Thesis for the Master's degree in Biology

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Grazing facilitation or delayed competition between reindeer and sheep: An experimental study of reindeer feeding preference.

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Abstract

There is considerable controversy regarding the effect of sheep grazing on reindeer populations in Norway. Sheep grazing during summer may affect the critical fall, winter and spring range conditions for reindeer either through negative (delayed competition) or positive (grazing facilitation) interactions. An important first step is to study the aversion or preference of sheep summer feeding sites by reindeer during spring and fall. The aim of this study was to experimentally test the feeding preference of reindeer in fall and spring towards summer sheep grazed (high and low grazing pressure, respectively), human cut or untreated control plots. Reindeer feeding preference was recorded during three seasons (autumn 2003, spring 2004, and autumn 2004) on two separate agricultural pastures representative of surrounding coastal areas in northern Norway. Reindeer showed a preference for the cut and sheep grazed plots during fall 2003 and spring 2004, whereas low concentration sheep grazed plots were preferred during fall 2004. The control plots were grazed less than the other plots during the first two seasons. In general, reindeer grazed more intensively during spring than fall. There were no measurable indications of negative effects from the sheep grazing, such as faeces aversion or trampling. Interestingly, a 3 - 4 day cycle in feeding preference may have represented a form of self induced, short time scale (3 - 4 day cycles) grazing facilitation produced by the reindeer themselves. The implications of this work show that the worst thing for reindeer (in terms of their feeding preference) along the coastal pastures of Finmark is not to use the pastures for more than sporadic, low intensity reindeer grazing. Importantly, grazing facilitation between sheep and reindeer was clearly supported by this experiment and should be considered as an important aspect for sustainable and productive management of coastal pastures where these two species co-exists.

Introduction

There is considerable controversy regarding the effect of sheep (*Ovis aries*) grazing on reindeer (*Rangifer tarandus*) populations in Norway. Many studies have addressed within season competition (summer) and interactions between reindeer and sheep (Colman, 2000; Colman et al., 2001). In northern grazing systems, the spring and summer growing season is highly productive compared to winter, fall and early spring. Thus, less negative grazing interactions between sheep and reindeer may be expected during spring and summer. Critical periods for reindeer are after the rut for males, late winter for all animals, and spring and summer for gestating and lactating females (Alpe et al., 1999). During these seasons, high quality forage is especially important. Thus, summer sheep grazing on shared reindeer pastures may affect reindeer in these critical periods. Surprisingly, no previous studies have addressed this. It is during critical periods for reindeer that negative (delayed competition) or positive (grazing facilitation) interactions between reindeer and sheep could be manifested. An important first step in documenting between-season interaction for reindeer and sheep and optimizing their potential dual-species management is to study the aversion or preference of sheep summer feeding sites by reindeer during spring and autumn.

Gordon (1988) showed that red deer (*Cervus elaphus*) preferentially grazed in areas in spring that had previously been used by cattle (*Bos taurus*), while Colman et al. (2001) showed that reindeer avert from pastures having high concentrations of faeces. Delayed competition is when the effect of summer sheep grazing negatively influences reindeer when sheep are no longer present, i.e. during autumn, winter and spring. Delayed competition can occur through overgrazing, trampling, interference or aversion of faeces (Moe et al., 1999a; Colman, 2000). For example, Moe et al. (1999a) and Colman et al. (2001) showed that reindeer avert from feeding where faeces is present from either reindeer or sheep, and that the aversion towards faeces was positively correlated to the faeces concentration. Delayed competition may also be a consequence of overgrazing and decreased pasture quality or quantity.

Grazing facilitation is when one herbivore improves range properties for subsequent feeding by another herbivore (Bell, 1971). The grazing facilitation mechanisms may either occur in the near-term (within year) or long-term (successionally) (McNaughton, 1975; McNaughton, 1979; Urness, 1981; Post and Klein, 1996; Mysterud and Mysterud, 1999). In the long term, sheep grazing may enhance or deteriorate reindeer range by driving plant succession toward development stages more or less valuable for reindeer. In the short term, moderate grazing may improve pasture by keeping graminoids in a young phenological stage, which is usually of higher quality than later and senescent stages (e.g. Kelting, 1954; McNaugthon, 1984). For example, Anderson and Scherzinger (1975) showed that ungrazed grassland resulted in tall low-quality food in winter for elk. Cattle grazing in spring maintained the grass in a growing state for a longer period. If cattle were removed before the end of the growing season, the grass could re-grow sufficiently to produce a shorter, high quality stand for elk. Their population increased from 320 to 1190 after prescribed grazing management was introduced. Clipping experiments and comparisons of grazed and ungrazed arctic meadows have shown the potential of arctic graminoids to respond positively to grazing by lesser snow geese (*Chen caerulescens*) (Cargill and Jefferies, 1984; Hik and Jefferies, 1990), muskoxen (*Ovibos moschatus*), caribou (*Rangifer tarandus*) (Henry and Svoboda, 1989; Ouellet et al., 1994; Post and Klein, 1996) and sheep (Moe et al., 1999b).

The aim of this study was to experimentally test the feeding preference of reindeer in fall and spring towards summer sheep grazed, human clipped or untreated control plots.

I predicted that grazing facilitation could be measured and tested by a higher use by reindeer of areas grazed by sheep.

Materials and methods

Study area

The study was conducted spring, summer and fall 2003 and spring, summer and fall 2004, in a semi open farm landscape in Sopnes, approximately five km from Langfjordbotn, Finmark County (69º59'N, 22º19' E). The study area included two 0.2 ha fields at sea level. This area has not been cultivated for decades, but has been sporadically used for low-density reindeer summer grazing and harvested for cattle fodder during two years five years prior to this study. Before this, the area had not been plowed, cut or grazed for over 15 years. The vegetation was dominated by *Agrostis cappilaris*, *Deschampsia cespitosa*, *Poa pratensis* and *Trifolium repens*. The fields effectively represent the familiar abandoned, “old-pasture” characteristic of the surrounding area and much of the coastal landscape of Finmark in general. The experimental areas were situated on west facing slopes surrounded by trees and high shrubs.

