

Master of Science thesis

**The effect of sheep grazing on
beetles and spiders in an alpine
ecosystem**

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Oslo, December 2005

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Forord

Arbeidet med denne masteroppgaven er utført under veiledning av Atle Mysterud ved Senter for Evolusjonære og Økologiske Synteser, Biologisk Institutt, Universitetet i Oslo. Masteroppgaven er en del av et større prosjekt som ser på økologiske effekter av sauebeiting i et konsentrert fjellområde i Hol i Buskerud kommune. Mitt fokus har vært å se på invertebrater- biller og edderkopper i dette området.

Jeg vil med dette benytte anledningen til å takke Atle Mysterud for å ha latt meg ta del i dette prosjektet! Det har vært utfordrende og interessant.

I forbindelse med artsbestemmelser av de innsamlede invertebratene, har jeg også hatt et nært samarbeid med Naturhistorisk Museum på Tøyen. Lars Ove Hansen, Jan Emil Raastad, Stephan Olberg og Karsten Sund fortjener en stor takk for å ha gitt meg arbeidsplass, utstyr og hjelp når jeg har spurt om det!

Kjetil Aakra ved Midt-Troms Museum, Fjordmuseet, har også vært en god støttespiller når det gjelder bestemmelse av edderkopper. Takk for god hjelp!

Familie og gode venner har også vært gode støttespillere gjennom hele studietiden. Takk, mor og far!

Joachim Tørum Johansen og Erik Brenna fortjener også en stor takk. Dere har vært der når jeg virkelig har trengt hjelp. Det setter jeg pris på! Til alle dere andre: ”Jeg går aldri lei av å diskutere fisk, bille eller fugl”!

Og til slutt vil jeg takke jenta mi, Marit Helgerud, for at du har vært snill, hjelpsom og tålmodig gjennom hele masterstudiet. Jeg hadde ikke klart dette så bra uten deg.

Oslo, desember 2005

Ragnar Mathias Aaserud

Summary

Invertebrate community responses to grazing were studied within a fully replicated, landscape scale experiment where densities of domestic sheep were manipulated in alpine ecosystems in Hol, Norway. I determined species richness and abundance of beetles and spiders with pitfall trapping in each of the enclosures with three different levels of sheep densities (no, low and high). Strong effects of sheep grazing on the species richness and abundance of beetles were found. Species richness was lower at high density of sheep compared to treatments with low density or no sheep. There was however no difference in species richness between enclosures with low density or no sheep present. The abundance of both of the two most common herbivore beetles was negatively affected by grazing. *Byrrhus fasciatus* (Byrrhidae) was negatively affected even at low densities of sheep. Only *Patrobus assimilis* (Carabidae) of the three predatory beetles were reduced in abundance due to grazing and then only at high sheep density. The abundance of the other two predator beetles species as well as the spider community, which are also predators, were not affected by sheep grazing to the same extent. The insight obtained from this study is thus that sheep grazing is affecting the invertebrate community, but that effects differ between different functional groups, being stronger for herbivores than predators. Although this is based on analyses of a limited number of species, it may suggest that the effect of sheep grazing diminishes further up the food chain.

Introduction

Large herbivores contribute to ecological changes in many ecosystems by grazing, browsing, trampling, defecating and urinating (Augustine and McNaughton 1998; Austrheim and Eriksson 2001; Jefferies et al. 1994). Ecosystems such as lakes, streams, grasslands and forests all react to grazing, but will respond to grazing impacts differently depending on whether they are nutrient-rich or nutrient-poor (Proulx and Mazumder 1998). Comparisons show that in nutrient-poor ecosystems, high-grazing pressure decreases the diversity of species. Increasing grazing pressure in nutrient-rich ecosystems shows a significant increase in the amount of species richness (Proulx and Mazumder 1998). Grazing may not only lead to a vegetation change, but in addition other organisms may be competed out of the environment because they depend on the vegetation for food and shelter (Steen et al. 2005). So-called trophic cascade effects may occur where primary effects on the plant community, due to grazing are transferred over to the herbivores which in turn may affect predators. A trophic cascade effect is often difficult to predict. It is expected when an ecosystem is changed as a result of a new dominating regime, whether man-made or as a result of a natural change. In particular, we cannot currently predict exactly how individual invertebrate species or communities will respond to grazing based on how plants tolerate different grazing pressures (Milchunas et al. 1998).

There are a number of recent studies which demonstrate how grazing by large herbivores affects the invertebrate community (Baines et al. 1994; Dennis et al. 1998; Rambo and Faeth 1999). Typically, these show how invertebrates are affected by the presence or absence of grazing herbivores, but few relates this to more than one level of grazing, or even to a known grazing pressure. The impact of reindeer (*Rangifer tarandus*) grazing on ground-dwelling Carabidae and Curculionidae was tested in Lapland, Finland (Suominen et al. 2003). Curculionidae - a herbivore beetle family, was significantly more common in ungrazed plots. In contrast, Carabidae - a family of only predators, was significantly more common in grazed plots (Suominen et al. 2003). This demonstrates that invertebrates with different functional roles, being either herbivores or predators, may react differently to grazing.

