Long term effects of sheep grazing on Alpine avifauna .

Langtidseffekter av sauebeiting på den alpine fuglefaunaen

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MASTER THESIS (M.SC.)

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PREFACE

This thesis completes my master degree in Natural Resource Management at the department of ecology and wildlife management at the Norwegian university of Life Sciences (UMB).

First of all I would like to thank my supervisor Leif Egil Loe for giving me the opportunity to perform this investigation, for guiding me in the field work and for helping me trough (almost) countless errors and complications in R. I will also thank him for valuable inputs and help during the writing process.

Atle Mysterud, project manager from University of Oslo, deserves thanks for both help and support in the field and in the search for relevant articles. Anna Blix is to be thanked for funny times and company during the field season and Erik Sveingard for great hospitality and help when needed during the field season.

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I´m greatful towards all of my study mates for help, support, understanding and entertainment through the seven years of studies this thesis puts an end to. It wouldn't be the same without any of you! Elisabeth Iversen, Jørgen Remmen and Tale Nedberg still deserves special acknowledgments for helping me with their inputs and experience during the writing process.

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And last, but not least, a big thank you goes to my dog Rex for warming my toes during cold winter nights writing, for forcing me to take breaks and enjoy nature and for standing by me through frustration, happy field days, sunshine, rain and seven long years of study.

Finally I have to thank the nature, with its mysteries and beautiful scenery giving me inspiration and wet boots during the very rainy field season of 2011.

Oslo, 10.05.2013

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Sigrid Elise Lium

SUMMARY

The ecosystem changes caused by livestock grazing are considered to be among the main reasons for the severe and steady decline observed in the abundance of many grassland birds worldwide. Several studies have shown negative effects of livestock grazing on bird abundance as grazing intensity increases, while other studies have shown positive effects at low grazing levels compared to no grazing at all. Factors that are initially positive may be reversed over time, emphasizing the need to investigate both the short and long term effects of sheep grazing.

In a short term (four years), full scale study in Norway Loe et al. (2007) found positive effects on bird abundance at high sheep density grazing levels. In the present study I repeated the same field study after ten years of grazing to test the two competing hypotheses:

- H1) a positive long term effect of high level of sheep grazing on the abundance of birds (predicting the same pattern as found in 2005)
- H2) a reversal of the positive short-term effect due to overgrazing, predicting a decreased abundance of birds at high sheep density, but an increase at low sheep density

Distance sampling was used as data collecting method and the data were divided into four groups; all birds, insect eaters, meadow pipit and willow grouse. The bird density in each treatment group ("high", "low" and "no sheep") was estimated with the Distance 6.0 version 2, software. Linear mixed models fitted by restricted maximum likelihood (REML) using nlme in R 2.15.2 were used to evaluate differences on bird densities among treatments and years. Conditional F and T-tests were used to evaluate differences between treatment levels. The data from 2011 were first analyzed separately on R 2.16.2 before the two years were analyzed together.

The results from my study indicate that low sheep grazing levels may be beneficial for birds in the long term. Although initially beneficial to alpine birds the highest sheep grazing levels in this experiment may not be sustainable on a time scale of decades. Since the results are statistically inconclusive, I cannot reject or confirm either hypothesis H1 or H2. The differences indicated between the studies in 2005 and 2011 shows the importance of long term studies, and the importance of not only studying grazing effects versus no grazing, but also the effect of different grazing levels against each other.

SAMMENDRAG

Endringer i økosystemer som følge av beitende husdyr anses å være blant de viktigste årsakene til nedgangen i mange fuglebestander, som er observert i beiteområder over hele verden. Flere studier har vist at beiting har negativ innvirkning på tettheten av enkelte fuglearter ved økende beiteintensitet. Andre studier har vist positive effekter på fuglebestander ved lav beiteintensitet sammenlignet med ingen beiting overhode. Det som i utgangspunktet er positive effekter av beiting, kan over tid endres til negative effekter, derfor er det viktig å undersøke både kort- og langsiktige effekter av beiting.

Loe et al. (2007) gjennomførte i 2005 en fullskala studie i et norsk fjellbeiteområde med sau, der de på kort sikt (fire år) fant positive effekter på fuglebestanden ved høy beiteintensitet. I forbindelse med mitt mastergradsstudium har jeg gjentatt den samme feltstudien etter ti år med beiting av sau for å teste de to konkurrerende hypotesene:

- H1) en langsiktig positiv effekt på forekomsten av fugl som resultat av høyt beitepress fra sau (det vil si samme mønster som i 2005)
- H2) en reversering av den positive kortsiktige effekten sett i 2005 på grunn av overbeiting. Forekomsten av fugl i områder med høyt beitepress fra sau har gått ned, mens fugletettheten har gått opp i områder med lavere beitepress.

Linjetaksering ble brukt som datainnsamlingsmetode. Dataene ble delt inn i fire grupper; alle fugler, insektetere, heipiplerke og lirype. Fugletettheten for hvert behandlingsnivå ("høyt sauetetthet", "lav sauetetthet" og "ingen sau") ble beregnet med programvaren Distance 6.0 versjon 2. Til å beregne forskjeller i fugletettheter mellom hegn med ulik beiteintensitet og mellom de to ulike årene benyttet jeg lineære mixed modeller tilpasset med restricted maximum likelihood" (REML) ved bruk av nlme i R 2.15.2. Conditional F og T-tester ble brukt til å evaluere forskjeller mellom de ulike behandlingsnivåene. Dataene fra 2011 ble først analysert separat i R 2.16.2, før data fra de to årene ble analysert sammen.

Mine resultater tyder på at lav beiteintensitet med sau kan være gunstig for forekomsten av fugl i et langtidsperspektiv. Selv om høy beitetetthet av sau var gunstig for alpine fugler etter få års beiting, viser tendensene i mine resultater at dette ikke holder seg over tid. Da mine resultater er statistisk usikre kan jeg hverken avvise eller bekrefter hypotese H1 eller H2. Forskjellene sett i materialet mellom studiene i 2005 og 2011 viser viktigheten av langsiktige studier, der man ikke bare sammenligner effekter av beiting mot ingen beiting, men også sammenligner effekten av ulike beiteintensitets- nivåer mot hverandre.

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1 INTRODUCTION

Nature is constantly changing and has been affected by natural disturbances such as fire, herbivore grazing, extreme weather and climate changes for millions of years (Knapp et al. 1999). Humans became an important factor for ecosystem change when we started the domestication of animals and cultivation of the land approximately 10 000 years ago. Through natural disturbances, and later also human disturbances, the worlds ecosystems have evolved and developed into the vegetation, fauna and landscapes we see today. When the industrial revolution began at the end of the 19th century, agriculture was the main occupation for most humans worldwide. The revolution also led to changes in the traditional agricultural practices (Parker 2008) and the cultivation of land for agriculture has expanded and been intensified worldwide ever since (Maron & Lill 2005). Livestock is today one of the most important drivers for changes in ecosystems and is the main "user" of land in a global perspective (FAO 2002; Fleischner 1994). This results in loss and fragmentation of natural vegetation and grasslands (Maron & Lill 2005).