Study design

The study design was similar to Gordon (1988), and Rhodes and Sharrow (1990), Alpe et al. (1999), and Colman et al. (2003). The set up and fencing was of a simple four by four latin square design. There were two separate study sites with three treatments and a control at each site. Within each study site, there were four replicates for each treatment and control, providing 16 plots per site (Figure 1.1). Site A was 46 x 70 m, providing a plot size of 11.5 x 17.5 m and Site B was 32 x 100, giving a plot size of 8 x 25 m. Varying sheep grazing pressures, controlled with animal density and number of days (10 grazing days) in the area during summer (beginning of June), induced two types of treatment. One treatment consisted of two sheep (one adult and one juvenile; hereafter denoted as Sheep Low (SL)), and the other consisted of four sheep (one adult and three juveniles; hereafter denoted as Sheep High (SH)). The third treatment was to simulate harvesting of round-bails (fodder) by cutting plots to five cm in height during the summer (beginning of June) with a lawn mover and removing the cut grass (hereafter denoted as Cutting (CU)). The CU area was cut during the same day as when the sheep were removed. The control plots were similar to the treatment plots except they were neither cut nor grazed (hereafter denoted as Control (CO)). The boundaries of the study sites as well as the treatment and control plots within the sites were fenced prior to the experiment (Figure 1.1). This allowed for the latin square design of equal number and size of treatment and control plots encompassed within the study site. The fencing within the study sites was then removed after treatment and prior to the introduction of four two-year-old reindeer males simultaneously into each site (Figure 1.2). The eight reindeer were allowed to graze undisturbed for two weeks in fall 2003, two weeks in spring 2004, and two weeks in fall 2004.

CO	SL	CU	SH
SH	CO	SL	CU
SL	CU	SH	CO
CU	SH	CO	SL

1)

CO	SL	CU	SH
SH	CO	SL	CU
SL	CU	SH	CO
CU	SH	CO	SL

2)

Figure 1. A schematic illustration of one study site with 4 replications for each of 4 types of plots; control (CO), cutting (CU), 2 sheep (SL), and 4 sheep (SH). 1 and 2 represent the same study site at different times of the year; (1) during treatments and (2) while 4 male reindeer were released into the site for direct observations of their feeding preference. I tested reindeer feeding preference with simple use (all plots are equally available) of grazed, cut or control plots. There were 2 separate study sites with the same design, allowing for true replication at the landscape scale. See appendix for pictures of the study areas.

Sampling method

The reindeer feeding activities ware recorded using two direct observational sampling techniques simultaneously to document their feeding preference in relation to treatment vs. control plots within the study sites. Altmann's (1974) instantaneous scan sampling technique was used on each group of animals in each study site at 10-minute intervals and focal animal sampling of individuals occurred for up to 30 minutes while the individual under observation was engaged in a feeding bout (Colman, 2000). Prior to each recording and in connection with the observers positioning themselves in the observation towers, the observer remained still for 10 minutes to avoid possible bias caused by their approach to the area and potential disturbance towards the reindeer. Observations were mostly made by eyesight, although binoculars were used when necessary. Notes of feeding behavior, environmental variables such as weather and noise or disturbances, observer, date and time were recorded every 10 minutes and for each observation on either pre-prepared field sheets or spoken into a dictaphone. Location (plot number) and activities were recorded for each individual reindeer every 10 minutes or during a focal observation. I classified the activities as feeding, standing, walking, running, and lying. Since I aimed to test the feeding preference/choice of the reindeer, recording behavior and area use was conducted during active/feeding bouts only. Thus, when more than two animals lay down, the observation period was terminated. The rate of change in activity/sec in the feeding category while the animal was engaged in a feeding bout was calculated from focal observations (Colman et al., 2003). A feeding bout was defined as the time a focal animal was engaged in feeding bout without engaging in other behavioral activities for more than 2 min (Colman et al., 2003).

Statistical analysis

All analyses were first tested within each site and when no significant differences were found between the two sites, data was combined for both sites and tested for overall trends. During the experiment, several people were involved with conducting reindeer observations. A test for observational bias was conducted using Mann-Whitney U test, and no significant differences were found. Repeated measures ANOVA were used for comparisons between and within each treatment category between and within each season. The feeding activity was used in the analyses of feeding preference and was tested with treatment plot. Data was transformed using log $(x + 1)$ to meet the assumptions of an ANOVA (Sokal and Rohlf 1995). Data was prepared in Excel XP while SPSS ver. 12.0 (SPSS Inc.) was used for all the statistical analyses. A significance level of α = 0.05 was used for all statistical tests.

Results

Treatment preferences

During fall 2003 and spring 2004, the reindeer allocated most of their feeding to the CU, SH and SL treatment categories compared to CO, whereas during the fall 2004, only SL was the most preferred treatment (Figure 2). In fall 2003 and spring 2004, CU, SH and SL was equally preferred (fall 2003: 0.27 ± 0.03, 0.28 ± 0.03, 0.28 ± 0.03; spring 2004: 0.31 ± 0.04, 0.27 ± 0.04, 0.26 ± 0.04), whereas CO was used the least (fall 2003: 0.15 ± 0.03, 0.16 ± 0.04). In fall 2004, SL (0.34 ± 0.03) became the preferred plot and was significantly higher than CO (0.23 ± 0.03; $p < 0.02$), CU (0.23 ± 0.03; $p < 0.02$) and SH (0.20 ± 0.03; $p < 0.01$) (Table 1).

