Composition of late summer diet by semi-domesticated reindeer (*Rangifer tarandus tarandus*) in different grazing areas in northernmost Finland

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Abstract: This study aims to investigate the diet composition of semi-domesticated reindeer (*Rangifer tarandus tarandus*) in late summer in different kinds of grazing conditions in northernmost Finland. The composition of diet by reindeer was determined on the grounds of microhistological analysis of feces samples collected in early August in different seasonal grazing areas (winter or summer/year-round grazing areas) in three reindeer management districts. Although the proportion of different plant groups varied between the studied districts, the quantified group of ground lichens (which also contained small amounts of mushrooms) was the most abundant, varying from 33.0 to 46.4% in the analyzed samples. In general, there were significant differences in the proportions of lichen between districts, but not between grazing areas. The proportion of lichen in samples increased significantly when the amount of lichen pasture around a sample site increased. The proportion of dwarf shrubs and leaves in samples varied from 24.9 to 37.9% and differed significantly between districts, but not between grazing areas. In the same way, the proportion of graminoids varied between 20.9 and 36.2% and differed significantly between districts and also between grazing areas. Higher amounts of graminoids in feces were observed in summer/year-round grazing areas than in winter grazing areas. Finally, the proportion of bryophytes varied between 2.9 and 6.5% and was significantly different between districts, but not between grazing areas. An increase in old and mature coniferous forest around a sample site significantly increased the amounts of bryophytes in samples. The results indicate that reindeer adapt their summer diet composition according to the availability of food plants. The results also show that when reindeer are allowed to select their summer ranges freely, reindeer tend to use lichen pastures intensively also during summer, which causes a considerable reduction in lichens due to grazing and trampling. Therefore, a proper seasonal pasture rotation system to protect lichen pastures from grazing and trampling, from early spring to late autumn, is an essential part of sustainable pasture use in reindeer herding.

Key words: diet; northernmost Finland; reindeer; *Rangifer tarandus tarandus*; microhistological analysis.

Introduction

Semi-domesticated reindeer usually forage in large pasture areas, where they change their pastures according to their seasonal grazing pattern (between summer, spring/autumn, and winter) (Steen, 1968). This grazing pattern enables semi-domesticated reindeer to obtain forage most suitable for each season, with high contents of carbohydrates in winter and proteins in summer (Albon *et al.,* 1992; Bjorkvoll *et al.,* 2009). In summer, semi-domesticated reindeer can use the pasture landscape for grazing freely; while in winter, grazing of reindeer is more controlled by reindeer herders. The summer habitat preference of reindeer depends mainly on factors connected to insect harassment, vegetation types, and plant growth (Skarin *et al.,* 2008), although many kinds of human activities can also disturb foraging (Anttonen *et al.,* 2011).

The diet composition of semi-domesticated reindeer varies seasonally and is dependent on the quality and availability of different food plants on pastures (Bjorkvoll *et al.,* 2009). In summer, reindeer food contains a large variety of herbs, grasses, sedges, horsetail, dwarf shrubs (e.g. blueberry), leaves of deciduous tree, mushrooms, and lichens (Westerling, 1970; Sulkava *et al.,* 1983). The availability of grasses and herbs is relatively high in mesic and submesic forest and mires, and therefore the use of these pasture types increases in summer (Kumpula *et al.,* 2007). Intensive use of most suitable summer grazing areas is connected to the reindeer's need to fulfill their requirements for proteins and minerals from green plants during a short summer season. During summer, reindeer select a great variety of plants and usually consume only growing parts of plants or their new growth. In normal grazing conditions, reindeer have no difficulties during summer in fulfilling their nutritional requirements: proteins, minerals, and other necessary trace elements (Steen, 1968).

