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Geese protection vs. settlement: The distribution and land use of Greenland White-fronted Geese on Hvanneyri fields and their reaction to disturbances

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Hér með lýsi ég því yfir að ritgerð þessi er byggð á mínum eigin athugunum, er samin af mér og að hún hefur hvorki að hluta né í heild verið lögð fram áður til hærri prófgráðu.

Abstract

Dropping counts of Greenland white-fronted geese *Anser albifrons flavirostris* were used as an index of grazing intensity to investigate the effects of human disturbance on the distribution and land use of the birds on Hvanneyri, West Iceland, in autumn 2005. The study took into account the effects of distance to the road and ditches, food quality and abundance.

The presence of the road had a serious depressing effect on goose utilisation over a range of 0-300m, whereas ditches seem to affect goose use over a distance of 0-5 metres.

The geese significantly preferred barley over *Phleum pratense* and over mixed swards. In addition, disturbance tolerance of geese increases with the increasing quality of food: most reaction to disturbance was shown on mixed swards, and no avoidance response was found in the barley field.

As the geese obviously react to human made disturbances and the number, size and quality of the fields at Hvanneyri remain at the present level, increased disturbance at the farm will result in a decrease in the effective carry capacity of the farm as a whole.

Ágrip

Talning á driti grænlandsafbrigðis blesgæsa *Anser albifrons flavirostris* var notað til að ákvarða dreifingu fuglanna á völdum túnum á Hvanneyri haustið 2005. Rannsakað var hvernig truflun af mannavöldum hefur áhrif á þessa dreifingu og landnýting gæsanna. Áhrif vega og skurða og gæði og útbreiðsla helstu plöntutegunda í sverði túnanna voru könnuð sérstaklega.
Neikvæð áhrif umferðar um vegi virðist ná allt að 300m inn á túnin. Áhrif skurða reyndust mun minni og ná aðeins fimm metra frá skurðbakka.
Gæsirnar sóttu marktæk meiri í bygg en annað fóður. Jafnframt völdu þær vallafoxgras *Phleum pratense* frekar en aðrar grastegundir. Þol fuglanna gagnvart truflun eykst með vaxandi gæði fóðurs: mestu viðbrögð við truflum virtist vera á gömlum túnum með blönduðu gróðurfari, en gæsirnar létu ekki nærveru vegar trufla sig á byggakri. Gæsirnar bregðast augljóslega við truflun af mannavöldun. Ef fjöldi, stærð og gæði túnanna haldast á óbreytt samfara vaxandi vexti þéttbýlis á Hvanneyri gæti það leitt til rýrnunar á búsvæði gæsarinnar á Hvanneyrarjörðinni.

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Ríkharð Brynjólfsson was a very skilled contact person concerning the statistics, thanks to him for all the help, even during his Easter vacation! Special thanks to the employees of Orkuveita Reykjavíkur in Borgarnes, who borrowed my a metal detector for the time of data collection! Thanks also to Guðmundur Hallgrímsson for providing information of the farm land and for borrowing materials for carrying out the data collection. Halla Kjartansdóttir was so nice to borrow me her headlight, a special thanks for that!

Contents

1. Introduction

1.1 Key questions and objectives of the study

The present study was carried out during autumn 2005 to investigate the effects of human disturbance on the distribution and land use of Greenland white-fronted Geese that might be occurring around the expanding village at the Hvanneyri Agricultural University of Iceland.

Geese are sensitive to human disturbance, the presence of which can cause energetic and physiological stress. The presence of people or human activities can cause birds to stop feeding, or in extreme, fly away from most disturbed areas. This can mean they are displaced from their optimal feeding distribution (reducing food intake) and suffer enhanced energy expenditure caused by flying to other areas. In this way, their energy budget is affected by both reduced intake and enhanced energy expenditure. It is therefore important to understand if geese avoid areas of human activities, and if so by how much. If we can show the area over which goose densities are reduced, we can begin to estimate the extent of effective habitat lost to feeding birds that occurs from human presence. The habitat is not physically lost, but is rendered effectively lost to feeding geese by human activities.