Domestic sheep (*Ovis aries L.)* have become an increasingly more important grazer worldwide during the last half of the 20th century and the number of sheep increased in several European countries during this time period (Beaufoy et al. 1994). Norway has a long tradition in using the outfield resources for livestock grazing (tracing back to 6000 years before Christ) and is one of relatively few countries in the western world still making use of this uncultivated land for livestock grazing (Eide et al. 2008). In earlier years all kinds of livestock (i.e. horses, goats, sheep and cattle), were grazing in the outfields during the summer months, but even in Norway the domestic sheep have become the main grazer in outfield areas (St. meld nr. 9 2011- 2012). Fifty per cent of the Norwegian land area consist of mountains which make up the main grazing habitat for Norwegian sheep (Mysterud 2005). From the 1920s to mid 1980s the number of sheep in Norway increased significantly, but has since then remained relatively stable (St. meld nr. 9 2011- 2012). In 2009 two million of a total of 2.3 million Norwegian sheep were grazing on outfield pastures during the summer season. The Norwegian Forest and Landscape institute estimated that as much as half of the usable outfield pastures were used in 2009, indicating the importance of these resources as grasslands for sheep and other herbivores (St. meld nr. 9 2011- 2012). Livestock grazing is an important way to utilize the resources that the outfields represent, and in Norway this is important for our national self-sufficiency (Eide et al. 2008).

Figure 1: Trollheimen in Sør- Trøndelag, Norway.

Grazing affects the whole ecosystem and grazing-induced vegetation changes are considered to be one of the main reasons for the severe and steady population declines observed for many grassland birds over the last decades worldwide (Fuller et al. 1995). Birds are sensitive to the impact of livestock grazing, including effects on biomass and plant species composition (Fuller 2001). Several studies show negative effects of livestock grazing on bird abundance as grazing intensity increases (Decalesta 1994; Evans et al. 2005; Evans et al. 2006; Martin & McIntyre 2007; Willcox et al. 2010). It is suggested that the reduced availability of food (mainly invertebrate biomass) as a result of changes in vegetation is the most important negative factor affecting the bird fauna (Evans et al. 2005; Evans et al. 2006; Pedersen et al. 2007; Vandenberghe et al. 2009). Interestingly, some studies have found that low levels of livestock grazing can promote bird abundance and is preferable over no sheep grazing at all (Evans et al. 2006; Vandenberghe et al. 2009). Livestock grazing may partly outweigh for natural disturbances caused by fires or extreme weathers which positively affect bird species specialized for living in such biotopes (Martin & McIntyre 2007). This demonstrates that the effects of grazing on the bird fauna are complex (Martin & McIntyre 2007) and we can rarely point out one single factor as the cause of the changes observed and the relative effect of grazing versus other factors is poorly understood (Clark & Nudds 1991; Knopf 1994). Studies indicate that other factors such as the biomass and species composition of the vegetation, food supplies, predation pressure and nest losses due to trampling caused by livestock grazing are factors that can affect both the amount and diversity of birds in an area (Decalesta 1994; Fuller 2001). In a long term study (ten years) the population of hen harrier (*Circus cyaneus*) increased as sheep declined, pointing to an effect of sheep grazing e. In the same study little effect was found on the meadow pipit (*Anthus pratensis*) (Amar et al. 2011). Vegetation studies of Norwegian mountain habitats showed only small effects of sheep grazing, with a small positive effect at low grazing levels and small negative effect at high levels (Evju et al. 2006; Evju et al. 2011). Factors that are initially positive may be reversed (or changed) over time, emphasizing the need to investigate both short and long term effects.

Figure 2: Grazing ewe with twin lambs at the study site

Most of the research on the ecological effects of sheep grazing is conducted in countries where sheep graze on grassland pastures year round at very high densities, like in Scotland (several hundred ewes per km^2) (Simpson et al. 1998). This is very different from the Norwegian management where the sheep grazing densities usually are between 10- 80 sheep per km^2 and the sheep are grazing in the outfields during the summer months only (Steen et al., 2005; St. meld nr. 9, 2011-2012). This makes "high" grazing density in Norway equal to "low" grazing density in countries such as Scotland, which is important to take into account when comparing research results from different studies. This makes it difficult to apply the Scottish results directly on Norwegian conditions, and it is important to perform Norwegian studies as basis for the right management advises and decisions for sheep grazing in the Norwegian outfields.

In 2005 Loe et al. (2007) performed a fully replicated landscape scale study with three realistic levels of grazing sheep densities in Norway. They found that the short term (four years) effect of a high sheep grazing pressure was positive; the density of birds was higher in the high sheep density areas compared to the low sheep density or no sheep areas. In the present study, I repeated the same field study after ten years of grazing to investigate if the longer grazing history has altered the positive effect of grazing on the alpine bird fauna. I test the two competing hypotheses;

- H1) a positive long term effect of high level of sheep grazing on the abundance of birds (predicting the same pattern as found in 2005)
- H2) a reversal of the positive short-term effect due to overgrazing, predicting a decreased abundance of birds at high sheep density, but an increase at low sheep density

2 MATERIAL AND METHODS

2.1 THE STUDY AREA

2.1.1 Localization

The study area is localized in an alpine environment at Minnestølen in Hol municipality, Buskerud county in southern Norway (between 7°55`- 8° 00`E and 60° 40`- 60° 45`N (Loe et al. 2007; Steen et al. 2005). The lower border of the study area is just above the forest line at 1050 m.a.s.l, and the top border is in the middle alpine zone at 1300 m.a.s.l (Steen et al. 2005). The highest point in the area is Flynuten (1326 m.a.s.l), just north of the top-east border (Rekdal 2001).

2.1.2 Climate

Minnestølen has a sub continental climate with low winter temperatures and fairly high summer temperatures considering the altitude (Figure 3) (Aune 1993 in Rekdal 2001).

The yearly mean temperature for each field season (2005 and 2011) were two and three times higher than the normal yearly mean in the area. 2011 was generally warmer than 2005, especially note the difference in April mean temperature (Figure 3). All metrological data are from the metrological station at Geilo, which is the closest metrological station to Minnestølen with reliable information (Norwegian Metrological Institute).