In contrast, during winter, reindeer need dietary energy for locomotion, digging, and thermoregulation (Steen, 1968; Westerling, 1970). Reindeer lichens (*Cladonia* spp.) are therefore an essential part of the diet for reindeer in winter, as they contain a lot of easily digested carbohydrates and also promote the digestion of more fibrous food (Nieminen *et al.,*1989; Aagnes *et al.,* 1995). Reindeer lichens can also form an important part of the diet in spring, when the snow has already melted but green plants are still scarcely available (Ophof *et al.,* 2013). Reindeer can also use lichens in summer (Westerling, 1970), but there are very few studies available on the consumption rate of lichens by reindeer during summer. If reindeer are allowed to graze on lichen pasture areas during the summer season, this also considerably affects the condition of lichen pastures due to grazing and trampling (Kumpula *et al.,* 2011;2014).

One of the most important objectives in semi-domesticated reindeer herding is, however, to ensure sufficient availability of suitable pastures and food plants for reindeer in each season, since seasonal nutritional conditions, dependent on the availability of natural food, affect the reproduction, milk quality, calf birth weight, growth, and mortality of reindeer (Rognmo *et al.,* 1983). In overgrazed or by other means deteriorated or insufficient pastures, the nutritional needs of reindeer are not fulfilled. Especially in Finland, supplementary winter feeding of reindeer has increased due to the lack of natural winter food, in order to keep herd productivity high enough (Helle & Kojola, 1993). Especially the condition of lichen pastures has deteriorated markedly during recent decades. Since summer grazing may considerably affect the condition of lichen pastures, it is important to know which factors increase the use of lichens by freely grazing reindeer during summer, and how much reindeer use ground li-

chens in the summer in different kinds of grazing conditions. This kind of information will probably help to develop pasture use systems in reindeer herding in such a way that the most important winter food resources, lichen pastures, are grazed as optimally as possible.

The aims of this study were to clarify how much lichen and other main food plants semi-domestic reindeer (*Rangifer tarandus tarandus*) use in different kinds of districts and grazing areas in the late summer season, and whether the type of pasture area and the availability of different pastures affect this selection and increase the use of lichens in summer. For this, we analyzed the diet composition of reindeer in early August by using reindeer fecal samples collected in different grazing areas in three reindeer management districts located in northernmost Finland.

Materials and methods

The study districts and their reindeer herding systems and grazing areas

The fecal samples for analyzing the composition of the diet of semi-domesticated reindeer in the late summer season were collected in early August in different seasonal grazing areas in the Paistunturi, Muddusjärvi, and Sallivaara reindeer management districts in northernmost Finland (Fig. 1). One of these districts (Paistunturi) is located in the mountainous area where there are no separate seasonal grazing areas. The lack of a proper seasonal pasture rotation system allows reindeer to graze lichen pastures also in summer. The other two districts (Muddusjärvi and Sallivaara) studied are located in mountainous and pine forest areas, and in both of these districts a large winter pasture area has been separated by pasture rotation fences. The winter stock density (according to the maximum allowed number of reindeer) in Muddusjärvi is 2.6, in Paistunturi 2.2, and in Sallivaara 2.6 reindeer/km^2 land area, respectively. In the Muddusjärvi and Sallivaara districts, which are located in both mountainous and pine forest areas, a distinct winter grazing area has been separated from other seasonal pasture areas by a pasture rotation fence. The main vegetation types in these districts are formed by different aged pine forests, as well as mountain birch forests and open heaths above the tree line. In the Paistunturi district located in the mountainous area, open heath land above the tree line and mountain birch forests dominate the vegetation, and reindeer can graze virtually in the whole district area all year round. In Muddusjärvi and Sallivaara, a few reindeer always stay in the winter grazing area during summer, which enabled the collection of fecal samples from reindeer in these winter range areas, as well.

Fecal sample collection

The fecal samples were collected after observing defecating reindeer or by recognition of fresh feces on pastures. The observed reindeer were from both male and female/calf groups and probably the unobserved reindeer that left fresh fecal samples were also of both sexes, although it was not possible to identify the gender of these reindeer. In order to obtain fresh fecal samples, the age of feces was determined from odor, moisture, and the presence of mucus. The location of each sample was defined by a GPS device. The number of samples collected was 20 in the Muddusjärvi district (7 samples in the winter grazing area and 13 samples in the summer/autumn grazing area) and 25 in the Sallivaara district (10 samples in the winter grazing area and 15 samples in the summer/autumn grazing area). In the Paistunturi district, 25 samples were collected in the summer/year-round grazing area. After collection, the samples were stored in plastic bags in a freezer (-20°C).