There are a number of studies reporting effects on beetles (Dennis et al. 2002; Suominen et al. 2003), and a few studies have examined grazing impact on spiders (Dennis et al. 2001). The spiders are all predators, but they constitute a diverse group and their biology differs greatly from that of predatory beetles. These differences are best expressed through their discrete hunting techniques. Ambushing hunters use vegetation of contrasting heights over small distances as hunting grounds. For example the spider *Xysticus cristatus* sits on top of flowers waiting for flying insects to come close enough for an attack. Running hunters (Lycosidae) or thermophilic web builders (Linyphiidae) are usually more common in shorter swards. Web builders are most common on higher vegetation which provides anchorage for web building (Dennis et al. 2001). Due to this heterogeneity of hunting techniques within spiders, the species is expected to react to different levels of grazing.

Numbering around 2,200,000 sheep (*Ovis aries*) are the most abundant large herbivore during summer in Norway (Myserud and Austrheim 2005). A large amount grazes freely on outlying alpine pastures. Apart from some studies of grazing effects on plants (review in Austrheim and Eriksson 2001), we have little knowledge of the effects of grazing on other aspects of Norwegian alpine ecosystems (Myserud and Myserud 1999). In this study, as part of a fully replicated landscape-scale experiment (Myserud and Austrheim 2005), I report the short-term impact of sheep grazing on two abundant invertebrate groups – beetles and spiders. Within the same experiment, no impact of sheep grazing on abundance of mainly Hemiptera and Diptera was found in an earlier study (Myserud et al. 2005). Based on the available literature, I derived the following main hypothesis to be tested:

(H₁) Increasing grazing pressure in Norwegian alpine ecosystems makes the number of invertebrate species decrease.

I expect that the response of specific invertebrates is related to their functional role in the ecosystem.

(H₂) I expect herbivore beetles to be directly negatively affected by competition from sheep over available food.

(H₃) I expect predator beetles to be negatively affected by sheep grazing only if their preys are reduced in number, since predatory beetles are not directly affected by competition, but may be indirectly affected by the loss of vegetative structure, the reduction in herbivore prey and the deterioration of the soil.

(H₄) I predict the presence of the sheep to have a negative effect on spiders, as sheep disturb the vegetative structure, and since spiders hunting with webs prefer stable habitats.

Material and Methods

Study area

The study area covers 2.7 km² of mountain habitat in the Hol municipality, Buskerud county, Norway (Mysterud and Austrheim 2005). The area is enclosed with standard sheep fencing (110 cm high) 17.3 km in length within 7°55'-8°00' and 60°40'-60°45' (UTM). The climate in the Hol municipality is characterized as sub alpine with moderate to low annual precipitation 700-800 mm (Førland 1993). The bedrock consists of metaarkose (Sigmond 1998). The soil is moderately base-rich, which is typical of land with seepage water (Austrheim et al. 2005a).

The study area is situated in a harsh alpine environment on a south facing slope which rises between 1050 – 1300 m above sea level (Figure 1). The lower border of the study area is close to the tree line. The vegetation is dominated by low shrubs interspersed with grass – dominated meadow, and a few scattered birches (*Betula* spp.) (Rekdal 2001). The study area was exposed to a low grazing pressure by domestic sheep prior to fencing (<10 sheep per km²). Individuals or small herds of wild reindeer occasionally grazed the area in winter and early spring. Moose (*Alces alces*) occasionally grazed during summer nights. Large herbivores other than sheep are likely to have a negligible effect on the system (Mysterud and Austrheim 2005).

Experimental design

The study area was split into nine treatment enclosures. Average size of enclosures was 0.3 km² with some variation due to practical problems with fences where only bare solid rock was visible. A block-wise randomization design was used. Each of the three adjacent enclosures (blocks) was randomly assigned with treatments: control (no sheep), low and high density of sheep (Mysterud and Austrheim 2005). Thus three full replicates could be run. Each enclosure shared the same altitudinal range, and the distribution of main habitats used by sheep was similar between the enclosures (Rekdal 2001). The grazing value of the vegetation in the area was assessed in 2001 by a grazing ecologist (Rekdal 2001). Based on the recommendations provided, 25 sheep per km² were used as

low density and 80 sheep per km² as high density of sheep (Figure 1.) (Myserud and Austrheim 2005). This estimate covers most of the variation in the numbers of sheep grazing on mountain pastures in Norway. Density was calculated relative to the area of grazeable habitat, and the gross densities were consequently slightly lower. The sheep used was the “Kvit norsk sau” breed (formerly referred to as “Dala” breed), which is the most common breed in Norway. The grazing season lasted from the last week of June to the first week of September, which is the same as that in most mountainous regions in southern Norway (Myserud and Austrheim 2005).

