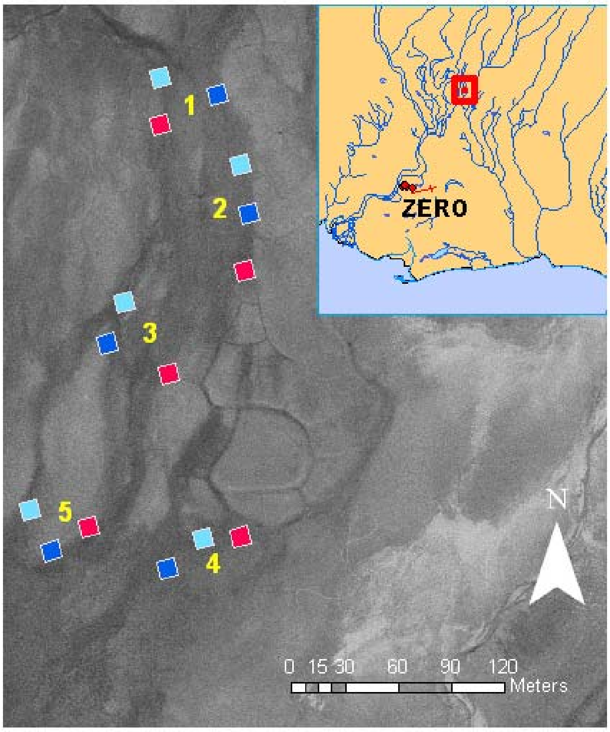


Figure 1. Location of the controls (light blue), snow-controls (dark blue) and the exclosures (red) in Rylekærene, Zackenberg.

The fence used is ordinary 100cm sheep fence (100/9/15) with 6 strings (upper and lower string 3mm, intermediary strings 2mm). In each of the corners holding the fence, a 5mm V-shaped iron bar is positioned, supported by two 5mm iron braces. Between corner poles, a 25mm iron pole is positioned for every 2 meters. The fence is fastened to posts and poles using 2mm steel wire. The NNW side in the SC plot is constructed similarly. The control is marked by V-shaped iron posts in each corner only. All posts and poles are forced into the permafrost.

Stiles were placed in all EX plots to reduce the wear on the fence (Figure 2). To minimize the potential trampling effects on the vegetation, board walks were placed in the wet parts of the plots. Additional board walks will be laid out in 2011.

Figure 2. Stiles were placed at the exclosures.

3 Baseline data: methods and preliminary results

3.1 Vegetation characteristics

To examine the vegetation biodiversity, we conducted frequency analyses in all plots, and estimated a number of vegetation characteristics to facilitate future re-examinations to be done in a non-invasive way.

3.1.1 Frequency analysis

Within each plot, two types of vegetation can be found, namely continuous fen (wet) and grassland (moist). In all plots, permanent pin point plots were established in both vegetation types, and a detailed frequency analysis conducted. The position of the pin point frame is marked by 4 aluminium sticks. All pin point analyses were conducted during the period 24 July to 31 July 2010 by Christian Bay and Ditte K. Kristensen.

Each pin point frame consisted of 10x10 points, and was examined using a 70x70cm ITEX frame. Frames are placed with the A-corner towards SW, and facing N. First point at the A-corner is 1,1 [line, point], and points continues towards N, and lines continues towards E.

Table 1. List of all registered species and groups during pin point analyses in wet and moist sites, respectively. Numbers are the total number of vertical hits within each vegetation type.

Species/group	Abbreviation	Wet	Moist
Arctagrostis latifolia	ARCLAT	120	171
Carex hybrid	CARHYB	6	
Carex hyperborea	CARHYP	44	24
Carex pratensis	CARPRA	4	
Dryas sp.	DRYSP		5
Dupontia psilosantha	DUPPSI	342	177
Equisetum arvense	EQUARV	26	34
Equisetum varigatum	EQUVAR	2	1
Eriophorum scheuchzeri	ERISCH	205	62
Eriophorum triste	ERITRI	14	66
Pedicularis hirsuta	PEDHIR		2
Polygonum viviparum	POLVIV	41	62
Salix arctica	SALARC	52	161
Saxifraga cernua	SAXCER	21	
Vaccinium uliginosum	VACULI		4
Moss sp.	MOSS	1491	1483
Lichen sp.	LICHEN	1	2
Organic crust	ORGCRU		5
Litter	LITTER	230	387
Bare soil	SOIL		2
Faces	FAECES	4	