The proportions of the main pasture types and ground lichen biomass (formed mainly by *Cladina* spp.) on lichen pastures around each

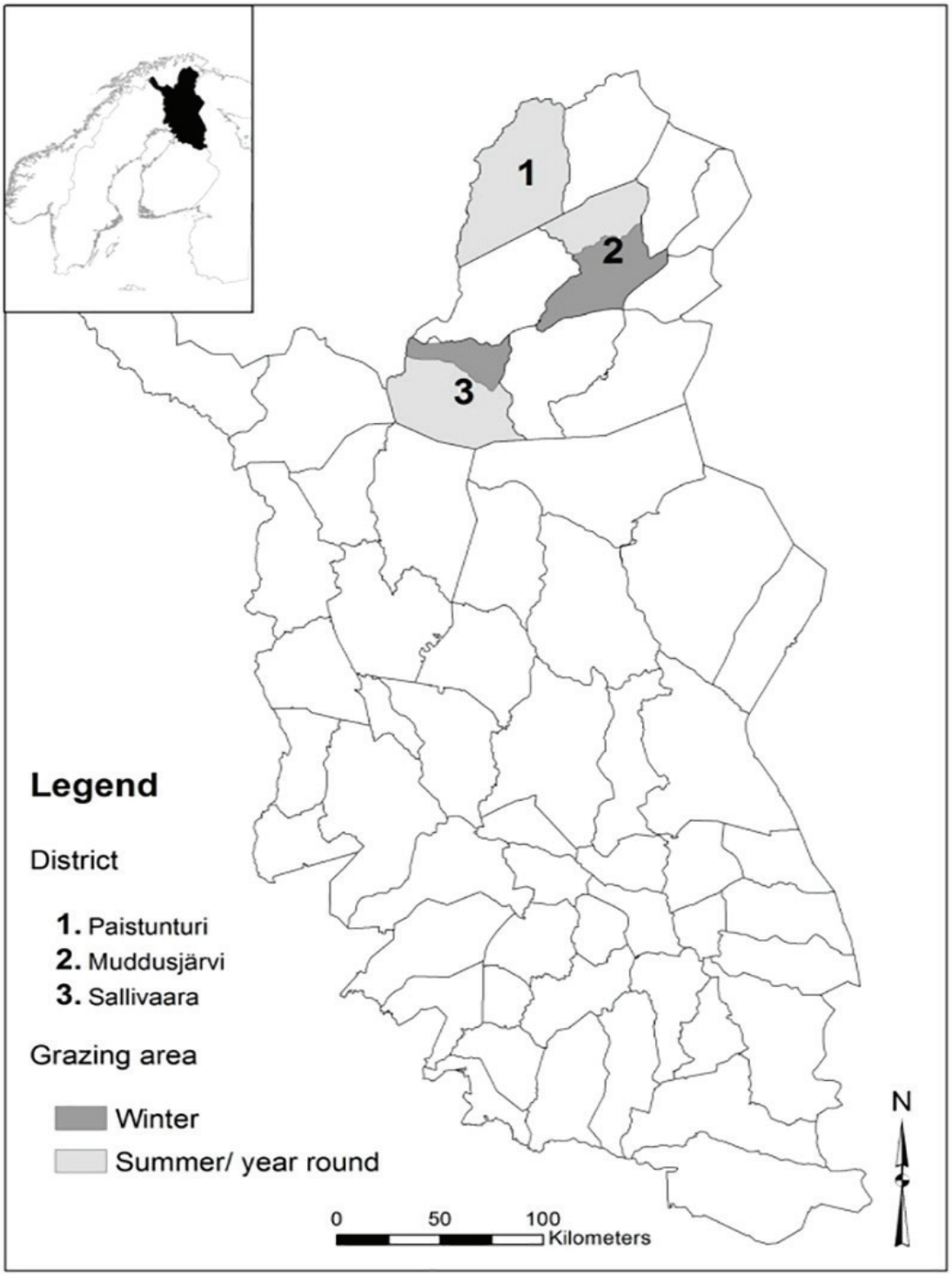

Figure 1. The study districts in the reindeer management area of Finland and their seasonal grazing areas used in summer/year-round or only in winter.