Because geese move around during the course of a feeding day, counts are not necessarily the most efficient means of calculating relative goose use of different areas. For this reason, it has become normal to count droppings of geese as a more reliable short term means of comparing goose use and densities (e.g. Walsh, 1991 and Kristiansen et al., 2001). Because of that, this study used dropping counts in different field as an index of grazing intensity.

The problem is that the use of fields by geese is affected by other factors, such as risk of predation, food quality and quantity, so any study of the distribution and abundance of geese must also look at the effects of these factors as well as human behaviour. That's why the effects of the distance to nearest ditch was also studied.
Ditches could hide potential predators (although there are not many in Iceland, polar fox being the most likely) and may therefore be potential source of danger for the grazing birds, affecting overall goose utilisation as well. It is known that geese react to landscape features like hedges and channels (Madsen, 1985), but it has not been shown if the geese react to ditches as well. Geese also show strong food preferences (Nyeland, 2001 and Fox, 2003), so the study also took into account the effects of food quality and abundance (using grass sward composition and sward height as parameters).
The conflict between increasing human activity and the site's international importance on the population of Greenland White-fronted Geese is discussed.

1.2 Background information on Greenland White-fronted Geese

1.2.1 Status and distribution

Greenland white-fronted geese *Anser albifrons flavirostris* breed in West Greenland and migrate through Iceland to winter in Ireland and Britain. It is the most morphologically distinct sub-species of the circumpolar White-fronted Goose *Anser albifrons* (Fox, 2003).

What makes the Greenland white-front so different from most other arctic geese is that it takes two migration flights to arrive at its breeding areas (Fox et al., 1999). In spring they fly 1500 km from Ireland or Britain to Iceland, where they stage between middle of April and middle of May to restore and accumulate fuel reserves to sustain the following flight (Fox, 2003). This leads them another 1500 km across the ocean and cross the 2800 m high Greenland ice cap to spring staging areas and, later on, to ultimate summering areas along the west coast of Greenland (Nyeland, 2001). In autumn during their migration back to Britain and Ireland, the birds stop in Iceland again from the end of August until the end of October (Fox et al., 1999), because they cannot acquire enough fat to make the journey directly (Fox, 2002 & 2003).

In Iceland, the geese concentrate in southern and western lowlands (Fox et al., 1999), but the most important site is the protection area around Hvanneyri in west Iceland. Here, extensive *Carex lyngbyei*-dominated wetlands, boglands, lakes and hayfields create an area particularly attractive to staging geese (Fox & Stroud, 2002 and Nyegaard, Fox, Kristiansen & Walsh, 2001). The global population size of the geese has been estimated of 23,840 for the spring 2005 (Fox & Francis, 2005), which represents a decline since the peak of over 35,600 in spring 1999 as a result of reductions in reproductive success (Fox, Glahder & Walsh, 2003). In September 2005, a maximum of 3300 birds had been counted on Hvanneyri, which represents about 14% of the population (Fox & Francis, 2005). As a result, an area at Hvanneyri was designated as a nature reserve in 2002 to protect the migrating geese, recognising the international importance of the habitats to the staging birds in spring and autumn (Stjórnartíðindi, 2002).

1.2.2 Feeding and diet

The Greenland White-fronted Geese in Iceland spend 70-90% of daylight hours feeding, which was generally more than on the wintering grounds. This increased feeding activity is not only a compensation for feeding on less profitable food, it also reflects an increased demand for gaining weight fast (Nyegaard, Kristiansen & Fox, 2001).

Traditional feeding plants of the geese are *Eriophorum angustifolium* and *Carex lyngbyei*. The geese traditionally fed on the below ground lower stem (an overwinter storage organ of both these plants) which they extracted from the soft boggy substrates in which they live.

In order to maximise their feeding efficiency geese are known to select plants of highest profitability. Energy-rich habitats are exploited, which is nowadays is increasingly agricultural farmland, where instead of digging for their food, the geese now graze agricultural grasses (Fox & Stroud, 2002 and Nyeland, 2001).