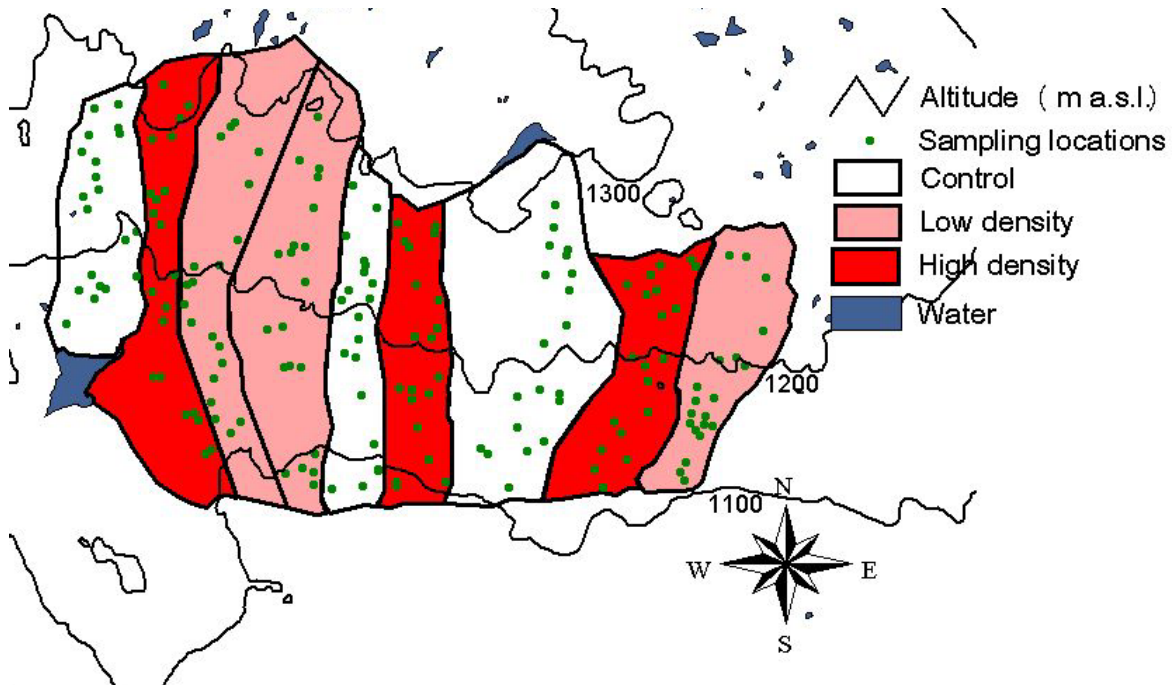


Figure 1. An overview of the study area close to Minnestølen in Hol, Buskerud. The area (2.7 km²) is divided into nine enclosures with 3 replicates of control (no sheep), low density of sheep and high density of sheep.

Collection of invertebrate data

Barber traps (Picture 1) were used to sample beetles and spiders from the area. Each of the nine enclosures had 20 traps situated at random locations where the vegetation composition was known (see below). Traps were plastic cups of 6.8 cm in diameter and 9.0 cm in depth. Transparent plastic covers were placed over each trap to limit the effect of trampling and to reduce the risk of flooding during heavy rain. We used a mixture of water, soap and ethylenglycol in the barber traps to prevent the samples escaping or decomposing. The traps were sampled early and late during the grazing season, each within a 3 day period to ensure equal period of sampling.



Picture 1. Pitfall trap used to sample invertebrates summer 2003. Photo: Atle Mysterud

Pitfall traps is a common method of sampling ground-living terrestrial arthropods. The method is inexpensive, easy to manage, and can sample day and night for long periods of

time. It has been used to elucidate diurnal activity cycles (Blumberg and Crossley 1988) and to compare species assemblages (Culin and Yeorgan 1983). However, pitfall traps have certain disadvantages that are important to be aware of. The method is not always suited to compare abundance between species (Uetz and Unzicker 1976). This is a result of problems regarding different activities, capture rates and different responses between species as to habitat structure (Den Boer 1986; Desender and Alderweireldt 1990), mate-searching (Tretzel 1954), female dispersal, postcopulatory search for ovioposition sites (Duffey 1956) and search for food (Grüm 1971). The way I have used this method is to compare individual species sampled from enclosures with different grazing treatments, and possible biases are likely similar between the treatments. I also compare responses of herbivore and predatory species. For this comparison I have to assume equal trapability.

Taxonomic classification

In the lab, spiders and beetles were separated out from rest of the samples by hand and put in a solution of 70% ethanol. Spider specimens were sent to specialist (Kjetil Aakra). Beetles specimens were determined with help from Stephan Olberg. Both groups were determined down to species level. The number of individuals of all species was counted for each sample.

Available plant data

Data from a study in 2003 of the frequency of vascular plants in 180 permanent locations (Austrheim et al. 2005a) was used as background for looking at the relationship between the invertebrate data and the vegetative structure and plant community. This data provided an indication of the variety of plant species, giving the dominant (first axis) of a Principal Component Analysis (PCA) on the frequency of the ten most common plant species sampled that year.