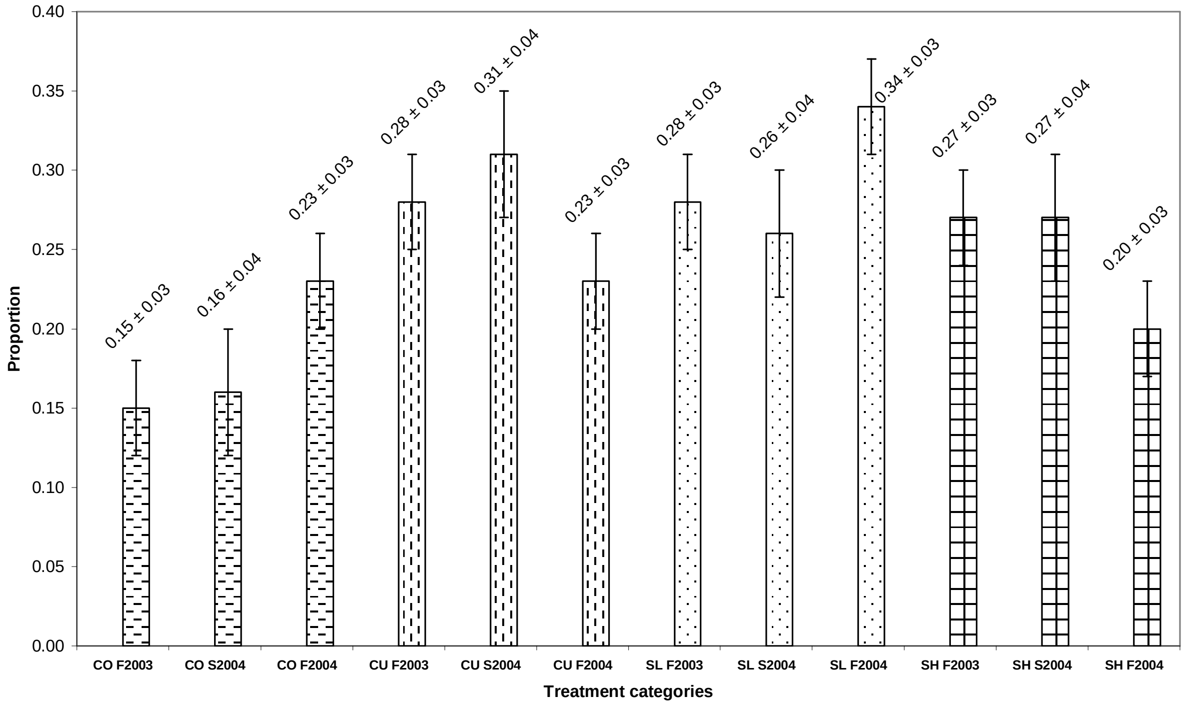


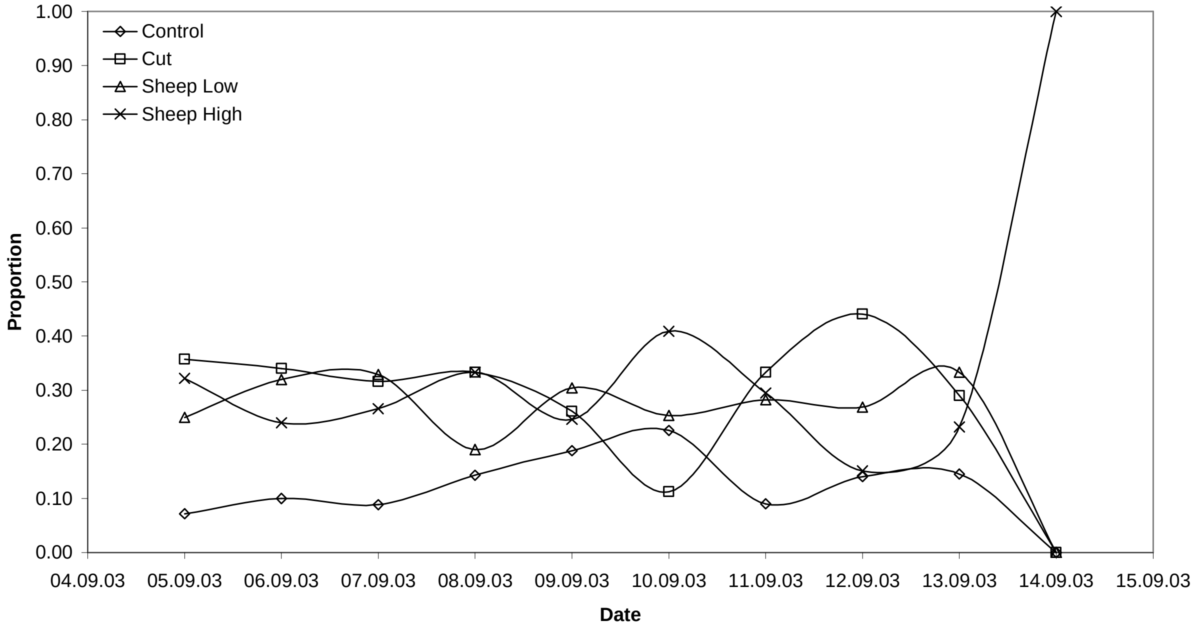
Figure 2. Mean proportion of allocated feeding time in treatment categories during fall 2003, spring 2004 and fall 2004, Sopnes, Langfjordbotn, Norway. Figure shows mean allocation ± SE. CO denotes Control, CU denotes Cut, SL denotes Sheep Low, and SH denotes Sheep High. Capital F denotes Fall and capital S denotes Spring. See table 1 for sample sizes.

Between the seasons, only significant differences in allocated feeding were found in the CO treatment category, where reindeer allocated significantly less time during fall 2003 (0.15 ± 0.03) compared to fall 2004 (0.23 ± 0.03) ($p < 0.05$) (Table 1).