The predominant species on Hvanneyri fields are *Poa pratensis, Deschampsia caespitosa* and *Phleum pratense*. The two former species are native to Iceland, whereas *Phleum* has been introduced from Norway (Fox & Francis, 2005 and Nyegaard et al., 2001).

Studies made in the spring 2001 showed that feeding on *Phleum* gave the birds the highest energy intake to the other sward types, and that they favoured *Phleum* over *Poa* and over *Deschampsia* (Nyeland, 2001).

2. Materials and Methods

2.1 Study area

The study was carried out at Hvanneyri Agricultural University of Iceland, Borgarfjörður, in west Iceland (64°34'N, 21°46'W) on selected days from 21 September to 14 October 2005.
Hvanneyri is an expanding University with a campus of around 400 inhabitants, and an experimental farm in West Iceland. The increase in the level of human activity at the site could potentially affect the use of the nature reserve by the geese. The size of the protected area is about 1.744 ha, including Hvanneyri village, associated farmland and range area (Stjórnartíðindi, 2002). The area is the most important spring staging site known for the Greenland White-fronted Geese (e.g. Nyegaard et al., 2001). It includes around 60 hayfields (total area around 80 ha) in close proximity to safe roost sites, which are the Borgarfjörður and lake Vatnshamrarvatn. "The concentration of such a large area of hayfields in close proximity to extensive wetland and peatland habitats makes the area particularly attractive to staging geese" (Nyegaard et al., 2001, 5).
The fields at Hvanneyri farmland are heavily used by the geese, although the densities of grazing birds varies considerably, dependent to a large extent on the different sward composition characteristics of each field. The swards in most fields were composed or even dominated of *Poa pratensis, Deschampsia caespitosa* and/or *Phleum pratense*. The abundance of the three species depends to a large extent on reseeding because of grazing selection (in this case mainly through geese) and competition with other plants. New sown *Phleum* fields are very attractive because they have highest densities of the favoured grass species, but over a period of years, the native *Poa, Deschampsia* and other native grasses reinvade the sward. Although these grasses are eaten by geese, they are less profitable as forage, and therefore support lower densities. This has been discussed elsewhere (Fox & Stroud, 2002, Nyegaard et al., 2001 and Nyeland, 2001).

2.2 Sampling Procedure

Field utilization by Greenland White-fronted geese was assessed by counts of dropping densities in selected pastures in late September 2005. Since grazing geese produce droppings at short intervals throughout their period of feeding (Pink-footed geese show intervals of about 5 min. (Fox et al., 2005), Greenland White-fronted Geese produce droppings at a rate of 0,315 droppings/minute (Kristiansen, Fox, Boyd, Nyegaard & Nachman, 2001)), the density of goose droppings is therefore an excellent indicator of field utilization.

To find out the distribution and land use of Greenland White-fronted geese on the research fields, the following data was collected:

a) dropping density
b) distance from road/ditch,
c) sward height
d) composition of vegetation.

For estimating dropping density, a frame of 84x84cm was used, which covered the total size of 0.7056m^2. In this study, dropping density it either declared as dropping/frame or droppings/m^2.

2.3 Study no. 1: The effect of roads on goose utilisation

The fields on Hvanneyri farmland are similar in shape: extended and very long, in this case from 270 up to 550 metres in length, but usually only 50m wide.
Human access on the farm as a whole is relatively restricted away from the buildings, therefore the major source of human disturbance, likely to affect goose distribution is associated with the roads, where pedestrian, horse-riding and vehicular traffic all affect the distribution of geese. To find out the effect of roads as the main human disturbing factor on the feeding behaviour of geese, 5 different fields were chosen (field no. 7, 37, 39, 201, 202: see Figure 1). All had the road one of the narrow ends, and were heavily grazed by the birds during the days before sampling. For more information about the selected fields: see chapter 3.1.1.