sample location within a radius of 3.0 km were determined by ArcMap 10.0 using the reindeer pasture inventory data from the years 2005-2008 (Kumpula *et al.,* 2009; Colpaert *et al.,* 2012). In cases where pasture rotation or another fence prevented reindeer from grazing certain areas within a circle around a sample location, these areas were removed from the pasture analyses. We used this size of radius around a sample site to identify all potential main pasture types available to reindeer during 2-3 days before sample collection.

Handling of fecal samples

The samples were prepared for analysis using a method adapted from Hansson (1970) and Viro and Sulkava (1985). Each sample was thawed and then crushed with a mixer, and rinsed with running water through strainers with apertures of 0.125 mm and 0.250 mm. A small quantity of sample separated between these strainers was put for one minute in 70% alcohol. Again a small part of this sample was colored by 1% methylene blue for about 15 seconds to raise the contrast of cell tissues and then to help to identify each type of cell tissue. The colored sample material was rinsed with running water for one minute and then left to dry for one minute. Then the sample was put in 70% alcohol for one minute and quickly rinsed in 96% alcohol. The final plant material preparation was then spread onto a micro slide. Some drops of Euparal mounting medium were added, and the micro slide was covered with a cover slip. From each fecal sample, three subsamples were prepared in this way.

In the earlier study on winter and spring diet composition of reindeer, only one 0.125 mm filter was used to rinse crushed samples (Ophof *et al.,* 2013). In that study, no plant particles were observed to be removed from winter and spring samples using the 0.250 mm filter. This is probably because the structure of winter and spring feces is less fibrous and contains smaller plant particles than summer feces. This difference is due to the reindeer diet composition in summer and winter (Steen, 1968) and the digestibility of plants (Thomas *et al.,* 1980).

However, in order to compare the differences in the filtering methods for summer fecal samples, 15 samples (five samples in each district) were also prepared using only the 0.125 mm aperture filter. In this way, we were able to compare the differences caused by these two filtering methods on the relative proportion of each plant group in the samples.

Microhistological analysis

The sample slide analyses were performed with a microscope (size of enlargement x200). In each subsample, five different views were randomly chosen and studied. In each view, the relative proportion of main food plant groups was calculated in the grid, which had 25 crossing points. The plant particles were identified in these crossing points and defined in four classes: ground lichen, graminoids (grass and sedges), dwarf shrubs (*Vaccinium* spp., *Empetrum nigrum*) and leaves (mainly willows and birch), and bryophytes (mosses). The proportion of mushrooms could not be estimated separately in the samples, as they were difficult to identify, and due to a lack of available mushrooms in pastures at that time, the amounts were also probably very small in the samples. It is therefore very likely that a few mushrooms in the samples are included in the lichen class. Due to a very dry summer (Finnish Meteorological Institute, 2013), there were no or very few mushrooms observed within the sampling sites. However, only two weeks after the actual sample collection, there were already many more mushrooms available for reindeer.

Statistical analysis

Statistical analyses were based on the calculated mean values of plants in each sample (average of 15 windows) derived from microhistological

analysis. An independent sample t-test was used to analyze whether there is a significant difference between the proportions of plant groups in two different filtering methods. Multivariate ANOVA was fitted to determine whether a significant difference exists in the proportion of plant groups between the reindeer herding districts. Correlation between different plant groups was analyzed using the Pearson correlation coefficient.

A mixed linear model (GLMM) was used to analyze the effects of different background factors on the proportion of different plant groups in fecal samples. These independent factors were study district, grazing area, and the following pasture variables: proportions of lichen pastures, arboreal lichen pastures (mature and old coniferous forest), dwarf shrub/grass dominated pastures, mires, and bare mountain areas around the sample places. In GLMM, summer and year-round grazing areas were handled as one grazing area, and the winter area as another grazing area. The estimate of ground lichen biomass (kg/ha) on lichen pastures around a sample location was also included as one independent variable in the analyses.