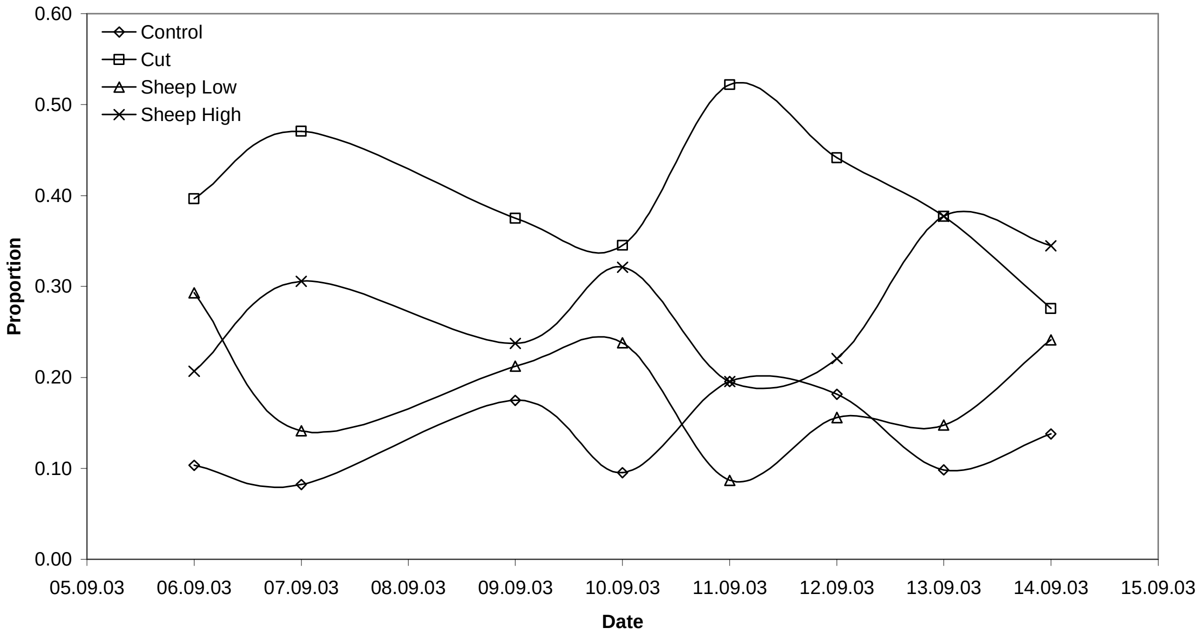
Table 1. Proportion of allocated feeding time (mean ± SE) during fall 2003, spring 2004 and fall 2004, Sopnes, Langfjordbotn, Norway. Sample size is denoted by *n* (number of sample replica). A different vertical capital letter denotes treatment category (CO=Control, CU=Cutting, SH=Sheep high, SL=Sheep low) preference during feeding that are significantly different within each season (p = 0.05). Horizontal lower case letter denotes differences in feeding preference between seasons. Repeated measures ANOVA were used for comparison within and between each treatment category within and between seasons.

	Fall 2003				**Spring 2004**				**Fall 2004**			
	Allocation (%)		Sig. Levels		Allocation (%)		Sig. Levels		Allocation (%)		Sig. Levels	
Treatment	mean ± (SE)	*n*	Treatment	Season	mean ± (SE)	*n*	Treatment	Season	mean ± (SE)	*n*	Treatment	Season
CO	0.15 ± 0.03	76	A	a	0.16 ± 0.04	56	A	b	0.20 ± 0.03	48	A	ab
CU	0.27 ± 0.03	76	B	a	0.26 ± 0.04	56	B	a	0.23 ± 0.03	48	A	a
SH	0.28 ± 0.03	76	B	a	0.27 ± 0.04	56	B	a	0.23 ± 0.03	48	A	a
SL	0.28 ± 0.03	76	B	a	0.31 ± 0.04	56	B	a	0.34 ± 0.03	48	B	a

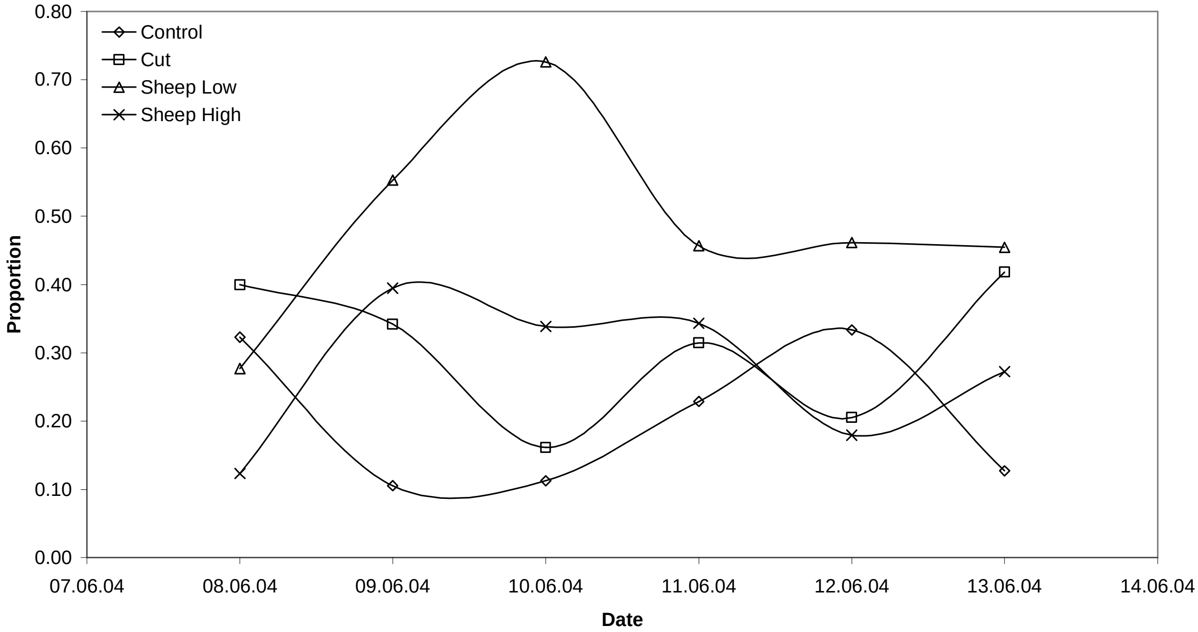
Within each season, the reindeer allocated varying degrees of time to the different treatment categories as well as to the control in sites A and B (Figure 3A - F). It appeared that two interconnectivities existed between the CO – CU and the SH – SL treatment categories; especially during fall 2003. The interesting trend to note is the approximate 3 - 4 day cycle between peaks, especially during the fall 2003 and spring 2004 seasons.