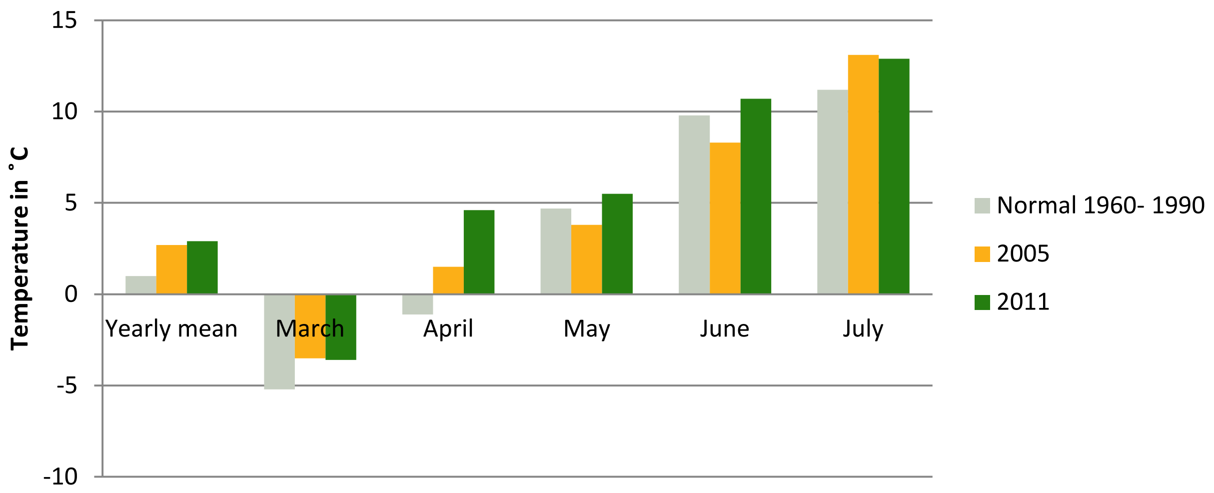

Figure 3: Yearly mean temperatures and mean temperatures for each month from March to July at Geilo (772 m.a.s.l., 22.4 km south-west of Minnestølen). Data were collected from Norwegian metrological institute.

The precipitation was markedly higher in both field seasons compared to normal precipitation. June 2011 was particularly wet, with almost three times the normal precipitation. In July both years there was markedly more rain than normal, with July 2011 as the month with heaviest rainfall (Figure 4).

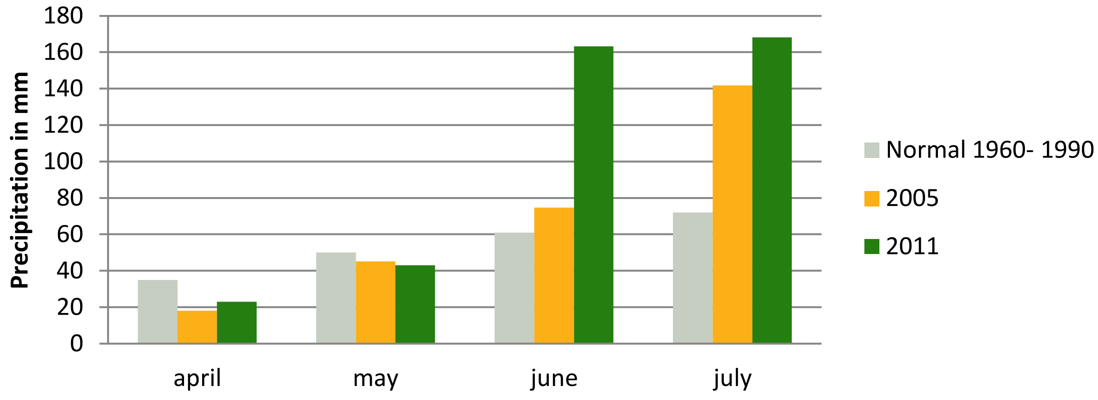

Figure 4: Precipitation from April to July in 2005 and 2011 compared to the normal during the period 1960 - 1990 at Geilo (772 m.a.s.l, 22.4 km south-west of Minnestølen). Data collected from Norwegian Metrological Institute.

2.1.3 Vegetation

The bedrock consists of metaarkose (The geological survey of Norway 2013), the soil is moderately base-rich (Steen et al. 2005) and the vegetation is evenly distributed in the enclosures (Rekdal 2001). Dwarf shrub heath is the dominating vegetation type covering 51.1 % of the area. Blueberry (*Vaccinium myrtillus*), wavy hair grass (*Avenella flexuosa),* dwarf birch (*Betula nana*), and black crowberry (*Empetrum nigrum* ssp. *hermaphroditum*) are the dominating species and the vegetation type is classified as good grazing habitat (Rekdal 2001). Lichen heath covers 17.7 % of the study area, often in mosaic with dwarf shrub heath. This vegetation type has very few pasture plants, but is often used by the sheep for resting (Rekdal 2001). Sedge and grass snow-bed are the third most common vegetation types and have the highest value for grazing of the three. It covers 12 % of the study area and is dominated by grasses and sedge species. It occurs evenly in depressions and leeward sides in the whole area and the snow usually melts in late June or beginning of July (Rekdal 2001).

Figure 5: Study area photographed from outside the southern part of the enclosures.

2.2 DESIGN OF THE FIELD AREA

The study area was established in 2001 and the main fenced enclosure (covering 2.7 km²) was split into nine treatment enclosures, hereafter referred to as sub-enclosure A-I (Figure 6) (Loe et al. 2007; Steen et al. 2005). Altitude is a main determinant of habitat in the mountains therefore the sub-enclosures were constructed so that their altitudinal ranges were similar (Steen et al. 2005). Of the whole study area 2.1 km² is considered useable for sheep grazing (Rekdal 2001), areas like water bodies, rocks and habitats with little or no forage was excluded (Steen et al. 2005).