Statistical analyses

The first sampling period (24 June – 22 July) yielded much data, while the data from the last period was insufficient to perform analysis on. Of the total data collected, there were several species that are relatively rare, and thus unsuited for detailed analysis. Of the 39

beetle species, the five most common species were selected for further analysis. Three of them were predators and two were herbivores. The three most abundant of the 67 spider species present were all ground living. Even for these common species, they were not recorded present at all locations. Hypothesis testing and parameter estimates were carried out using both generalized linear models (GLM) and generalized linear mixed-effects models (GLMM) with “enclosure” as a random effect. The aim of the latter was to eliminate a possible dependency of observations within the same enclosure (Crawley 2003; Lindsey 1999). Initial modelling, assuming a Poisson distribution showed evidence of a poor model fit. This was likely due to the problem mentioned of a lot of “zero” observations. Following this, we turned to a logistic regression using a Binomial error term. Model fit was assessed using goodness-of-fit. Analysis was done in R vs. 2.0.0. (Maindonald and Braun 2003).

Results

Beetles

A total of 802 individuals divided over 39 species were captured and identified during the summer 2003. The five species that were selected for further analysis accounted for 50% of the total number of individuals.

Species richness of beetles was lower at high density compared to low density of sheep ($T = -2.439$, $P = 0.016$), while there was no difference in beetle richness between enclosures with no grazing and low density of sheep ($T = -0.622$, $P = 0.535$) (Figure 5.). The difference between high and low density of sheep was not quite significant when using a more restricted GLMM with “enclosure” as a random term ($T = -2.188$, $P = 0.094$). The plant community (measured as PCA1) had a strong impact on beetle species richness ($T = 4.419$, $P < 0.001$).

Two of the most common herbivore species showed clear changes in abundance related to level of sheep density. The pill beetle (Byrrhidae), *Byrrhus fasciatus* (Forster 1771) was less abundant within enclosures with high grazing levels (Table 1, Figure 2), but also showed a decline in abundance within enclosures with low grazing impact. The plant community (measured as PCA1) had a measurable impact on the abundance of *Byrrhus fasciatus*. Plant species richness also had a measurable impact on this species. The weevil (Curculionidae), *Otiorhynchus nodosus* (O. F. Müller 1764), was significantly rarer in enclosures with a high density of sheep than those with a low density of sheep (Table 1, Figure 3), but did not differ between low sheep density and controls.

In contrary there was only one (*Patrobis assimilis* Chaudoir 1844) out of three species of carnivorous beetles (Carabidae) that was shown to be affected by sheep grazing, and then only at high grazing levels (Table 1, Figure 4). The abundance of two other carnivore beetles *Calathus melanocephalus* (L. 1758) and *Notiophilus aquaticus* (L. 1758) did not differ in between the sheep grazing treatments. The predators were shown to be affected

by the amount of beetles present in each enclosure, while there was no effect of the plant community.

Table 1. Results of analysis on presence and absence (logistic regression) of five beetle species sampled in Hol, Buskerud summer 2003.

Parameter	Estimate	SE	Z	P
<i>Byrrhus fasciatus</i> (herbivore)				
Intercept	0.1271	0.6106	0.208	0.835
Treatment High vs. Control	-1.2832	0.6182	-2.076	0.038
Treatment Low vs. Control	-1.1537	0.6328	-1.823	0.068
Plant PCA1	0.6813	0.1727	3.994	0.000
Plant species richness	-1.1294	0.0465	-2.783	0.005
Random effect	0.0007	0.2451	0.003	0.988
<i>Otiorhynchus nodosus</i> (herbivore)				
Intercept	0.4028	0.4802	0.839	0.402
Treatment High vs. Control	-1.2332	0.4658	-2.624	0.009
Treatment Low vs. Control	0.1395	0.4032	0.346	0.729
Plant PCA1	0.1887	0.1217	1.551	0.121
Plant species richness	-0.0731	0.0333	-2.193	0.028
Random effect	0.0053	0.1765	0.030	0.976
<i>Patrobis assimilis</i> (predator)				
Intercept	-0.4299	0.4792	-0.897	0.370
Treatment High vs. Control	-1.2040	0.4658	-2.586	0.010
Treatment Low vs. Control	-0.4717	0.4334	-1.088	0.276
Plant PCA1	0.4053	0.1263	3.209	0.001
Plant species richness	0.0165	0.0352	0.543	0.587
Random effect	0.0000	0.2240	0.000	1.000
<i>Calathus melanocephalus</i> (predator)				
Intercept	-2.1501	0.6032	-3.565	0.000
Treatment High vs. Control	0.2323	0.5048	0.460	0.645
Treatment Low vs. Control	0.6707	0.4893	1.371	0.170
Plant PCA1	-0.0502	0.1388	-0.362	0.717
Plant species richness	0.0461	0.0352	1.307	0.191
Random effect	0.7472	0.2240	3.336	0.001
<i>Notiophilus aquaticus</i> (predator)				
Intercept	-2.0308	0.7153	-2.839	0.005
Treatment High vs. Control	-0.1535	0.6214	-0.247	0.805
Treatment Low vs. Control	-0.5214	0.6889	-0.757	0.449
Plant PCA1	0.7770	0.1860	4.178	0.000
Plant species richness	-0.0167	0.0411	-0.405	0.685
Random effect	0.3722	0.2659	1.400	0.163

Byrrhus fasciatus (Herbivore)