All linear mixed models were performed using backwards steps, in order to remove non-significant factors from the final models according to AIC-values and *P*-values. The independent explanatory variables added at the beginning of all analyses were herding district (Muddusjärvi, Paistunturi, Sallivaara), grazing area (winter and summer/year round), relative proportions of different pasture types (five classes), and lichen biomass on lichen pastures around a sample location. The dependent variable in each model was a proportion of certain plant groups in the samples. Since the lichens, graminoids, and dwarf shrubs/leaves in the samples were normally distributed (Shapiro Wilk test; *P*-value > 0.2), but not the bryophytes (Shapiro Wilk test; *P*-value < 0.05), we made a log-transformation change to the bryophyte group before analysis. After this change, the Shapiro Wilk test showed that the bryophyte group was also within normal distribution (*P*-value = 0.09).

Results

Proportions of different plant groups in feces

There were significant differences in the relative proportions of lichens, grass and sedges (graminoids), and dwarf shrubs/leaves in reindeer feces between the study districts (ANOVA results for lichens: F = 20.530, *P* = 0.001; graminoids: F = 23.715, *P* = 0.001; dwarf shrubs: F = 20.530, *P* = 0.001). However, in the proportion of bryophytes (mosses), there were no differences between the districts (F = 0.206, *P* = 0.814).

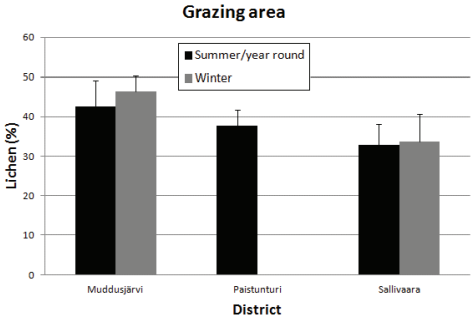

Figure 2. The relative proportions (%) of ground lichen group (mean±SD) in late summer feces of reindeer in each study district and their grazing areas based on the microhistological analysis.

In general, lichens (which included a small amount of mushrooms) were the most abundant food item group identified in the fecal samples (Fig. 2). Their proportion was highest in Muddusjärvi (summer grazing area: 42.58 ± 6.56%, winter grazing area: 46.35 ± 3.82%) and lowest in Sallivaara (summer grazing area: 32.95±5.12%, winter grazing area: 33.62 ± 6.99%). Graminoids and dwarf shrubs/leaves were the next most abundant plant groups in the fecal samples (Figs. 3 and 4). The proportion of graminoids was highest in Sallivaara (summer grazing area: 36.19 ± 6.99%, win-

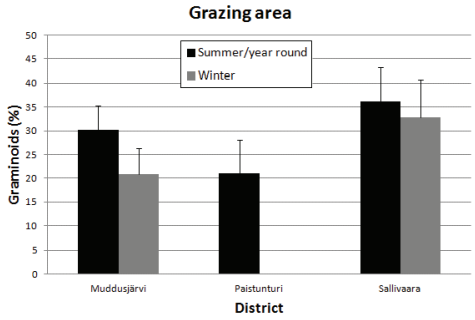

Figure 3. The relative proportions (%) of graminoids (grass and sedges) (mean±SD) in late summer feces of reindeer in each study district and their grazing areas based on the microhistological analysis.