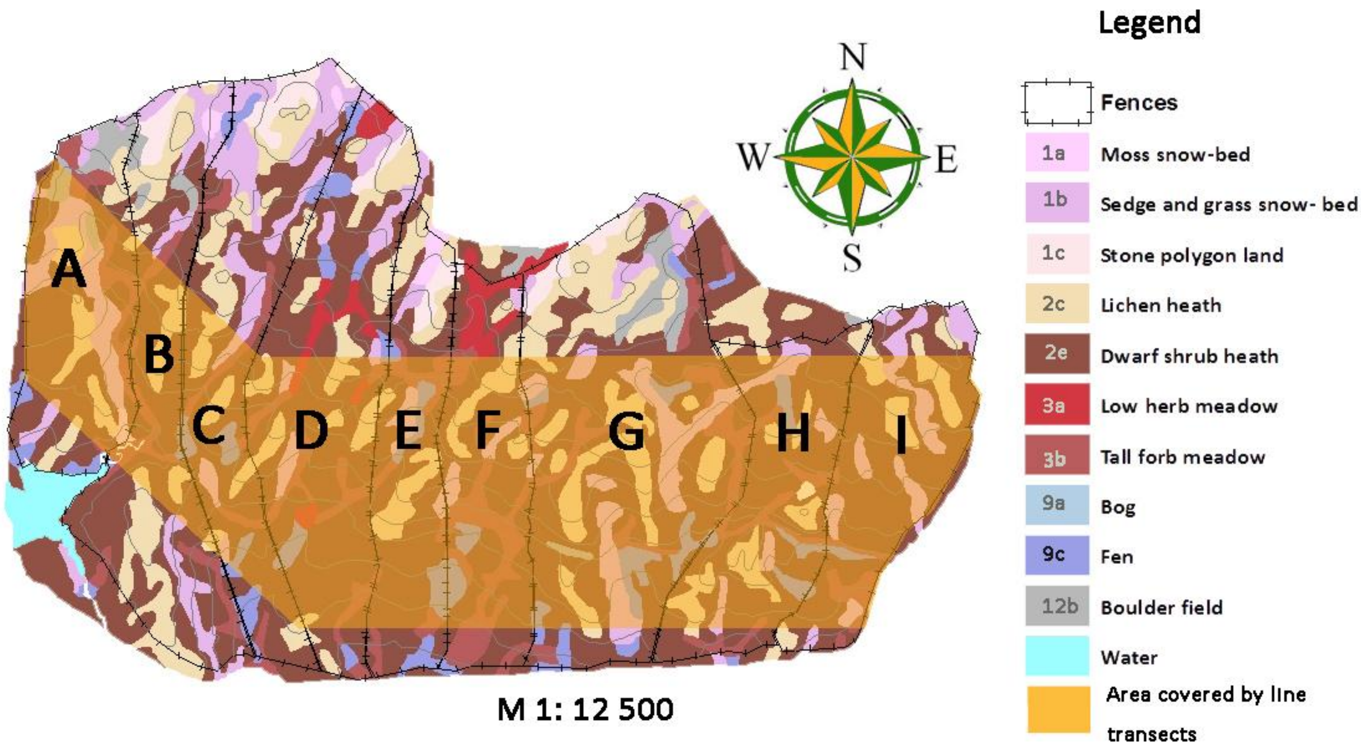

Figure 6: The study area consists of 9 sub-enclosures in a fully replicated randomised block design. Sub-enclosure A, E and G are controls with no sheep, C, D and I represent low sheep density and B, F and H are sub- enclosures with high sheep density. Different colours represent different vegetation communities (see legend) and the orange shadow shows the area of the sub- enclosures that were used for line transects.

Pre-experiment grazing pressure from domestic sheep in the study area was very low (less than 10 sheep per km²) (Loe et al. 2007; Steen et al. 2005). The density of sheep in the different sub enclosures was assigned by the use of block-wise randomization design. For each of three adjacent sub- enclosures (A-C, D-F, G-I) the treatments were randomly assigned “control” (no sheep), “low” and “high” density of sheep (Loe et al. 2007; Steen et al. 2005) (Figure 6). Sub-enclosure A, E and G are controls with no sheep, C, D and I represent low sheep density and B, F and H are sub-enclosures with high sheep density. The sub-enclosures had similar grazing values at the start of the experiment (Rekdal 2001). Based on recommendations from professional grazing ecologist Yngve Rekdal (The Norwegian Forest and Landscape Institute) 25 sheep per km² were used as “low” density and 80 sheep per km² were used as “high” density in the study. This covers the most common variation in sheep grazing densities in Norwegian mountain pastures (Steen et al. 2005).

The experiment has been run with the same sheep densities each grazing season between 2002 and 2011 with only minor differences. Sheep were released into the sub-enclosures in the end of June each year and collected late August or beginning of September (Loe et al. 2007). In 2011 the sheep were released on June 22nd and gathered on September 2nd.

2.3 FIELDWORK

To collect data for estimation of bird densities in the different sub-enclosures we used “distance sampling”, the line transect sampling method described by Buckland et al. (2001).

Ten different line transects, running exactly east- west in sub- enclosures D- I and 313/ 133 degrees in sub-enclosures A- C, were evenly spread in the study area. The change in walking direction in sub-enclosures A- C was to avoid a lake in the southern part of sub-enclosure A and to keep the lines at the same altitudinal gradient throughout the whole study area. The distance between each line was 65 m (i.e. transect line number two was 65 meters north of transect line number one). During the preparation for the 2005 field study, lines were selected randomly without replacements in sets of five following days (Loe et al. 2007). The rules that adjacent lines could not be walked on the same day and that a line could not be walked two consecutive days was applied. The exact starting location for each transect line was randomized +/- 32 meters north/south from the central line to cover the whole study area, and not only 10 distinct lines. The starting point of any given day was randomized (with replacements) for the first transect line each day, either starting from east (I), between east- and midblock (F/G), between mid- and westblock (C/D) or from the west (A) to avoid any confounding effect between bird density per enclosure and time of day. Starting from east or west the direction was given, when starting from one of the midpoints the starting direction was drawn randomly (with replacements). The second line on the same day was always walked in the opposite direction of the first line. The same schedule was used in both 2005 and 2011. In 2005 two lines were walked each day, in 2011 one and two thirds to two lines were walked each day.

Figure 7: Registration of observations in the field.

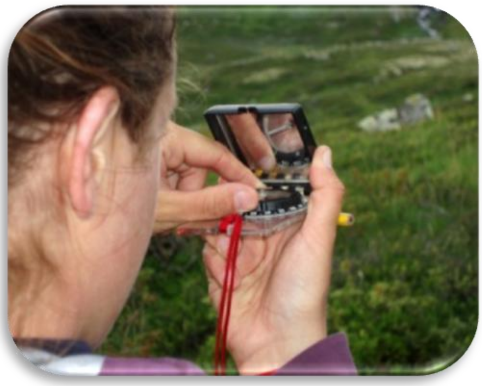

Figure 8: Me using the sighting mirror to determine bird angle during the fieldwork.

The observer walked on compass bearing along the transect line using a handheld compass with sighting mirror (Silva Ranger), which led to some random drift along the line (5- 15m). The observer did not know which sub-enclosures were control, low or high density before the sheep were released. Birds were not identified by song, but only through visual observation and by use of the book "Gyldendals store fugleguide" (Svensson et al. 2004) to determine the bird species. At each observation along the transect line bird species, sighting distance, sighting angle, habitat type, observers GPS position (using Garmin 62s) and bird behaviour (sitting on the ground or in a tree , in flight, bird landing or taking off) were recorded. Distance from observer was measured using a laser rangefinder (on Leica geovid binoculars) for all observations further away than eleven meters, when observations were closer than eleven meter a measuring line was used (because the rangefinder worked only beyond ten meters). The sighting angle from the line was determined using the handheld compass. Only visual observations were recorded. Temperature, wind and general weather impression were noted in the field at the beginning of every day and when there were marked changes in the weather. This information was not used in the analysis for this thesis and neither was the information about habitat type.