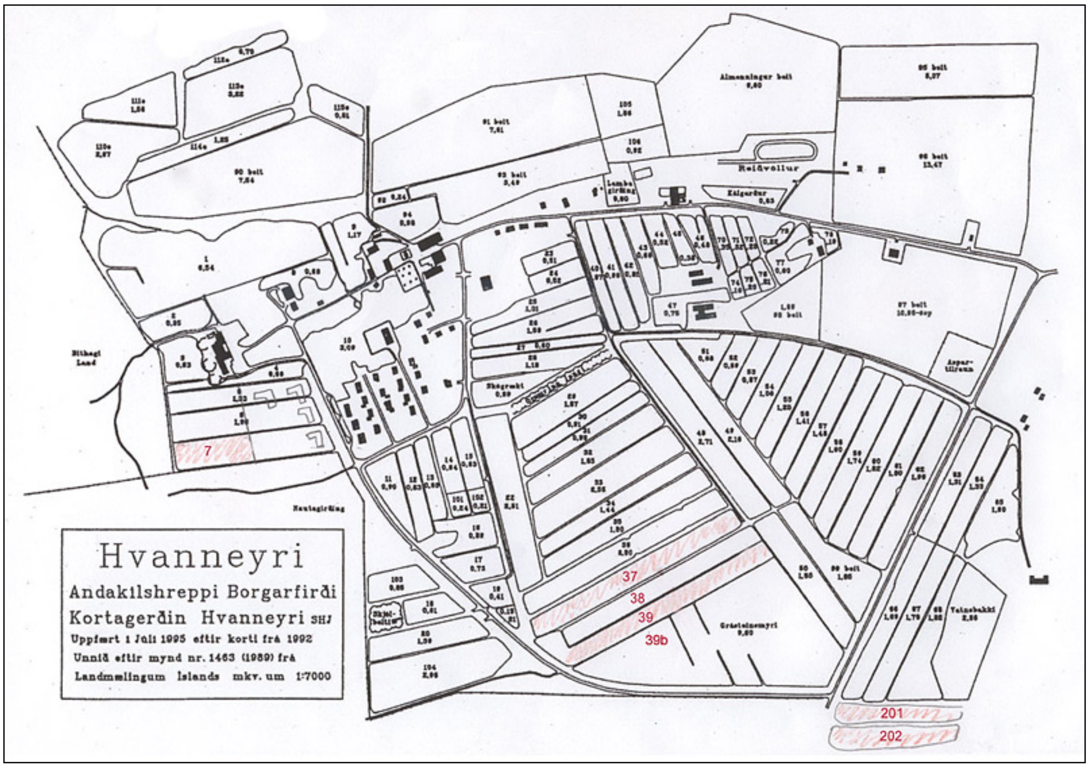

Fig. 1. Map of Hvanneyri farmland, West Iceland. The selected fields used for the present study are marked with red numbers.

The data was collected along a transect line, running the length of the field from the road end to the opposite end of the fields. As the behaviour of the geese was also likely to be effected by the closeness of ditches (see Study no.2), care was taken to position the transect line in the middle of the fields, to make sure that any potential effect of the ditches on the distribution of the birds would be minimised.
The counting frame was put down on the transect line every 5 meters. Droppings were counted as isolated faecal pellets independent of their size or consistency, and no distinction was made between faecal pellets produced while grazing or resting (Owen 1971 & 1971). The droppings were counted but not removed, which wasn't

necessary as this was a single counting operation. At the same time, the distance from the road and sward length were measured and the composition of plant species visually estimated as percentage cover. These sample measurements were repeated once every 5 meters along the entire transect to measure relative goose use.
To avoid disturbance to the birds and their feeding behaviour, the counting operation was carried out at night when the geese were absent at the roost.
For measuring of the sward length, a light cardboard 25x25cm square was dropped onto the vegetation with a ruler situated in a small hole in the middle. The cardboard was free to run up and down the ruler to enable the height of sward to be read off the scale when the base of the ruler was pressed to the soil surface. This was done to get an average measurement of the height of the different vegetation types.

The study was conducted during the period when most geese were present from middle to end of September. Droppings were collected and measurements done on fields 201 and 202 on 21.09.2005, field 7 and 37 on 23.09.2005, and field 39 on the 29.09.2005.