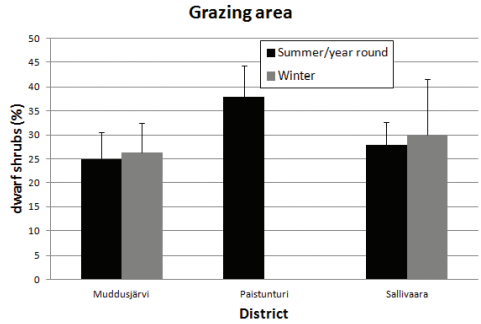

Figure 4. The relative proportions (%) of dwarf shrubs and leaves (mean±SD) in late summer feces of reindeer in each study district and their grazing areas based on the microhistological analysis.

ter grazing area: 32.76 ± 7.97%) and lowest both in Paistunturi (20.94 ± 7.11%) and in the winter grazing area in Muddusjärvi (20.93 ± 5.36%) (Fig. 3). The relative proportion of dwarf shrubs was highest in Paistunturi (37.85 ± 6.41%) and lowest in Muddusjärvi (summer

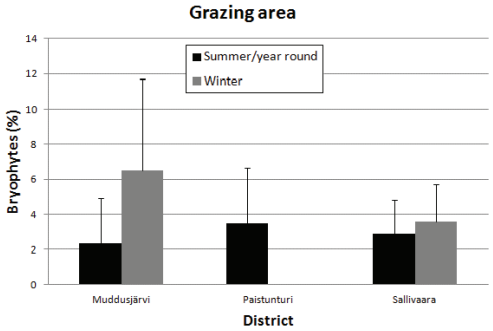

Figure 5. The relative proportions (%) of bryophytes (mosses) (mean±SD) in late summer feces of reindeer in each study district and their grazing areas based on the microhistological analysis.

grazing area: 24.92 ± 5.59%, winter grazing area: 26.25 ± 6.27%) (Fig. 4). The proportion of bryophytes was clearly lowest in the samples, varying between 2.9 and 6.5% in the different grazing areas in the districts (Fig. 5).

The correlation analysis shows a significant negative correlation between the proportions of lichen and graminoids ($P = 0.002$). In the same way, the proportion of lichen was correlated significantly negatively with the proportion of dwarf shrubs/leaves ($P = 0.019$). A significant negative correlation between the proportions of dwarf shrubs/leaves and graminoids was also observed ($P = 0.001$). There was no significant correlation between the proportions of bryophytes and other plant groups (Table 5).

Table 1. Dependence of lichen proportion (%) in fecal samples on the variables left in the final model. GLMM with backwards steps was used for the analysis.

		Estimate	Standard Error	Min	Max	t value	*P* value
Intercept		28.076	1.861	24.361	31.791	15.090	0.001p
Dis	Muddusjärvi	12.449	1.581	9.293	7.875	15.605	0.001p
	Paistunturi	1.750	1.634	-1.512	1.071	5.011	0.228
	Sallivaara	0.000	0.000	-	-	-	-
Lichen pasture		0.300	0.092	0.117	0.484	3.265	0.002

Table 2. Dependence of graminoids (grass and sedges) proportion (%) in fecal samples on the variables left in the final model. GLMM with backwards steps was used for the analysis.

		Estimate	Standard Error	Min	Max	t value	*P* value
Intercept		31.250	1.849	27.558	34.943	16.898	0.001p
District	Muddusjärvi	-8.170	2.041	-12.244	-4.096	-4.004	0.001p
	Paistunturi	-16.258	2.096	-20.442	-12.074	-7.758	0.001p
	Sallivaara	0.000	0.000	-	-	-	-
Grazing area	Summer/ year round	5.948	2.091	1.773	10.124	2.844	0.006
	Winter	0.000	0.000	-	-	-	-

Factors explaining the proportions of plant groups in samples

The GLMM analysis showed that the proportion of lichen group in fecal samples was significantly dependent on the district and on the proportion of lichen pasture around a sample site (Table 1). The proportion of lichen group in fecal samples was higher in Muddusjärvi than in the Sallivaara district (P = 0.001), but there was no significant difference between the proportions of lichens in the Sallivaara and Paistunturi districts. In general, the more lichen pasture there was around a sample site, the higher the proportion of lichens there was observed in the fecal samples (P = 0.002). The proportion of graminoids in fecal samples was significantly dependent (P = 0.001) on the district and on the grazing area, being lower both in Muddusjärvi and in Paistunturi than in the Sallivaara district (Table 2). In general, the relative proportion of graminoids (grass and sedges) was significantly higher in summer/ year-round grazing areas than in winter grazing areas (P = 0.006).