Data were collected during two periods. In 2005 Leif Egil Loe collected data from June 7th to July 6th. Altogether 1324 individuals of 24 species were observed (Loe et al. 2007). In 2011 I collected data from June 2nd to July 9th. The observations in 2011 were spread over 25 days and the observation time per day ranged from three to nine hours.

2.4 STATISTICAL ANALYSES

Density was estimated separately for "all birds" and the three subsets "insect eaters", "meadow pipit" and "willow grouse (*Lagopus lagopus*)". The study in 2011 is a replicate of the study done by Loe et al (2007), therefore the same subgroups were used in both years to describe the similarities or difference between the two years observations. Insect eaters were for both years the only functional group with sufficient sample size. Meadow pipit was chosen because it was the most common species and suffers from high grazing pressure in Scotland (Evans et al. 2005) and the willow grouse was chosen because of its importance as a small game species in Norway (Loe et al. 2007). Birds observed only in flight were not used in the analyses, only bird observations that could be associated with a unique enclosure (sitting, landing or taking off) were included.

2.4.1 Bird density

The bird density in each treatment group ("high", "low" and "no sheep") was estimated with the Distance 6.0, version 2, software (Thomas et al. 2009), which is a widely used program for estimating densities of biological populations combined with distance sampling as field method (Thomas et al. 2010). Every bird observed was recorded, and the distance from the line was measured for each observation as described in chapter 2.3. The Distance software system assumes that all birds on the line are detected, but that the detection probability decline with increased distances from the line. The point on the curve where the detection probability is 50 % is termed the effective half-strip width (ESW) and is used in the estimation of the density (see below).

In my investigation I observed single birds, and the estimated bird density in a unit (D_i) was calculated according to the formula: $D_i = n_i / 2l_i\mu_i$ (Hedley & Buckland 2004) where n_i is the number of birds observed in unit i_i, l_i is the total length of transect i and μ_i is the estimated effective half-strip width (ESW) of unit i (estimated using distance 6.0). The individual transects walked in a day per enclosure were used as the sampling unit (i) in this study.

The distance data were transformed into intervals, and data beyond the chosen truncations were discarded. According to Buckland et al. (2001) the approximately 5 % highest distances observed should be discarded. In this thesis I used the same grouping intervals and truncations as Loe et al (2007) to simplify comparison between years. Truncation distance and interval for "all birds" was set to 28 m and 4 m, for insect eaters to 30 m and 5 m, for meadow pipit 20 m and 4 m and for willow grouse I used 12.5 m truncation with 2.5 m intervals. Figure 9 shows the bird distribution from the transect line for the selected study groups calculated with Distance 6.0. The coefficient of variation (CV) in the estimated half-strip width (ESW) and confidence limits (95% CI) of bird density was estimated by non-parametric bootstrapping (999 replicates). I used half- normal cosine as detection functions for all study groups. The ESW for all birds was 12.9 m (CV= 5.26 %), for "insect eaters" 13.3 m (CV=5.45 %), for meadow pipit 13.1 m (CV=6.62 %) and for willow grouse 6.1 m with 20.1 % CV.

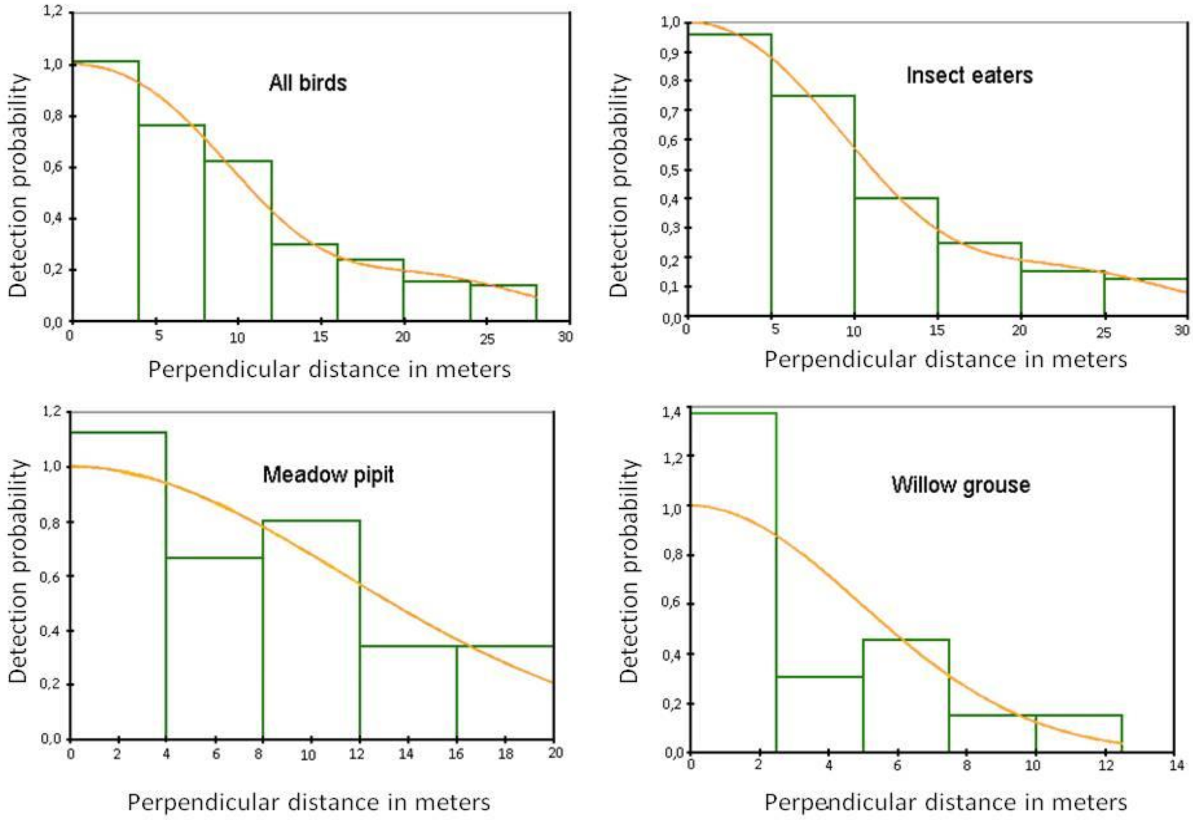

Figure 9: Distribution from transect line for the study groups all birds, insect eaters, meadow pipit and willow grouse and the best fit half-normal key function with a cosine series extension used as distance detection function.

2.4.2 Testing for differences in grazing effects within and between years

Linear mixed models fitted by restricted maximum likelihood (REML) using nlme in R 2.15.2 was used to test differences on bird densities among treatments and years. Conditional F and t-tests were used to evaluate differences between treatment levels (Pinheiro & Bates 2000). The data from 2011 were first analyzed separately in R 2.16.2 before the two years where analyzed together. Willow grouse was not analyzed separately for 2011 due to low sample size. In the 2011 test treatment was the only predictor variable (three level factor variable), bird numbers the response variable and the offset variable was the effective search area (line transect length multiplied with two times the group specific ESW estimate). For the model testing differences between 2005 and 2011, year (two level factor variable), treatment and the interaction between year and treatment were included as predictor variables. The response and offset variables were the same as for the 2011 test.