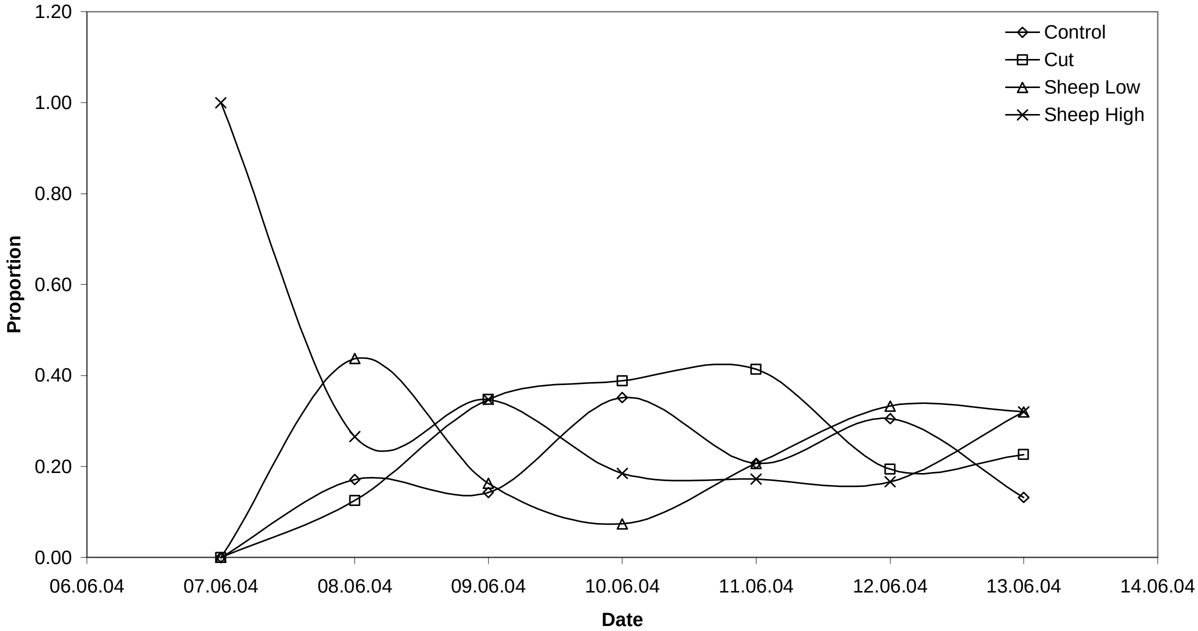
A) Feeding allocation in treatment categories - Fall 2003 - Site A



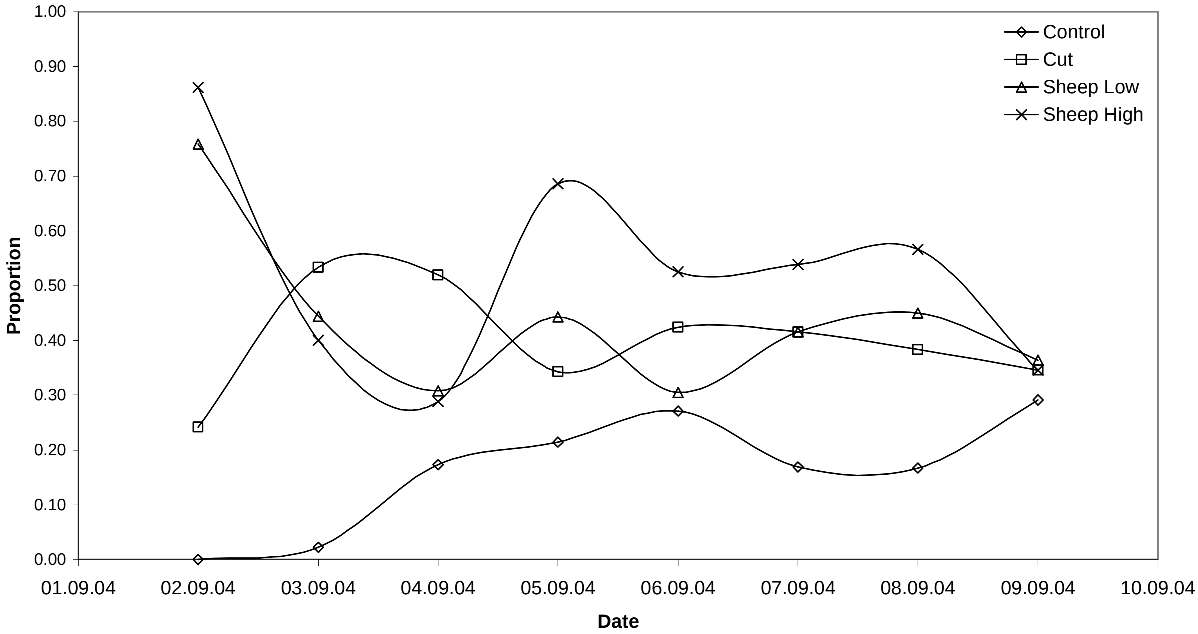
B) Feeding allocation in treatment categories - Fall 2003 - Site B