At each hit we registered the species / functional group, and the height (5mm intervals). All vegetation layers were examined at each point. Cryptograms were assigned to functional groups only, i.e. Lichens and Bryophytes. Dead plant material was registered as Litter, while hits on soil, gravel, stones etc. were registered as Bare ground. A complete list of registered species and groups is given in Table 1. The mean frequencies of the various species and groups are shown in Figure 3. Finally, at each pin point frame analysis, a digital orthophoto was taken.

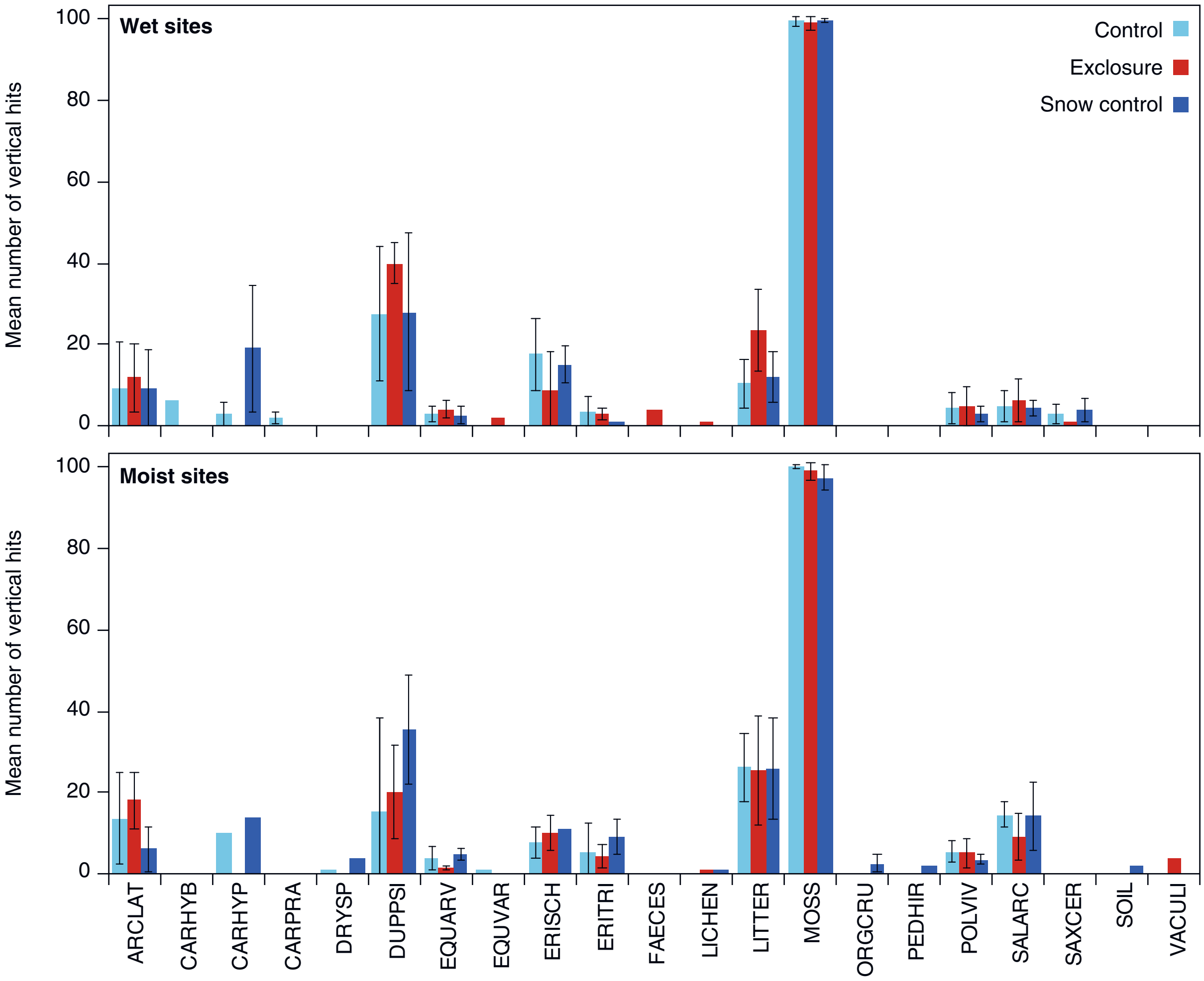


Figure 3. The mean number of vertical hits (+/- std) for species and groups in each treatment in the moist and wet sites, respectively. See Table 1 for full species list and abbreviations used.

3.1.2 NDVI, plant biomass, and leaf area index

To examine the relationship between plant productivity and the non-invasive measure of NDVI (plant greenness), we harvested the vegetation in small plots after having measured the reflectance. In each plot we randomly selected an area in the wet part and one in the moist part. First we measured the reflectance of the vegetation using a handheld RVI meter (Skye Instruments). The RVI meter was held app. 30 cm above the vegetation, and both reflectance in the 660nm and the 730 nm band was measured. Thereafter we harvested an area of 15x15cm (1 wet and 1 moist sample per plot; a total of 30 samples). The entire turf was brought back to the lab, where the all above-ground vegetation was cut and sorted into species / functional groups. All vascular plants were sorted to species level, whereas Bryophytes were lumped together as a functional group. Moss cover in all harvested plots was almost 100%.

All harvest and sorting took place during the period 25 July to 29 July 2010. Sorting was conducted by Niels M. Schmidt, Mads C. Forchhammer, Ditte K. Kristensen and Christian Bay.