3 RESULTS

3.1 BIRD OBSERVATIONS

Altogether 1056 birds of 17 species were observed in 2011, of which 1010 were included in the analyses. In 2005 Leif Egil Loe observed 1324 birds of 24 different species, of which 1114 observations were included in the material (Loe et al. 2007). Observations not included in the analyses were mainly birds observed in flight and not associated to an enclosure. The percentage of valid observations was higher in 2011 than in 2005, 95.6 % compared to 84 %. Information of bird species and numbers observed during the two field seasons are summarized in Table 1. One species, Lapland bunting (*Calcarius lapponicus*), was seen only in 2011, while eight species observed in 2005 were not seen in 2011 (Table 1).

For further information on bird distribution in the different enclosures in 2011 see appendix 1.

Table 1: The species names, functional groups, and numbers of all birds during the two field seasons (2005 and 2011). In total 2380 birds were observed, of which 2124 birds were included in the analyses for my thesis.

			Numbers observed	
Latin name	**Common name**	**Main food type**	**2005**	**2011**
Anthus pratensis	Meadow pipit	Insects	290	241
Asio Flammeus	Short-eared owl	Vertebrate prey	3	0
Buteo lagopus	Rough-legged buzzard	Vertebrate prey	1	1
Calcarius lapponicus	Lapland bunting	Insects	0	2
Carduelis chloris	Greenfinch	Vegetative	1	0
Carduelis flammea	Redpoll	Vegetative	49	25
Carduelis flavirostris	Twite	Vegetative	5	3
Corvus corax	Common raven	Vertebrate prey	5	3
Cuculus canorus	Cuckoo	Insects	8	6
Emberiza schoeniclus	Reed bunting	Insects	105	119
Falco columbarius	Merlin	Vertebrate prey	6	1
Falco tinnunculus	Kestrel	Vertebrate prey	1	3
Gallinago media	Great snipe	Other	3	0
Lagopus lagpous	Willow grouse	Vegetative	64	22
Lagopus mutus	Rock Ptarmigan	Vegetative	1	0
Luscinia svecica	Bluethroat	Insects	99	60
Mergus merganser	Goosander	Fish	2	0

Oenanthe oenanthe	Northern wheatear	Insects	164	102
Phylloscopus trochilus	Willow warbler	Insects	179	208
Pluvialis apricaria	Golden plover	Insects	3	0
Saxicola rubetra	Whinchat	Insect	1	0
Tirngat totantus	Redshank	Other	1	0
Turdus ilacus	Redwing	Insects	27	2
Turdus pilaris	Fieldfare	Insects	153	76
Turdus torquatus	Ring ouzel	Insects	87	101
Turdus sp.	Trush unidentified	Na	3	4
Passeriformes unidentified	Unidentified small passerine	Na	63	77
Total number of birds observed			1324	1056

3.2 EFFECT OF SHEEP GRAZING IN 2011

I found no significant overall effect of sheep grazing on bird density (mixed-model ANOVA; all birds, $F_{2, 226}$= 2, 14, p= 0.1201; Insect eaters, $F_{2, 226}$=2, 34, p=0, 1009; Meadow pipit, $F_{2, 226}$=0, 41, p=0, 06673; willow grouse; too few observations) in 2011. However, when comparing different sheep density-levels against control (no sheep), the bird density is significantly higher at low grazing levels for the two groups all birds (p=0.0400) and insect eaters (p=0,034) (Table2). When comparing high-density sheep level against low-density sheep level, and high- density sheep level against control there are no significant differences between these. This indicates a different pattern than the one seen by Loe et al. (2007) who reported highest bird densities at high grazing levels in 2005. For the sub-group meadow pipit no significant result was found. For the sub-group willow grouse the number of observations were too few in 2011 and this subgroup was left out of the individual analyses for 2011.

Table 2: Differences in bird densities between the three levels of sheep grazing (control, low and high). (Parameter estimates with associated p-value derived from mixed model (see chapter 2.4.2).

	Estimate	s.e	d.f	T- value	P- value
All birds					
High- control	0.158695	0.1442897	226	1.09983	0.2726
Low-control	**0.280074**	**0.1355518**	**226**	**2.06617**	**0.0400**
High- low	-0.121379	0.1411801	226	-0.85975	0.3908
Insect eaters					
High- control	0.157680	0.1517750	226	1.03891	0.3000
Low- control	**0.300840**	**0.1397729**	**226**	**2.15235**	**0.0324**
High- low	-0.143160	0.141979	226	-0.97257	0.3318
Meadow pipit					
High- control	-0.235537	0.3890168	226	-0.60547	0.5455
Low- control	0.107363	0.3869935	226	0.27743	0.7817
High- low	-0.342900	0.3892265	266	-0.880978	0.3793

3.3 COMPARING SHORT TERM AND LONG TERM EFFECTS OF SHEEP GRAZING

There was an overall higher density of birds in 2005 compared to 2011 for all birds and the three sub-groups (Table 3; Figure 10). The results when comparing changes in grazing effects from 2005 to 2011 were inconclusive. The confidence intervals were large and the interaction effect between year and sheep density, albeit a tendency in meadow pipit, was not significant in a global model (mixed model ANOVA; all birds: $F_{2, 411}$=2.03, p=0.1328; insect eaters: $F_{2, 411}$=1.69, p= 0.1859; meadow pipit $F_{2, 411}$=2.790, p=0.0626; willow grouse: $F_{2, 411}$=0.651, p=0.5221).

Still, there was substantial variation in the grazing effect patterns between years (Figure 10). Except for willow grouse, the between-year differences in bird density at high and low sheep density either approached significance (all birds and insect eaters) or was significant (meadow pipit; Table 3). For these groups, bird density was higher at high sheep density in 2005 and at low density in 2011 (Figure 10). For grouse the pattern were similar both years, but note the small sample size for grouse (Table 1; Figure 10).

Table 3: Differences in bird densities between the three levels of sheep grazing (control, low and high) and the two study years (2005 and 2011).(Parameter estimates with associated p-value derived from mixed model (see chapter 2.4.2).