The proportion of dwarf shrubs/leaves in fecal samples was significantly dependent on the district (P = 0.001), being higher in Paistunturi than in Sallivaara (Table 3). There was no significant difference in the relative proportion of dwarf shrubs/leaves between Muddusjärvi and Sallivaara. The relative proportion of bryophytes in fecal samples was significantly dependent on the district and on the proportion of arboreal lichen pasture (mature and old coniferous forest) around the sample site (Table 4). The proportion of bryophytes was significantly different in Paistunturi and in Sallivaara (P = 0.030). The more arboreal lichen pasture there was around a sample site, the higher the proportion of bryophytes was observed in the fecal samples (P = 0.002).

Table 3. Dependence of dwarf shrubs and leaves proportion (%) in fecal samples on the variables left in the final model. GLMM with backwards steps was used for the analysis.

		Estimate	Standard Error	Min	Max	t value	*P* value
Intercept		28.794	1.370	26.060	31.528	21.022	0.001p
District	Muddusjärvi	-3.411	2.055	-7.511	0.690	-1.660	0.102
	Paistunturi	9.057	1.937	5.191	12.924	4.676	0.001p
	Sallivaara	0.000	0.000	-	-	-	-

Table 4. Dependence of bryophytes (mosses) proportion (log-%) in fecal samples on the variables left in the final model. GLMM with backwards steps was used for the analysis.

		Estimate	Standard Error	Min	Max	t value	*P* value
Intercept		0.247	0.113	0.022	0.473	2.193	0.032
District	Muddusjärvi	0.14	0.099	-0.058	0.338	1.409	0.164
	Paistunturi	0.273	0.123	0.028	0.517	2.225	0.030
	Sallivaara	0.000	0.000	-	-	-	-
Arboreal lichen pasture		0.01	0.003	0.004	0.017	3.243	0.002

Differences between two sample processing methods

The independent sample t-test results showed that there was a significant difference between the proportions of lichen group in the two filtering methods (mean for one filter method 33.04 ± 1.629% and for two filters method 39.12 ± 2.029% ; t = 4.712, $P = 0.001$). Using one additional filter with an aperture of 0.250 mm, the proportion of lichen increased by 15.5% (from 33.04 to 39.12%) in the subsamples, compared to the method of using only one filter with an aperture of 0.125mm. That means that the difference between the relative proportions of lichen in the filtering methods amounted to 6.077 ± 4.995%. In other plant groups, there were no significant differences between these two methods ($P > 0.110$).

Discussion

The observed high amount of lichen in the summer diet of reindeer is somehow an unexpected result, since due to their high energy content, lichens are considered to form the forage group important for reindeer nutrition mainly in winter (Westerling, 1970). Our results, however, show that lichen can also form a considerable part of the reindeer diet in the summer season, if reindeer have free access to lichen pastures during summer. Lichens probably also compensate for some of the more common summer forage groups, if these forage groups are not sufficiently available. We observed that reindeer compensated for graminoids with lichen and dwarf shrub/leaves when there was a lack of graminoids on pastures but when lichens and dwarf shrubs, in contrast, were easily available, as in Paistunturi (see Table 5 and Figs. 2 and 3). If there are no available mushrooms (which form an important part of the reindeer diet in late summer and early autumn), reindeer are probably also more eager to eat lichens.

Depending on plant availability and quality, reindeer utilize a wide variety of plants in summer (Bjorkvoll *et al.,* 2009). Usually, reindeer feed selectively on several dozens of vascular plants in summer (Nieminen *et al.,* 1989). However, our study shows that in certain pasture conditions in summer, ground lichens can dominate the reindeer diet. Similarly to our study, Staaland et al. (1995) also observed that during the summer season, when reindeer had high access to lichens, the selection of grasses, forbs, and leaves dropped to 45-70%, and lichens formed the most utilized food item group (lichen intake varied between 15-42%) for reindeer grazing in dry graminoid heath and low alpine shrub heath.