Upon sorting, all green plant leaves were scanned digitally (600dpi) to obtain the species-specific leaf area index (LAI). A reference-area of 5cm^2 was included in the scanned images. Moss leafs could not be scanned individually, but registered as 100% coverage in all samples.

Hereafter all sorted plant material was oven-dried in small paper bags at 70 degrees for 5 days. Biomass of the respective plant species and functional groups will be estimated from the dried, sorted samples. Moss biomass will be estimated from the above-ground moss in a 1x1cm subsample from each 15x15cm sample.

3.2 Soil and soil fauna characteristics

To examine the soil fauna biodiversity and community structure, we collected 5 samples from each plot and cut turf/soil blocks of 30x20x10 cm. In addition to this, we also laid out litterbags to allow for the estimation of the rate of decomposition in the plots.

Field collections were conducted by Niels M. Schmidt, Ditte K. Kristensen and Mads Forchhammer, while all soil fauna laboratory analyses were conducted by Zdenek Gavor and Elin Jørgensen supervised by Paul Henning Krogh.

3.2.1 Soil characteristics

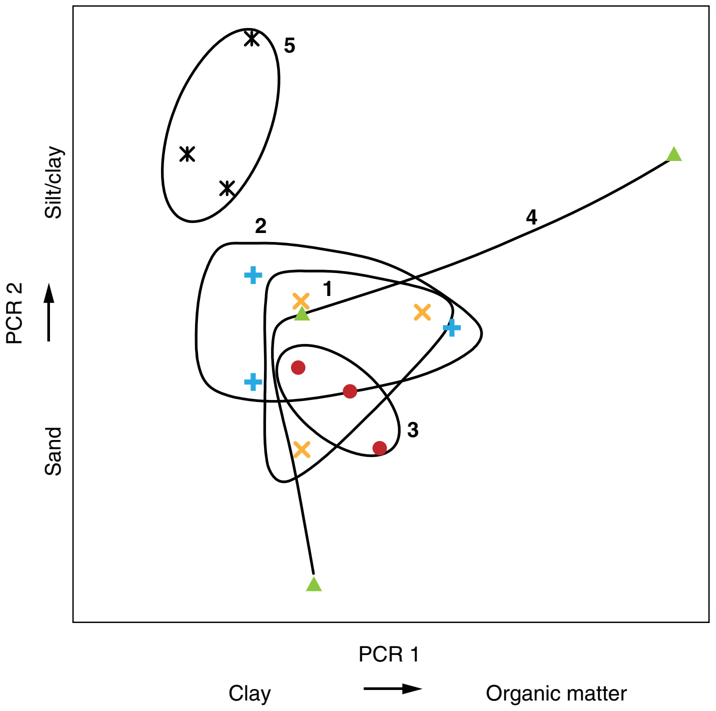
Soil samples from the individual plots were subject to standard soil analysis in order to characterise the soil properties. The seven soil variables: coarse sand, 2000 - 200 μ, fine sand 200 - 20 μ, silt 20 - 2 μ, clay < 2 μ, humus, C and N were subject to a principal component analysis. The first principal axis was a loam to organic matter axis and the second axis was a sand to silt/loam axis. Plots were homogeneous within blocks except for block 4 that had high organic matter content in one plot and a high sand content in another plot (Figure 4). Data on soil characteristics can be included as covariates in future analyses of data on soil fauna etc.