	Estimate	s.e	d.f	T- value	P- value
All birds					
Bird density in 2011 vs. 2005	-0,482515	0.12406057	411	-3.88935	0.0001
High-control 2011 vs. 2005	-0.129772	0.18330567	411	-0.70795	0.4794
Low- control 2011 vs. 2005	0.234398	0.17700684	411	1.32423	0.1862
High- low 2011 vs. 2005	-0.361320	0.18418093	411	-1.96177	0.0505
Insect					
Bird density in 2011 vs. 2005	-0.424718	0.12685099	411	-3.34816	0.0009
High-control 2011 vs. 2005	-0.108778	0.18857907	411	-0.57683	0.5644
Low-control 2011 vs. 2005	0.226251	0.17941069	411	1.26108	0.2080
High- low 2011 vs. 2005	-0.335027	0.18859345	411	-1.77645	0.0764
Meadow pipit					
Bird density in 2011 vs. 2005	-0.523161	0.2202657	411	-2.37514	0.0180
High-control 2011 vs. 2005	-0.460488	0.3261217	411	-1.41201	0.1587
Low- control 2011 vs. 2005	0.320204	0.3171082	411	1.00976	0.3132
High-low 2011 vs. 2005	-0.770589	0.3280877	411	-2.34873	0.0193
Willow grouse					
Bird density in 2011 vs. 2005	-1.635227	0.6580855	411	-2.484825	0.0134
High-control 2011 vs. 2005	0.946087	0.8587776	411	1.101667	0.2713
Low-control 2011 vs. 2005	0.790151	0.9374884	411	0.842838	0.3998
High- low 2011 vs. 2005	0.155771	0.8654611	411	0.179986	0.8573

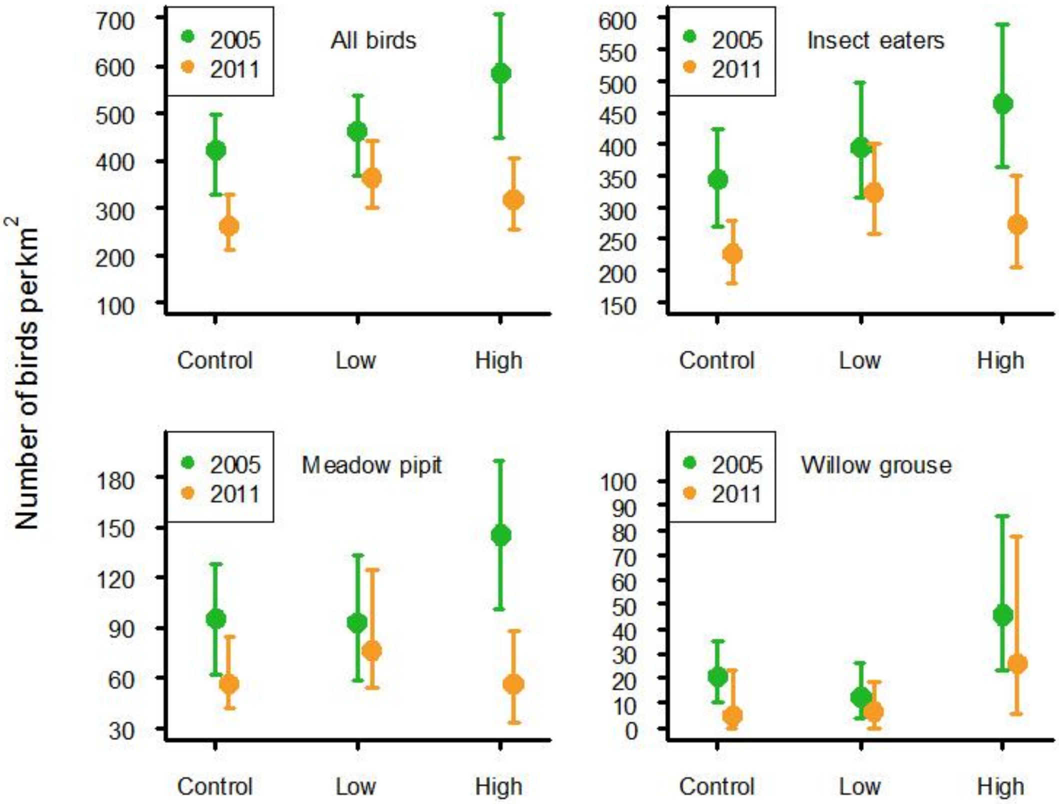

Figure 10: Density estimates (with 95% confidence limits) of all study groups; all birds and the three subsets insect eaters, meadow pipit and willow grouse at the three sheep grazing levels (control, high and low) in both 2005 and 2011.

4 DISCUSSION

In this thesis I have examined the long term (10 years) effect of sheep grazing and compared the long term effects with the short term (four years) effects of sheep grazing found by Loe et al (2007). My reported patterns indicate that the optimal level of sheep grazing has changed from high to low from 2005 to 2011. This indicates that the highest sheep grazing levels in this experiment, although initially beneficial to alpine birds, may not be sustainable on a time scale of decades. However, the fairly large differences observed between years do not have strong statistical support, probably due to low sample size.

4.1 THE LONG TERM EFFECT OF DIFFERENT SHEEP GRAZING LEVELS

When comparing my findings in 2011 with the findings of Loe et al (2007) in 2005 fairly strong differences in patterns without strong statistical support inhibit a formal separation of hypotheses H1 and H2. My results indicate a different pattern in bird densities among treatments in 2011 compared to that reported by Loe et al (2007) in 2005. The positive effect of high intensity sheep grazing observed after four years seems to be reversed in the longer term. The highest bird densities occurred at high sheep grazing levels in 2005, but at low levels in 2011, indicating some support for hypothesis H2. In both years the highest densities of birds were found in enclosures with sheep (compared to controls without sheep), indicating that sheep grazing at the moderate levels commonly used in Norway is positive for most bird populations.

Changes in vegetation are thought to be the most important mechanisms by which grazing animals (livestock and wild) may affect bird communities (Fuller 2001; Martin & McIntyre 2007; Vandenberghe et al. 2009; Willcox et al. 2010). Different types of vegetation will be affected differently, not only affecting differences between pastures, but also within pastures (Martin & McIntyre 2007; Willcox et al. 2010). As a consequence the effect of grazing on birds may differ from vegetation type to vegetation type. Whether grazing will affect bird communities positively or negatively depends on a combination of grazing intensity and type of vegetation in the pasture (Martin & McIntyre 2007; Willcox et al 2010). The most common response found by Martin & McIntyre (2007) was that high bird abundance appeared at low grazing levels, with twice as many birds at low grazing intensity compared to high grazing intensity in wooded riparian sites as an example. This supports the findings I made in 2011. Interestingly, they also found that in native pastures the relative abundance of birds increased as grazing intensity increased, which is in accordance to the observations described by Loe et al. (2007). At the study site used for this thesis previous research have shown only small effects of grazing on vegetation. Comparison between different grazing levels showed a small positive effect in enclosures with low sheep-grazing levels and a small negative effect in enclosures with high sheep grazing levels (Evju et al. 2006; Evju et al. 2011). The small effect of different grazing levels on the vegetation may be an important explanation for the weak long term results and may help explaining the lack of significant difference between the two years.