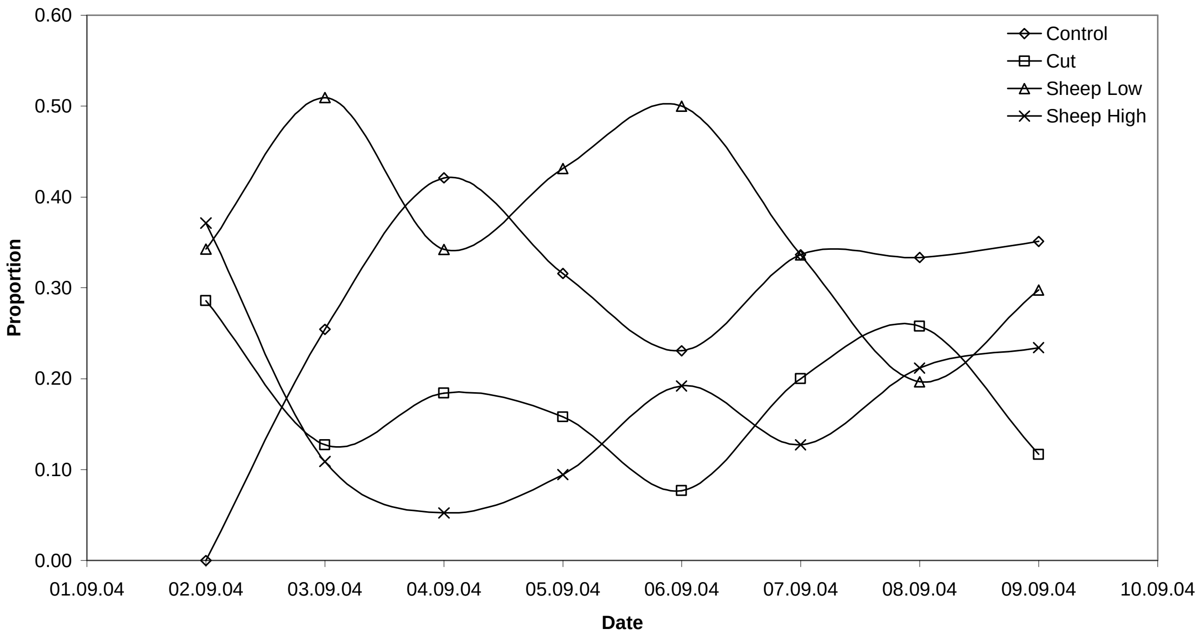
C) Feeding allocation in treatment categories - Spring 2004 - Site A



D) Feeding allocation in treatment categories - Spring 2004 - Site B



E) Feeding allocation in treatment categories - Fall 2004 - Site A



F) Feeding allocation in treatment categories - Fall 2004 - Site B

Figure 3. The proportion of daily reindeer feeding allocation in treatment categories in sites A and B during fall 2003, spring 2004 and fall 2004, Sopnes, Langfjordbotn, Norway.

Frequency of behavioral shifts

Within the seasons, no significant differences were found between the treatments (Table 2). This indicates that when feeding, the reindeer fed with a similar intensity in all plots. An interesting trend was found when comparing all plots between the seasons. From fall 2003 to spring 2004, significant declines in behavioral shifts per 2 min feeding bout were found in all treatment categories. Significant increases were found in the CO, CU, and SL categories from spring 2004 to fall 2004. CO was significantly different between fall 2003 and both the spring ($p < 0.01$) and fall 2004 ($p < 0.01$) season. No difference was noted between spring and fall 2004 ($p = 0.24$). In the CU treatment, only spring 2004 was significantly different to fall 2003 ($p < 0.01$) and fall 2004 ($p < 0.05$). Between 2003 and 2004, significant differences were found in SH between fall 2003 ($p < 0.01$) and spring 2004 ($p < 0.01$), but not between spring and fall 2004 ($p = 0.38$). For SL, fall 2003 was different to spring 2004 ($p < 0.01$), but no to fall 2004 ($p = 0.26$), and spring and fall 2004 differed significantly ($p < 0.05$) (Figure 4, Table 2).

Table 2. Activity changes per 2 min in a feeding bout (mean ± SE) during fall 2003, spring 2004 and fall 2004, Sopnes, Langfjordbotn, Norway. Sample size denoted by n. A different vertical capital letter denotes treatment category (CO=Control, CU=Cutting, SH=Sheep high, SL=Sheep low) preference during feeding that are significantly different within each season ($p = 0.05$). Horizontal lower case letter denotes differences in feeing preference between seasons. Repeated measures ANOVA were used for comparison within and between each treatment category within and between seasons.

	Fall 2003				**Spring 2004**				**Fall 2004**			
	Activity shifts		Sig. Levels		Activity shifts		Sig. Levels		Activity shifts		Sig. Levels	
Treatment	mean ± (SE)	*n*	Treatment	Season	mean ± (SE)	*n*	Treatment	Season	mean ± (SE)	*n*	Treatment	Season
CO	4.52 ± 0.50	50	A	a	1.68 ± 0.29	50	A	b	2.12 ± 0.24	50	A	bc
CU	4.32 ± 0.67	50	A	a	1.60 ± 0.25	50	A	b	3.02 ± 0.38	50	A	a
SH	4.74 ± 0.53	50	A	a	1.56 ± 0.23	50	A	b	2.36 ± 0.33	50	A	c
SL	3.74 ± 0.50	50	A	ac	1.48 ± 0.29	50	A	b	2.64 ± 0.35	50	A	bc