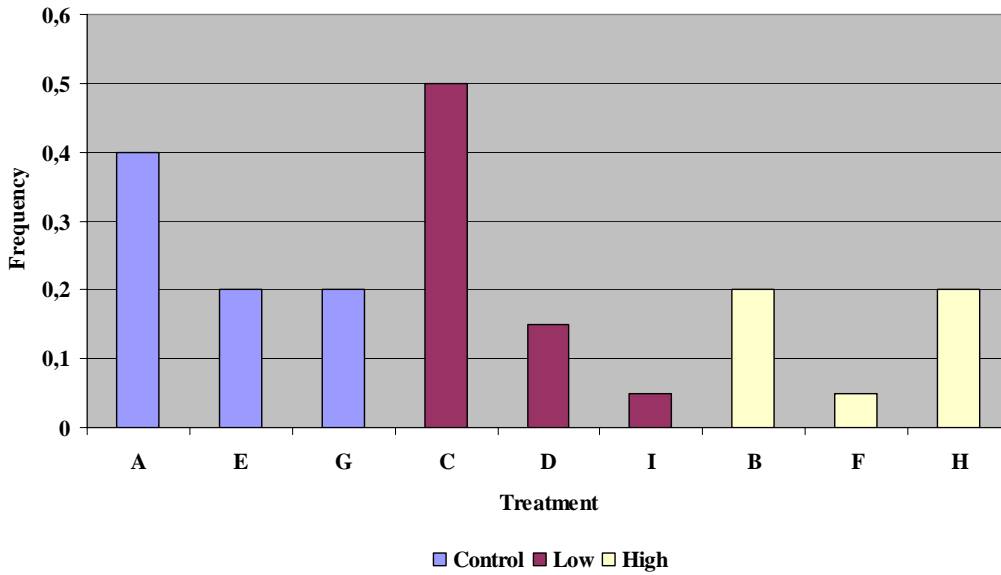


Figure 2. Frequency of *Patrobus assimilis* in enclosures with three different levels of sheep density (treatment).

Otioryncus nodosus (Herbivore)

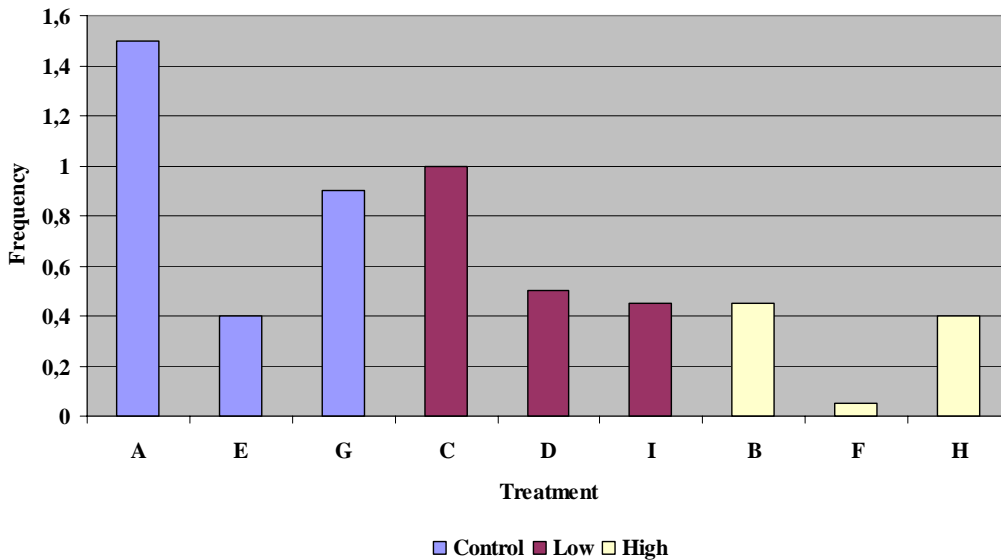


Figure 3. Frequency of *Patrobus assimilis* in enclosures with three different levels of sheep density (treatment).

Patrobus assimilis (Predator)