3.2.2 Soil fauna biodiversity

Within each plot we collected 5 soil cores at random sampling points in the moist part. A soil core had a diameter of 5.8 cm and a depth of 5.5 cm. Sampling and processing of soil cores were conducted following Aastrup *et al.* (2009). At each sampling, volumetric soil moisture content was measured using a handheld TethaProbe Soil Moisture Sensor. All soil sampling was conducted on 2 August 2010.

Upon collection, soil samples were kept cool, and brought back to Denmark for analyses. In the lab, soil samples were extracted using a high gradient heat extractor of the MacFadyen type.

Figure 4. PCA of the soil properties, clay, silt, fine sand, coarse sand and humus, of the various plots. Numbers refer to block numbers.



Microarthropod abundances were about 100.000 individuals per square meter in the top soil layer and dominated by Oribatida (Acarina). We found 14 species of Collembola (Table 2) where *Anuridae polaris* was too rare for abundance estimation. The abundance is expectedly doubled for the whole soil profile, e.g. down to the permafrost. The snow-control plots had a significantly higher density of collembolans while this may be at the expense of the oribatids that were reduced to a half of the control and exclosure plot levels. Abundances are given in Table 2 and subject to a mixed model with PROC MIXED taking into account the random factor of the RCBD and selecting the covariance structure with optimal AIC (SAS Institute 2009).

3.2.3 Trophic structure analysis

Main types of dead and alive organic matter sources were identified from blocks of turf including bottom mineral soil cut from all the plots on August 2, 2010. Table 3 lists all these sources of plants, roots and shoots as well as the invertebrates encountered in the soil and turf. Microarthropods were collected alive from MacFadyen type of high gradient extractions of turf samples.

The general food-web structure as revealed by isotopic signatures is illustrated in Figure 5. The top position of the velvet mite on the δ^{15}N-axis, Trombidiidae, known for its bright red colour, is evidence of its role as a predator. The onychiurids, *Oligaphorura* sp., are likely not to be predated by this species as the rule-of-thumb of 3 ‰ units between trophic levels is not met. *F. quadrioculata*, Collembola and oribatids, Acari, may very well be predated by predatory mites having a δ^{15}N of +7 ‰.

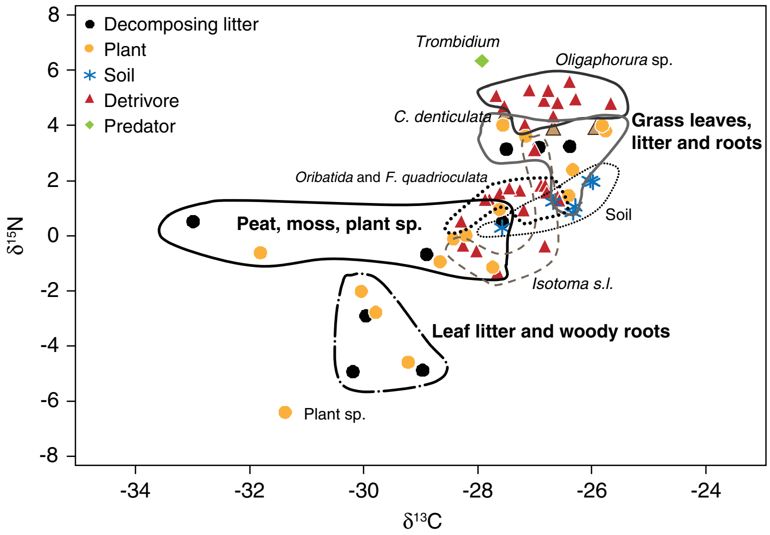
Table 2. Mean population abundances (1000 indv. m^{-2}) in the three treatments. 95% confidence limits in brackets. Significant differences between the treatments (P<0.05, Tukey's test) are indicated by superscript letters.