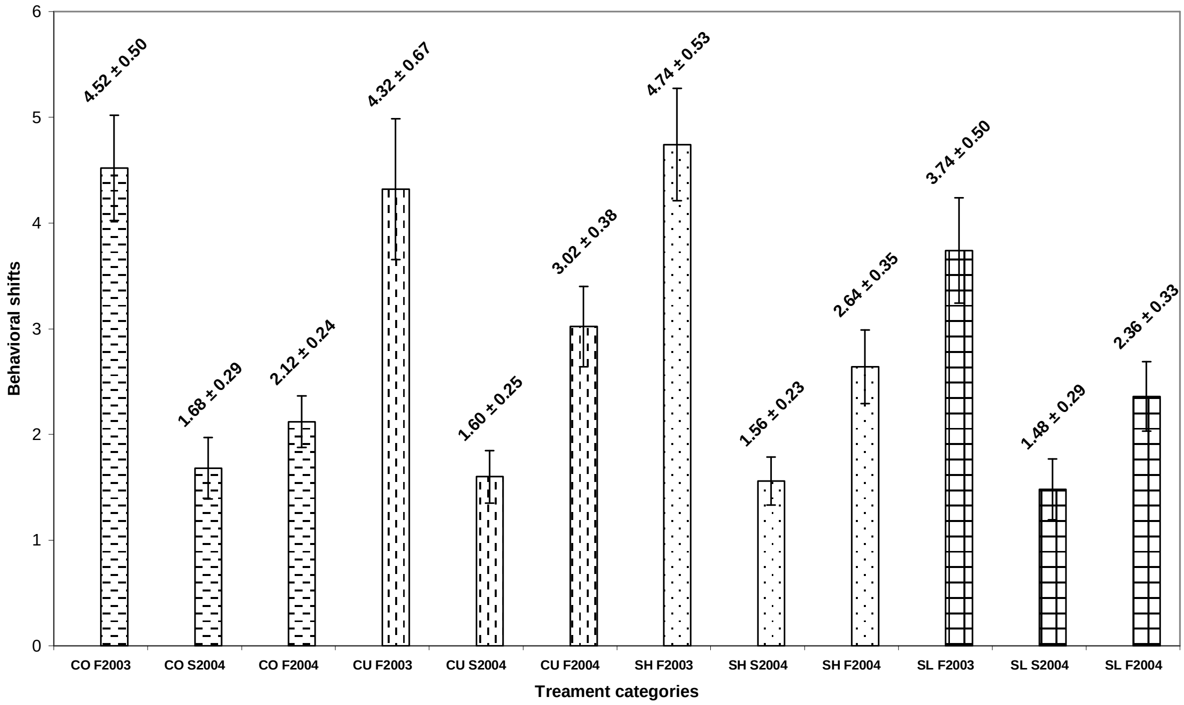


Figure 4. Mean (± SE) behavioral shifts per 2 min for reindeer engaged in a feeding bout in treatment categories during fall 2003, spring 2004 and fall 2004, Sopnes, Langfjordbotn, Norway. CO denotes Control, CU denotes Cut, SL denotes Sheep Low, and SH denotes Sheep High. Capital F denotes Fall and capital S denotes Spring. See Table 2 for samples sizes.

Discussion

Grazing facilitation or delayed competition

An important result was the clear choice by the reindeer not to use the control areas, during the first two seasons. Interestingly, the reindeer showed no significant differences during the last field season in feeding preference in the control, cut and high sheep concentration plots. Throughout the experiment, reindeer preferred treatment areas previously grazed by sheep as well as cut plots. Although the reindeer initially allocated a significant amount of their feeding to the cut plots, there were no significant differences in allocation from fall 2003 to fall 2004 during the experiment. The same trend was found for the areas with high density of sheep grazing, where the reindeer allocated a decreasing amount of time throughout the field experiment. In the low sheep concentration plots an opposite but non-significant trend was found, especially during the last season, where reindeer allocated an increasing amount of time.

Grazing facilitation has been reported in a number of cases. In a pioneer study on the Serengeti plains (Bell, 1971), migratory wildebeest (*Connochaetes taurinus albojubatus*) were found to consume approximately 85% of the initial standing crop and was claimed to prevent senescence and stimulated net primary productivity of the plains. Successionally, Thomson's gazelle (*Gazella thomsoni*) was found to prefer areas previously grazed by the wildebeest (Bell, 1971). Although facilitation has been claimed to occur in Serengeti (Bell, 1971; McNaughton, 1975), several authors have questioned whether interactions associated with the three species wildebeest, Thomson's gazelle and zebra (*Equus burchelli*) can be described as grazing facilitation (Sinclair and Norton-Griffiths, 1982; Illius and Gordon, 1987; Deboer and Prins, 1990 Clark et al., 1996). Van der Wal et al. (2000) reported in a >25 year study that brown hares (*Lepus europaeus*) were shown to facilitate grazing by brent geese (*Brenta bernicla*) in salt marshes in the Netherlands, where regrowth of the shrub *Atriplex portulacoides* was prevented. Clipping experiments mimicking hare grazing were utilized by brent geese more than twice as frequently as untreated control plots (van der Wal et al., 2000). On the Isle of Rhum, Scotland, red deer (*Cervus elaphus* L.) preferred summer grazing areas grazed by cattle the previous winter. Cargill and Jefferies (1984) and Gordon (1988) also reported an increase in biomass and green grass being more available in grazed areas compared to ungrazed, suggesting that grazing in their areas may stimulate primary production by increasing the nitrogen cycling.

The potential mechanisms functioning during grazing facilitation may occur in the near-term, such as within a year, as was studied by van der Graaf et al. (2002). Although not addressed in the literature, grazing facilitation could also be occurring at a much shorter time span, for example, within days. Factors influencing this would depend on season, vegetation community and the plant species being grazed, i.e. the plants ability for above ground compensatory growth and production rate. During this experiment, the allocation of time feeding to the different treatment categories varied within each season in a marked cyclic manner, especially during fall 2003 and spring 2004. The most pronounced relationship was found during the spring 2004 season, where CU and CO showed the same 3 - 4 day cyclic patterns, while SL and SH to some degree also showed a similar pattern in the beginning of the season. During the fall of 2003, cyclic patterns were less pronounced, but the same trend of interconnectivity between CO – CU and SL – SH was apparent. The fall 2003 season was characterized by a collapse in the cyclic patterns as well as a lack of visible interconnectivity. The appearance of a 3 - 4 day cycle in late spring, where production is extremely high, could be a short-term form of grazing facilitation the reindeer produced during their time grazing within the enclosures. The regeneration of forage, especially in the spring season when plant productivity is high (Klein, 1990), could be fast enough for the reindeer to benefit from this self-induced facilitation. The fact that a similar 3 - 4 day cycle is absent during the fall of 2004 is probably best explained by slowing plant growth in the fall and in this year in particular. An alternative explanation for the appearance of a 3 – 4 days cycle could be that the reindeer simply avoid areas with their own fresh pellets (Moe et al 199b).

Marked changes in feeding intensity in the treatment categories (CU, SH and SL) from fall 2003 to spring 2004 and to fall 2004 was noted, with the most intensive feeding taking place in the spring 2004. After a winter of scarce food resources, reindeers' metabolism and feeding intensities increase dramatically Thomson (1977). The reindeers' intensive feeding in spring 2004 is in agreement with this. The highest numbers of behavioral shift and thus lowest feeding intensity was found in the start of the experiment, fall 2003. Furthermore, as northern ungulates have an increased feeding efficiency and intensity in the growing season (e.g. spring vs. fall), a decline compared to spring feeding would be expected. The pasture is also generally less productive and nutritious in fall compared to spring Alpe et al. (1999). Grazers such as reindeer would then need to move more and spend more time searching for green shoots and preferred plants or plant parts.