Mysterud et al. (2010) have conducted investigations to study the effects of grazing on the invertebrate communities in the same field area as the present study was performed. They found that the occurrence of herbivorous beetles (*B. fasciatus* and *O. nodosus*) first was affected at high grazing levels. The beetles decreased in high grazing areas compared to low grazing or control areas, which may indicate that the simple alpine habitats in the study area are sensitive to disturbances caused by grazing sheep (Mysterud et al 2010).

Meadow pipit was the most common bird in both study years. Research have shown that they forage in areas with preferred vegetation rather than areas with only the highest invertebrate biomass, and the effect increased as grazing intensity increased (Vandenberghe 2009). Reduced food accessibility seems to be a more important effect of grazing than reduced food abundance (invertebrate biomass) (Vandenberghe et al 2009; Pedersen, Nilsen & Andreassen, 2007). In my study, meadow pipit was the only group with a significantly diverging change in density between low and high density, possibly because they are particularly sensitive to changes in vegetation structure.

4.2 DIFFERENCES IN OVERALL BIRD DENSITY BETWEEN THE TWO YEARS

When comparing the 2011 results with the 2005 results I find a significantly higher bird density in all study groups (“all birds” and the three subgroups “insect eaters”, meadow pipit” and “willow grouse”) in 2005. There might be several explanations for the differences in the number of birds observed in 2011 compared to 2005. Population of different species can vary dramatically from one year to another. The population density is influenced by the availability of food, the predation pressure and the weather conditions during and immediately after hatching.

A great majority of the birds observed in our studies are insectivorous which depend heavily on the availability of nutritious insect-larvae. In June 2011 (the main data collection period) the study area at Minnestølen experienced unusually heavy rainfall with a mean perspiration of more than twice as much as in June 2005, and nearly three times more than normal for this period. This may have affected the activity of the birds, and thereby the ability to detect them. There might also have been an observer effect. Nevertheless, there is no reason to assume that differences in the weather conditions or different registration pattern for different persons were systematically different in different sub-enclosures, and thereby will not have significant influence on the results when comparing the different grazing levels.

4.3 POSSIBLE EXPLANATIONS FOR THE LACK OF SIGNIFICANCE

The results from 2011 are not conclusive as no significant global effect of treatment was found, however the bird density was significantly higher at low levels for the groups all birds and insect eaters compared to control. There were no significant differences when comparing control with high grazing level and high grazing level with low. When comparing changes in grazing effects from 2005 to 2011 the results are inconclusive and the interaction between sheep density and year was not significant in a global model.

The lack of significantly conclusive results, despite fairly strong differences in bird densities between treatments and years, may be a result of too small sample sizes both years. Statistical significance is a function of sample size and with the strongly diverging patterns in bird density between the two years it is very likely that H2 would have been supported (with the exception of willow grouse) if more data had been sampled in both 2005 and 2011.

5 CONCLUDING REMARKS

My investigations indicate that a low sheep grazing pressure in Norwegian outfields may be beneficial for birds in the long term. Since the results are inconclusive I cannot reject or confirm either hypothesis H1 or hypothesis H2. The differences indicated in this study between the two years show the importance of studies that not only look at grazing versus no- grazing, but also differences between levels of grazing and long/ short term. This study also shows that it is important to follow trends over several years.

In Norway, grazing by livestock (primarily sheep) is important to keep the cultural landscape open and "alive". Managed in the right way, grazing can be used as a tool to promote both bird abundance and an ecologically sustainable food production (St. meld nr. 9 2011- 2012). Studies like the one described in this thesis are important tools for wildlife managers and advisers in the livestock industry to make decisions. As pointed out by many researchers previously, the transfer of results from one study area to another is difficult as different pastures react differently on grazing (Martin & McIntyre 2007; Willcox et al. 2010).

It is reasonable to assume that at high grazing levels the total effect of grazing on the vegetation and the population of insects will increase over time. This may explain why a positive effect of grazing in a short term may be changed to a less positive effect in the long term, as indicated by this study. The challenge is to find a grazing level that over time provides the best total ecological balance in a pasture or grazing area.

In future research monitoring of the effect of different levels of sheep grazing in the outfield should be conducted for several consecutive years. This would provide more knowledge about the long- term consequences of sheep grazing for the diversity and abundance of birds.

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APPENDIX

1 BIRD DISTRIBUTION IN THE DIFFERENT ENCLOSURES

Of the total of 1056 birds observed in 2011, 361 birds were observed in the “control” enclosure, 400 in the “low” enclosure and 295 in the “high” enclosure. The most common bird was meadow pipit (241) with willow warbler in second (208) and reed bunting (119) as the third most common bird, closely followed by the northern wheatear and the ring ouzel. All of the birds are most common in the “low” enclosure, with exception of the ring ouzel which had ten more observations in control than in “low” and the reed bunting which was most commonly observed in “control” as well. The highest number of “unidentified small passerine” was observed in “control” enclosure.

	Control			Total	Low			Total	High			Total	Total
Common name	**A**	**E**	**G**		**C**	**D**	**I**		**B**	**F**	**H**		
Meadow pipit	29	22	33	**84**	40	41	17	**98**	8	25	26	**59**	**241**
Rough-legged buzzard	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	**1**
Lapland bunting	1	0	0	**1**	1	0	0	**1**	0	0	0	**0**	**2**
Redpoll	1	1	3	**5**	4	4	3	**11**	1	8	0	**9**	**25**
Twite	0	0	1	**1**	0	1	0	**1**	0	0	1	**1**	**3**
Common raven	0	0	3	**3**	0	0	0	**0**	0	0	0	**0**	**3**
Cuckoo	1	0	0	**1**	0	1	0	**1**	3	0	1	**4**	**6**
Reed bunting	20	19	14	**53**	17	13	9	**39**	9	9	9	**27**	**119**
Merlin	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	**1**
Kestrel	0	0	0	**0**	0	2	0	**2**	0	0	1	**1**	**3**
Willow grouse	2	0	1	**3**	2	2	2	**6**	0	6	7	**13**	**22**
Bluethroat	8	1	7	**16**	9	9	11	**29**	7	2	6	**15**	**60**
Northern wheatear	11	1	21	**33**	12	18	10	**40**	17	6	6	**29**	**102**
Willow warbler	19	21	25	**65**	23	37	18	**78**	15	17	33	**65**	**208**
Redwing	0	0	0	**0**	1	0	0	**1**	0	0	1	**1**	**2**
Fieldfare	1	6	11	**18**	8	15	11	**34**	4	15	5	**24**	**76**
Ring ouzel	10	12	18	**40**	15	11	4	**30**	10	15	6	**31**	**101**
Trush unidentified	0	0	0	**0**	1	1	1	**3**	1	0	0	**1**	**4**
Unidentified small passerine	13	6	17	**36**	9	9	8	**26**	5	3	7	**15**	**77**
				361				**400**				**295**	