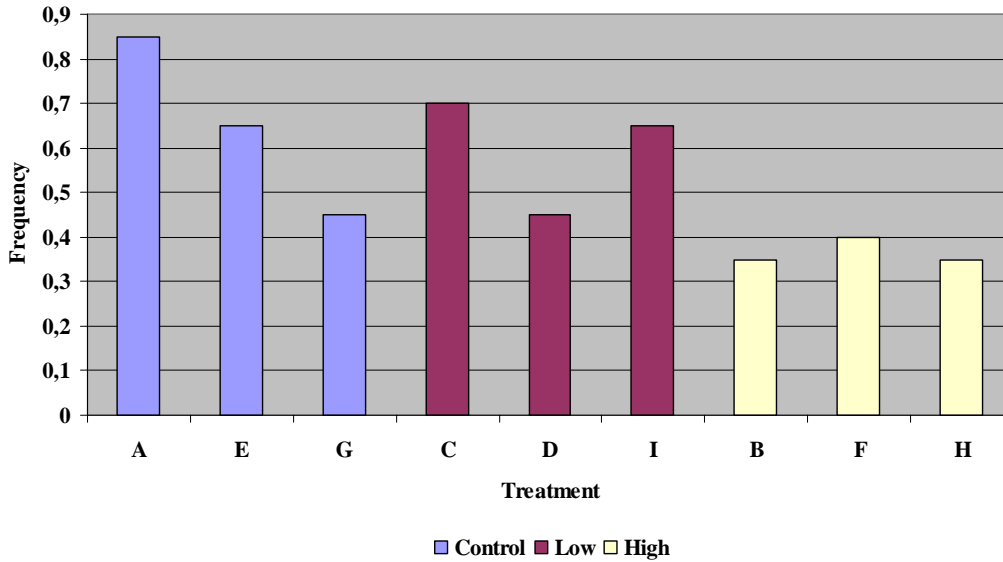


Figure 4. Frequency of *Patrobus assimilis* in enclosures with three different levels of sheep density (treatment).

Beetle species richness

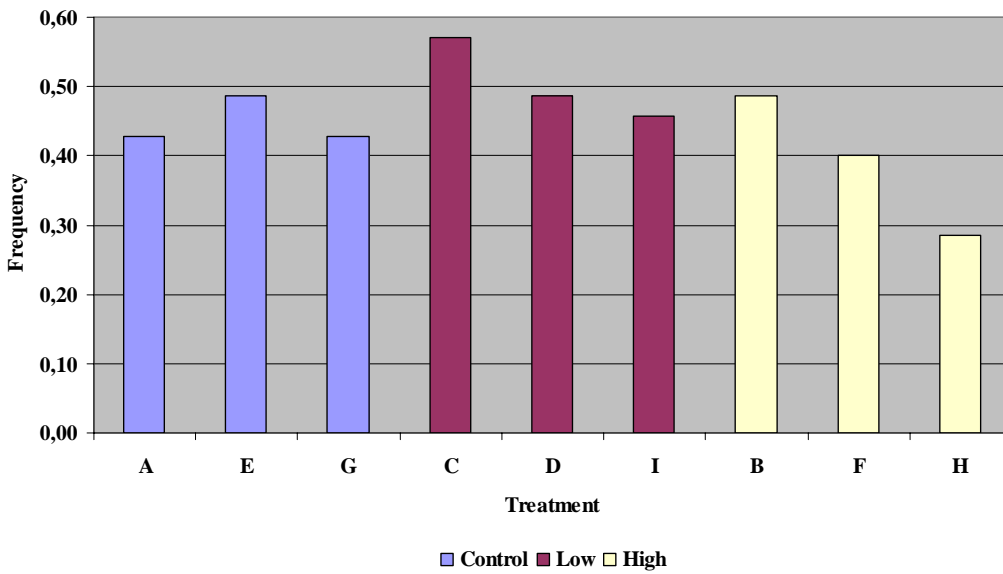


Figure 5. Beetle species richness in enclosures with three different levels of sheep density (treatment).

Spiders

A total of 3106 individuals spread over 67 species were identified and sorted during the summer of 2003. The three selected species (*Gnaphosa leporina* (L. Koch 1866), *Pardosa palustris* (L. 1758), *Pardosa hyperborea* (Thorell, 1872)) accounted for 75 % of the total number of individuals.

Spider richness tended to be lower at high density compared to low density of sheep ($Z = -1.883$, $P = 0.060$). The result was however over dispersed and when using a more restricted analysing method, where we found no trend in spider richness due to sheep density ($T = -1.429$, $P = 0.203$).

None of the three spider species showed significantly decline in abundance due to grazing. However, all showed qualitatively the same pattern as found in beetles with decreasing abundance the higher the grazing impact. *Pardosa hyperborea* was the species being closest to be significantly rarer in enclosures with high grazing than low grazing (Table 2).

Table 2. Results of analysis on abundance (logistic regression) carried out on three spider species sampled in Hol, Buskerud the summer 2003.

Parameter	Estimate	SE	DF	T	P
<i>Gnaphosa leporina</i> (ground living)					
Intercept	-0.5290	2.6323	348	-0.201	0.841
Plant PCA1	-0.0267	0.0820	348	-0.326	0.745
Plant richness	-0.0309	0.0216	348	-1.435	0.152
Altitude	0.0003	0.0021	348	0.150	0.881
Treatment High vs. Control	-0.5340	0.2893	6	-1.846	0.115
Treatment Low vs. Control	-0.0808	0.2751	6	-0.294	0.779
<i>Pardosa palustris</i> (ground living)					
Intercept	-15.5345	2.8260	348	-5.497	0.000
Plant PCA1	-0.0537	0.0835	348	-0.643	0.521
Plant richness	-0.0277	0.0222	348	-1.247	0.213
Altitude	0.0135	0.0023	348	5.942	0.000
Treatment High vs. Control	-0.4151	0.3995	6	-1.039	0.339
Treatment Low vs. Control	-0.2974	0.3941	6	-0.754	0.479
<i>Pardosa hyperborea</i> (ground living)					
Intercept	6.3729	2.5628	348	2.487	0.013
Plant PCA1	-0.1066	0.0793	348	-1.345	0.180
Plant richness	-0.0276	0.0206	348	-1.343	0.180
Altitude	-0.0049	0.0020	348	-2.416	0.016
Treatment High vs. Control	-0.6347	0.2886	6	-2.200	0.070
Treatment Low vs. Control	-0.2595	0.2832	6	-0.916	0.395