It did not appear as though reindeer in this experiment showed any signs of aversion towards sheep or reindeer faeces in any of the plots, since previously sheep grazed plots were grazed as much or even selected over the cut plots. This was equally true for both the spring and fall periods and for both years. A potential faeces aversion in the fall periods was expected, as this was only 6 weeks after sheep were present and thus much more realistic than the following spring. This was partially consistent with my findings, as I noted a drop in grazing intensity during fall 2003 compared to spring 2003, even though there were no differences between the plot categories. Nevertheless, if faeces aversion was a strong factor influencing the reindeer's choice of feeding plots, I would expect them to avert from the sheep plots during fall more than the cut or control plots because of their lack of sheep faeces. Faeces avoidance has been demonstrated in a pen experiment (Moe et al., 1999b) and on outdoor pastures (Colman et al., 2001). These studies used a relatively short time span of only 12-24 hours between "spreading" the faeces and when the reindeer were allowed to graze and their feeding choice was measured. The minimum time in my study from the removal of the sheep to the introduction of reindeer (60 days) may have been sufficient to diminish eventual negative effects from the sheep excrements. Future studies should address the consequences of different time spans between when faeces are dropped and the eventual amount of aversion by a grazer at later dates.

Severe trampling has been reported to degrade superficial organic horizons (Boudreau and Payette, 2004) and change the vegetation towards types dominated by dwarf shrubs, bare soil and *Cladonia* (den Herder et al., 2003). Furthermore, damage to roots in lichen woodlands (Morneau and Payette, 2000) and reduction of fine pine roots has been demonstrated (Väre et al., 1996; Ohtonen and Väre, 1998). However, with reduced caribou activity, Boudreau and Payette (2004) noted a re-colonization of lichens and *Cladonia*. Although negative effects have been reported, other studies have demonstrated that reindeer grazing may enhance nutrient cycling (Olofsson and Oksanen, 2002; Stark et al., 2002). The fact that introduced reindeer indeed utilized control plot that were characterized by large amounts of standing crop of dead above-ground biomass, and that reindeer fed more intensively during the fall 2004 compared to fall 2003 on all treatment categories, suggests that trampling may have enhanced soil nutrient cycling by increasing the litter decomposition rate (Shariff et al., 1994; Kielland et al., 1997; Kielland and Bryant, 1998). The plant community, landscape and environmental variables such as moisture are certainly important when trampling is considered. This experiment was conducted in a graminoid rich, mostly soft, moist soil, during summer on coastal pasture. Thus, I would claim that trampling would be more positive than negative in light of my two sheep treatment categories.

During the last season, a decline in time allocation and feeding intensity between the sheep low and sheep high treatment categories may indicate that delayed competition could be a factor when the density of sheep used in prescribed grazing is increased from one adult with one juvenile to one adult with triplets. The fact that this decline was noted in the last season could indicate a one year time lag. Interestingly, the reindeer allocated the same amount of time to the CU and SH treatment categories, which implies that both of these treatment categories resemble high foraging pressures that border a maximum beneficiary condition for the reindeer. The SL treatment may balance a healthier sheep grazing intensity and improved nutrient cycling with eventual positive and/or negative trampling and faeces fertilization effects as compared to the CU and SH.

Management implications

The effects of sheep summer grazing on resources available to reindeer are of great importance. Reindeer are a significant resource in Northern Norway. Their physical condition as well as calf production may either be compromised or improved (as in this study) by delayed effects of summer sheep grazing. In several studies, the use of domestic sheep in grazing programs have been found to be ideally suited because they are intermediate feeders that consume a wide range of vegetation species (Mosley, 1994; Mysterud and Mysterud, 1999), where an improvement of graminoid quantity and quality may be present (Wielgolaski, 1975; Bowns and Bagley, 1986; Mysterud and Mysterud, 1999). The controllable mobility and density of sheep matched at a specific landscape scale could be used to distribute grazing pressures uniformly and enhance positive effects (facilitation). Also a decrease in negative effects such as overgrazing and high concentration of faeces may be avoided. Major advantages with sheep grazing is the low-cost, low-energy input form of habitat management and that it can be implemented for many wildlife species in diverse habitats and on landscape scale. Examples are found in North America where scientists have applied livestock grazing as means of habitat improvement for the wildlife (Mosley, 1994). Improvements for the sheep farming production is also apparent as an increase in more high quality pastures may be available as the alternating reindeer and sheep grazing cycle progresses. Thus, the improvement may be beneficial for both the reindeer herdsmen as well as the sheep farmers.

Certain abiotic factors such as weather and thaw-freeze cycles as well as biotic factors such as insect harassment cannot or are difficult to control or manage, whereas quality and availability of graminoids may not be. Thus, reindeer condition can be improved by improving the availability and quality of their preferred ranges, especially during critical periods like spring and fall. Such an improvement may enable the reindeer to withstand or tolerate stochastic and severe weather events and to a certain degree, insects harassment or other hurdles that may compromise their survival and calf production.

There are important economical and social benefits of strong and productive reindeer herds. In northern Norway, farmers and pastoralists are two important cultural institutions where cooperation is of crucial importance if both institutions are to develop fruitfully in the future. The results of this study provide information that there is basis for improvement for the reindeer industry, the sheep farmers and landowners. Combining the results of this biological study with the results from an anthropological study involving the involved people's feelings and attitudes, cultural similarities and difficulties can be incorporated in a management scheme that will improve the basis for mutual understanding, cooperation and sustainable use of our natural resources.

Lack of maintenance and the re-growth (bush encroachment) of cultural landscape in parts of northern Norway has been swiftly advancing the past 20 - 30 years due to a combination of things. The number of cattle farms and sheep farmers have been decreasing, resulting in less harvesting of the original fields and less pasture utilization by sheep (Elgvin et al., 2004). As this study shows, such neglected and important cultural landscape could be better maintained by implementing a dual-species management scheme on a large scale - but only through cooperating reindeer herdsmen, sheep farmers and landowners. For reindeer, the worst case scenario is to do nothing.

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Appendix

Picture 1. Site A prior to introduction of reindeer

Picture 2. Site B after introduction of reindeer

Picture 3. Focal and scan sampling from observational tower

Picture 4. Sheep as prescribed grazing