	Control		**Snow-control**		**Exclosure**	
Micranurida pygmaea	0.2^{a}	[0.0 - 0.4]	1.1^{b}	[0.7 - 1.6]	0.3	[0.1 – 0.4]
Folsomia bisetosa	0.02	[-0.02 – 0.06]	0.02	[-0.02 - 0.06]		
Folsomia quadrioculata	2.4	[1.1 - 3.8]	5.7	[2.8 - 8.7]	2.1	[1.0 – 3.2]
Ceratophysella denticulata	0.2	[0.1 - 0.4]	0.5	[0.3 - 0.7]	0.4	[0.0 – 0.7]
Desoria tshernovi	0.6	[0.0 - 1.3]	1.3	[0.8 - 1.8]	0.4	[-0.2 - 1.0]
Megalothorax minimus			0.09	[0.00 - 0.18]		
Oligaphorura groenlandica	2.0^{ab}	[0.3 - 3.8]	4.5^{a}	[3.1 - 5.8]	1.7^{b}	[0.9 – 2.6]
Parisotoma ekmani	0.1	[-0.1 - 0.3]	1.0	[0.1 - 2.0]	0.2	[0.0 – 0.5]
Sminthurinus concolor			0.04	[-0.03 - 0.12]		
Sminthurides schoetti	0.02	[-0.02 – 0.06]	0.02	[-0.02 - 0.06]	0.02	[-0.02 - 0.06]
Willemia similis			0.04	[-0.01 - 0.10]	0.20	[-0.11 - 0.51]
Arrhopalites principalis	0.13	[0.04 - 0.23]	0.2	[0.1 - 0.4]	0.07	[0.00 - 0.13]
Oligaphorura ursi			0.02	[-0.02 - 0.06]	0.04	[-0.03 - 0.12]
Acaridida	1.4	[0.6 - 2.3]	1.6	[0.7 - 2.6]	0.9	[0.4 – 1.4]
Oribatida	72	[37 - 106]	27	[16 - 38]	51	[27 – 74]
Gamasida	0.5	[0.3 - 0.8]	0.6	[0.3 - 0.9]	0.4	[0.2 – 0.5]
Actinedida	5.7	[3 - 9]	5.3	[3 - 7]	5.1	[3 - 7]
Microarthropods	85	[51 - 119]	50	[36 - 63]	63	[40 – 86]
Collembola	6^{b}	[2 - 10]	15^{a}	[11 - 18]	5^{b}	[3 - 8]
Acarina	79	[45 - 113]	35	[23 - 47]	57	[34 – 80]

Table 3. Microarthropods, plant material and organic matter encountered from heat extraction and during inspection of turf blocks collected in summer 2010. The isotopic composition of $^{13}C/^{14}C$ and $^{15}N/^{14}N$ was determined for all the listed types of samples.

Group	**Description**
Decomposing litter	Grass litter
	Broadleaf litter
	Peat
Detrivore	*Ceratophysella denticulata*
	Folsomia quadrioculata
	Desoria tshernovi adult
	Isotoma ekmani
	Isotoma sp. juveniles
	Oligaphorura sp.
	Oribatida
Plants	Grass leaves
	Grass roots
	Moss
	Plant sp. (identification forthcoming)
	Woody roots
Predator	*Trombidium* (Acari)
Soil	Soil

Figure 5. Isotopic composition, $\delta^{13}C$ and $\delta^{15}N$, of arthropods, plants and selected soil components. Similar main types of plant material and microarthropod species have been encircled.