The relative proportions of lichen, graminoids, and dwarf shrubs/leaves in reindeer feces also varied significantly between the study districts. In general, the proportion of lichen was dependent on the proportion of lichen pasture around the sample site, which indicates that when reindeer graze on an area dominated by lichen type vegetation, they still actively select

Table 5. Correlation coefficients between the relative proportions of different plant groups in fecal samples.

	Lichen		Grass and sedges	
	Correlation	***P* value**	**Correlation**	***P* value**
Grass and sedges	-0.423	0.002	-	-
Dwarf shrubs	-0.035	0.019	-0.641	0.001p
Bryophytes	0.041	1.000	-0.272	0.136

lichens although the biomass of lichens is relatively low in pastures. The proportion of grass and sedges in samples was significantly higher in summer/year-round grazing areas than in winter grazing areas. This simply indicates that because these plants are probably most abundant in summer pasture areas, reindeer also use them there most intensively.

Trampling and grazing of lichens by reindeer are among the most important factors affecting the cover of lichens on pastures (Väre *et al.,* 1995). If reindeer are allowed to graze lichen pasture areas during the summer season, due to the lack of a proper seasonal pasture rotation system, lichen pastures probably deteriorate more heavily due to summer grazing and trampling than due to winter grazing (Kumpula *et al.,* 2014). It has been observed that during the summer season, 35% of the edible lichen biomass may be destroyed by trampling because it is dry and brittle (Pegau, 1969).

In addition to grazing and trampling, many other factors affect the growth and regeneration rates of lichens, such as rainfall and seasonal temperatures (Cooper *et al.,* 2001; Kumpula *et al.,* 2014). During some of the recent years, the average summer temperatures in Finnish Lapland have been repeatedly relatively warm. These kinds of summer temperatures have been measured only a few times in a century, and the summer of 2013 was especially warm and dry (Finnish Meteorological Institute, 2013). Warm summers may promote the growth of vascular plants but affect negatively the growth of lichens, especially if summers are also dry (Kumpula *et al.,* 2014). In a warm and dry summer season, grazing and trampling of lichens by reindeer are also more destructive for lichen pastures and should therefore be avoided in reindeer rangeland management.

Graminoids are usually the most important part of the reindeer summer diet (Westerling, 1970), but they were not consumed by reindeer as much as lichens in our study. One reason for this could be that, especially in the Paistunturi area and in the winter range area of Muddusjärvi, there is not as much mesic type of pasture available as dry and nutrient poor lichen type pasture. As a consequence, reindeer compensated for the lack of graminoids with a lichen and dwarf shrub diet. Our study also showed that very dry summer conditions, which make lichens dry, do not prevent reindeer from grazing lichens.

Concerning the two filtering methods used in the study, we noticed that the observed proportion of lichens in summer feces of reindeer was higher in the two-filter method compared to the one-filter method. In a previous study of fecal samples collected in spring and winter, the analyses were done with only one filter, and the coarse filter (0.250 mm) used did not separate plant particles at all (Ophof *et al.,* 2013). This may be caused by the fact that in winter, reindeer eat mostly lichens (Westerling, 1970), and the digestibility of plant groups in different seasons varies (Thomas *et al.,* 1980). This indicates that determining the diet composition of reindeer by fecal analysis is also sensitive to data-handling methods, and this has to be taken

into account when the actual composition of the foraged diet is assessed.

Intensive grazing and trampling of many lichen range areas, in addition to the increasing effects of other land use and climate change, can lead to continuing changes to the plant cover and composition of the reindeer pastures in northernmost Finland (Kumpula *et al.,* 2014). In certain pasture conditions, reindeer seem to prefer lichens also in the summer season. Therefore, it is important to develop such seasonal pasture rotation systems that prevent reindeer from grazing on the most important lichen pasture areas during the snow-free season. It is also important to pay more attention to the local vegetation and environmental conditions for reindeer, in order to optimize the seasonal pasture used by reindeer within different kinds of reindeer-herding districts. These efforts are important in promoting and developing reindeer management to be more sustainable and profitable in the future.

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