Discussion

Sheep grazing had a marked impact on the invertebrate community in the alpine habitat of Hol municipality, Buskerud county, Norway. Species richness of beetles was lower at high density of sheep than in areas with lower density of sheep. The herbivore beetles *Byrrhus fasciatus* and *Otiorhynchus nodosus* was significantly negatively affected at high sheep densities, but only *Byrrhus fasciatus* was negatively affected at low densities of sheep. Of the carnivore beetles, only *Patrobis assimilis* was significantly negatively affected at high sheep densities. The other two carnivore beetle species as well as the predatory spider community were not affected by sheep grazing to the same extent. Thus, the hypotheses H1 and H2 were supported, while there was some tendency for H3 and H4.

Effects of grazing on invertebrates – levels of grazing

There are a number of earlier studies showing changes in invertebrate communities due to grazing by large herbivores. A study was carried out on the effects of reindeer browsing on tundra willow (*Salix arctica*), and its associated herbivorous insects (Den Herder et al. 2004). They concluded that browsing reduces the densities of the most common insect herbivores. Leaf beetles of the genus *Gonioctena* (Coleoptera: Chrysomelidae) and gall-inducing sawflies (Hymenoptera: Tenthredinidae) belonging to the genera *Phyllocolpa*, *Eupontania* and *Euura* were all negatively affected by grazing. A study of guild structure of insects assemblages under grazing regimes in mountain grassland in central Argentina (Cagnolo et al. 2002), concluded that abundance, richness and biomass of the insect assemblages had minimum values in the most intensely grazed habitat, which also differed from the other sites in terms of the composition of insect families and coleopteran species composition. Rambo and Faeth (1999) found that insect species richness was not different between grazed and ungrazed habitats, although insect abundance increased four- to tenfold in ungrazed vegetation.

Common to these studies is that they do not compare grazing at different intensities. The current experiment was designed to test the invertebrate richness and abundance in

environments with not only the presence or absence of a grazer or not, but also to compare no grazing with both low and high grazing level. The intermediate disturbance hypothesis (Grime 1973) predicts that botanical diversity will increase with intermediate grazing levels. Among the spiders and beetles included in this study I did not find any increase in species richness or in the abundance of individual species at an intermediate level of sheep density. Hence, this provides further support to the claim that invertebrate and plant richness do not necessarily follow each other's responses to grazing (Haddad et al. 2001).

Effects of grazing on beetles and spiders

Beetles and spiders are two large heterogenic groups of invertebrates. They are represented in a wide range of environments. In Norway there are 3,300 identified species of beetles and 562 identified species of spiders and they are an important part of the Norwegian alpine environment. Both groups' abundance have been studied in other environments.

There are several accounts in the literature that beetles respond to grazing by large herbivores. A study carried out in the Scottish part of Cheviot Hills on the spatial distribution of upland beetles in relation to land formation, vegetation and grazing management (Dennis et al. 2002), found that the Carabidae species was sensitive to grazing intensity and species of mammalian herbivore. Other aggregations related to landform, and suggested a direct response to soil moisture and patterns of trampling by grazers. Dung beetles thrive where there is dung. The effects of the intensification of agriculture on northern temperate decrease dung beetle communities. Organic farms had significantly greater beetle biomass, diversity and species richness compared to intensive and rough grazing farms (Hutton and Giller 2003). Suominen et al. (2003) concluded that the relative difference between the number of individuals found in grazed and ungrazed plots increased linearly with the impact of reindeer on vegetation cover. Carabidae beetles, as a family, were more common in grazed plots in all sites. Curculionid beetles were more common in ungrazed plots in the birch dominated sites. This difference was mainly due to the species that feed on deciduous leaves. In the pine dominated sides with

high *Cladina* spp. cover and more changes in vegetation. The number of Curculionids feed in confers was higher in grazed plots. Two of three herbivorous species of beetles analysed in this study showed to be affected by grazing. One of the three species predator beetles was affected as well.

There are much fewer studies on the effect of grazing on spiders. The sheep density may be a limiting factor for spider richness and abundance. In a review of the implications of grassland and heath land management for the conservation of spider communities, Bell et al. (2001) stated that under high intensity management, spider communities often lack diversity and are dominated by a few r-selected species affiliated with bare ground. Low intensity management produces more complex communities introducing more niches for web spinners and climbing spiders. Gibson et al. (1992) presented results where heavily grazed areas were dominated assemblages of Linyphiidae. The dominant successional trend was however a gradual accumulation of species, especially in ungrazed control areas. The direct effects (disturbance of webs by treading) are clearly less important than indirect effects (the alteration of vegetation structure) (Dennis et al. 2001). Their study on the epigeal spiders, harvestmen and psuedoscorpions of upland *Nardus stricta*-dominated grassland supported their main hypothesis that vegetation structure has a greater effect on the species composition and abundance of arachnids than that of botanical species composition. In my study, none of the species of spiders were significantly reduced in abundance as a result of sheep density. The species that were most common were all ground living. A change in abundance patterns was mostly expected for species dependent on the vegetative structure for building webs.