The span of $\delta^{15}N$ over 6 ‰ units by the microarthropods is similar to studies of three different German deciduous forest stands (Chahartaghi *et al.* 2005). The mean and 95% C.L. for *Oligaphorura* sp. of $\delta^{15}N$ was 4.9 [4.6–5.2] and $\delta^{13}C$ -26.8 [-27.2 – -26.4], and there were no differences in the isotopic composition for the control and snow control, although population abundances differed significantly between these treatment for this genus (Table 2). Hence the ecological functioning of this species did not differ between the treatments.

The position of the grass in the isotope diagram (Figure 5) indicates the possibility of the nitrogen source originating from a secondary decomposition process, which could be internal immobilisation and mobilisation nitrogen cycles through microbial decomposers. The broadleaf plants retrieve their nitrogen from a source dissimilar from the N sources of the grass or they have different ways of biochemically processing the N resources.

3.2.4 Decomposition

In the moist part of each plot we placed 5 litter bags. Each litter bag holds 2 pieces of filter paper (a total of app. 1 gram per litterbag). Litterbags were laid out 31 July 2010. The location of each litterbag is marked by an aluminium stick. Litterbags will be recollected in summer 2011 and analysed thereafter.

3.3 Additional baseline data

In addition to the biological baseline data, we also aimed at describing the abiotic conditions in the plots.

3.3.1 Temperature loggers

In the moist part of each plot, we placed a MLOG-5 temperature data logger (www.geoprecision.com). The data logger was inserted app. 5 cm into the ground, and measures soil temperature every 12 hours. The location of the temperature logger is marked by an aluminium stick.

The data logger will run for several years, and data will be downloaded annually via a wireless connection.

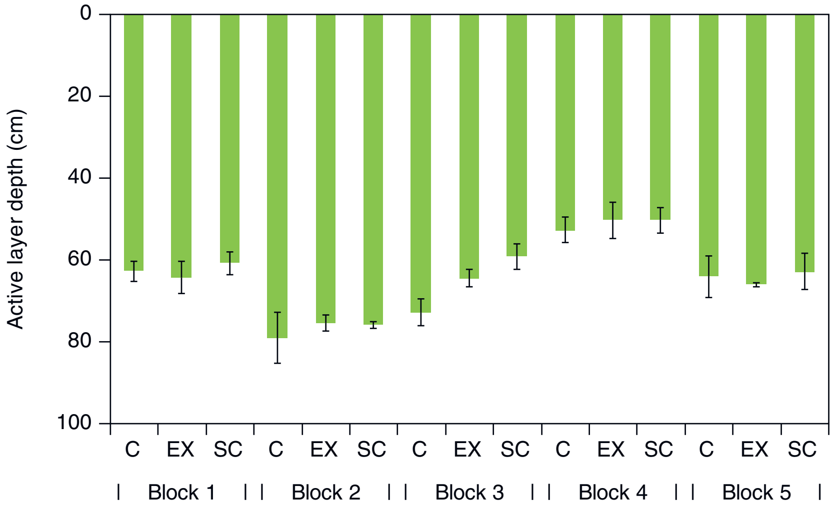
3.3.2 Nutrient probes

At each pin point frame in each plot, one set (anion and cation) RSP Nutrient Probes (www.westernag.ca) was inserted into the ground. In the moist part, probes were inserted into the ground next to the temperature data logger. Nutrient probes were employed on 31 July 2010, and will be recollected for analyses in summer 2011.

3.3.3 Depth of active layer

In each plot we estimated the depth of the active layer using a steel spear. A tape measure was laid out along the diagonal of the plot, and measurements were taken every 2 meters, starting at 2 m from the SW corner and going towards NE (Figure 6). All active layer depth measurements were conducted on 31 July 2010.

Figure 6. Mean depth of the active layer in the individual plots.



3.3.4 Photo documentation

At each plot, two digital photos were taken at the SE corner of the plot. One photo was taken towards W, and one towards N, thereby covering the entire plot (Figure 7). Photos were taken 31 July 2010.