Effects of grazing on invertebrates – functional groups

Invertebrates are a large group, and individual species may react differently to grazing. Beetle abundance was affected by sheep densities in this study, but there was no united trend within the five species analyzed. There is currently little theory to predict responses of different invertebrate species or groups to grazing (Myserud et al. 2005). In contrast, there are a large number of studies reporting how different plant functional groups respond to grazing (McIntyre and Lavorel 2001). Species of both spiders and beetles

show distinctly different morphological characters and life history strategies. This will clearly divide them into different functional groups. It will be important to study in more detail the mechanisms by which sheep grazing affects invertebrates and not only the patterns of the effects as in the current study. Invertebrates are an oligovorous group, but some species are more specialized than others. Their dependence on a stable environment will therefore increase with speciality within both biotic and abiotic elements.

Spiders start hunting as soon as they emerge from the egg cocoon. They are more likely to stay put in the same type of landscape over time if the structure suits their hunting techniques. Spiders are exclusively predators but the varied foraging strategies of different species require contrasting architectural features in alpine habitats. Web construction by spiders demands points of anchorage at different heights, whereas diurnal species, that use sight to pursue prey, are associated with patches of low vegetation. Tall, rigid plant species associated with successional changes contrast with existing vegetation and encourage the colonisation of web-building spiders (Gibson et al. 1992). Spider species composition is more directly affected by changes in vegetation structure. Indirectly, such types of changes can secondarily alter the host-plant specificity of their major prey species, namely the planthoppers (Homoptera: Auchenorrhyncha) (Waloff and Thompson 1980).

Another important aspect of spider life strategies is a place to hide from predators. Dense vegetation gives more shelter than sparse vegetation. Accumulation of dead plant material, typical of upland organic soils, was likely the explanation given to account for the dominance of money spiders (Linyphiidae) at higher altitude in the uplands in a study done by Dennis et al. (2001). The presence of sheep does also mean that if there is shelter present through litter, the chances of it being destroyed is greater with the number of sheep present. This is because trampling affects the structure of plant litter in a way that open spaces available to spiders within the litter become unavailable (Duffey 1975).

Sheep few in number usually avoid substantial patches of closed vegetation so that webs would not be damaged (Cherrett 1964). When the grazing impact increases, the sheep tend to become less selective and patches of vegetation that was not preferred will be

preferred. *Pardosa hyperborea*, *P. palustris* and *Gnaphosa leporina* are all ground living and hunt using sight. They were not significantly affected by sheep grazing. The alteration of vegetation and soil produced by sheep grazing does not inflict habitat preferences which three of the species rely on to thrive.

Erhardt and Thomas (1991) claimed that diversity of insect species increases under grazing management that maintains or enhances the structural and floristic diversity of vegetation in time and space. The abundance of both the herbivorous beetles (*Otiorhyncus nodosus* and *Byrrhus fasciatus*) was negatively affected by grazing in Hol, Norway. Beetles have been shown to be affected at the level of functional groups by other studies (Suominen et al. 2003; Woodcock et al. 2005). For herbivorous beetles it is the change of botanical composition that looks to be the primary factor in affecting species composition. For some species the botanical composition is more important than the structural characteristics and vice versa. The botanical as well as the structural plant composition change with sheep grazing management in alpine areas (Austrheim et al. 2005b). Austrheim et al. (2005b) found a decrease in the cover of vascular plants at high densities with sheep in our study area. For invertebrate species studied, both factors may be important.

Ecosystem effects of grazing

The study can also be used to suggest which mechanisms are likely to be involved in altering the composition of insect and spider species. This is a key question in order to assess the ecosystem effects of grazing, and the likelihood of so-called trophic cascade effects. Milchunas et al. (1998) investigated the animal and plant biodiversity of shortgrass steppe and the relationship of livestock grazing to ecosystem function. They found that some responses were large even when comparing ungrazed land to lightly or moderately grazed treatments. Birds appeared to be particularly responsive to grazing, and displaying a shift in the dominant species in response to the different grazing treatments. In addition to this shift in dominant species, three species of birds breeding in lightly or moderately grazed treatment areas were not found in heavily grazed treatment, and the opposite was true for two other species of birds. Steen et al. (2005) found that the

summer population growth rate and the autumn density of the field vole (*Microtus agrestis*) was lower at high sheep grazing density in the same study area in Hol municipality. It has been suggested that trophic cascades may be stronger and more frequent in more heavily managed, simpler terrestrial ecosystems (Halaj and Wise 2001; Hawkins et al. 1999). In my study, herbivore beetles were affected by sheep grazing, even at low densities. Ground living predatory beetles and spiders were not affected to the same extent. This may thus suggest that sheep grazing does not cause strong trophic cascades, or at least that the effect of grazing diminishes further up the food chain. However, clearly, this conclusion is built on a very limited number of species but requires further attention.

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