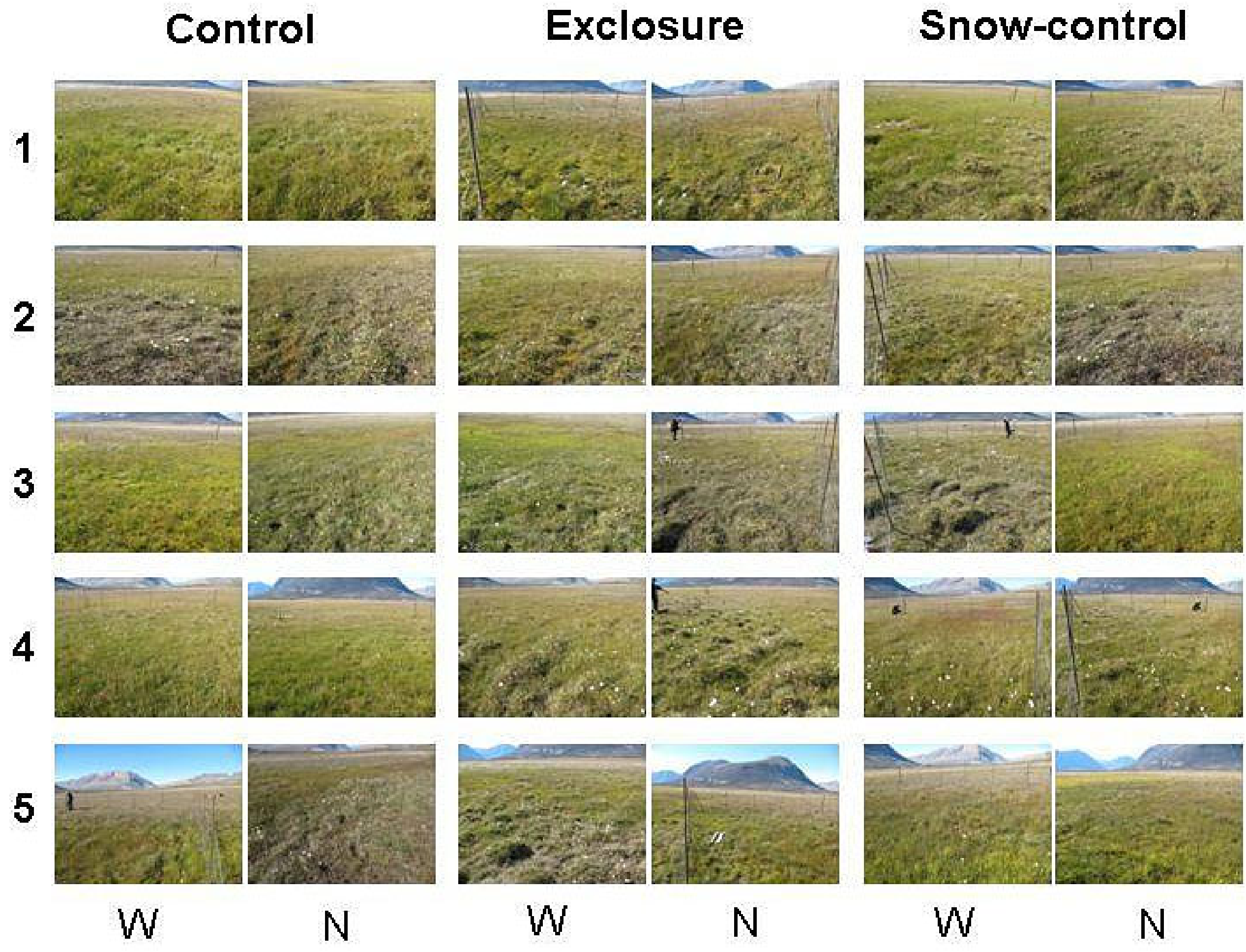


Figure 7. Photo documentation of plots in 2010. Numbers indicate Block number, while W indicates that the photo was taken towards the West, and N that the photo was taken towards the North.

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