2.4 Study no. 2: The effect of ditches on goose utilisation

To find out the effect of ditches as a permanent, physical and human made landscape element on the behaviour of geese, another counting operation was carried out. It also aimed
to show if the results from the previous study could have been influenced by the presence of ditches.
Four adjoining fields were chosen (field no. 37, 38, 39 and 39b) all of which shared the presence of the same road on one of the narrow ends (see Figure 1) but which were composed of different vegetation swards (see chapter 3.2.1).
The study was repeated twice to get comparable data and with the secondary aim of possibly gathering some information about feeding behaviour and rotational grazing by geese. For that, the exact same sampling areas had to be relocated and resampled again. In this study, transect lines were positioned across the fields from the longer edge to the opposing side. To make sure that the distance to the road would not have a confounding effect, they were situated 195m from the road.
The ends of the transect line were marked in the ditches with pegs to enable the exact transect to be located again. A string was tightened between the pegs during data collection to simplify the data collection. Starting from the western ditch, iron nails (4,6x125mm or 5inch in size) were placed in the ground, pressed into the soil down to surface level. It was important to hide the nails so as not to frighten the birds away, since geese can be very suspicious of unfamiliar objects on their feeding grounds.
Using a metal detector to find the hidden nails in the ground, the lower left edge of the frame (84x84cm in size) was positioned over the nail. The frame was finally brought into the same alignment as the string, which guaranteed to relocation of exactly the same sampling area. Then, data collection took place: the number of droppings was counted and the sward length measured, just as in the previous Study. Each dropping was removed after it had been counted so that it was not counted again on a subsequent occasion.
As the counting operation was finished, the string was taken down and hidden in the ditches to avoid any influence to the behaviour of the geese. Just like the previous

study, counting operations were carried out at night when the birds were absent at the roost.
Data collection occurred first 27.09.2005, 05.10.2005 and 14.10.2005. During the Icelandic weather conditions, droppings disintegrate within 1–4 weeks due to precipitation (Walsh, 1991) and it is safe to assume that all droppings deposited during there short sampling intervals.

2.5 Statistical analysis

When analysing field use by geese, simple linear regression and correlation (Excel and MINITAB) were used to test for the relationship between dropping density versus distance from the road, percentage of vegetation and sward length. Significant levels were determined.

When analysing geese use in study no. 2, multiple regression (GLM in MINITAB) was used to test for the relationship and crossover between dropping density (dependent variable, response) and distance from the road (independent variable, model). This was done both for the original data and log-transformation.
From the sums of squares (SS) of the regression, it was possible to explain variability in the relation of dropping density and distance from the ditch.
MINITAB was also used to calculate one-way analysis of variance ANOVA to show differences between groups.

3. Results

3.1 Study no. 1: The effect of roads on goose utilisation

3.1.1 Classification of fields

According to Nyegaard et al.(2001) and Fox (2003), fields can be classified as being dominated by a single plant species or co-dominanted by a few. Dominant species are those that constitute more than 50% of the sward. Fields are co-dominant where two species differ by less than 20% in their coverage. Therefore, the classification of the selected fields is as shown in Figure 2. Field 201 is co-dominated by *Poa pratensis* (Smooth Meadow-grass), *Deschampsia caespitosa* (Tussock Grass) and *Phleum pratense* (Timothy), whereas field 202 is composed by *Poa pratensis*, *Phleum pratense*, *Festuca rubra* (Red fescue) and *Deschampsia caespitose*. Field 7 and 37 are dominated by *Phleum pratense*, and field 39 was absolutely/exclusively dominated by *Hordeum vulgare* (Barley).

	Phleum pratense	*Poa pratensis*	*Deschampsia caespitosa*	*Festuca rubra*	*Caryo-phyllacae*	*Bistorta vivipara*	*Eriophorum angustifolium*
201	13,1	30,1	30	8,3	0	0	0
202	19,6	23,5	10,6	14	0	0	1,8
7	57,2	0	0	0	14,1	0,1	0
37	68,9	12,3	4,9	0,1	0	0	0
39	0	0	0	0	0	0	0
	Ranunculus sp.	*Rumex* sp.	*Bryophyta*	*Carex lyngbyei*	*Taraxacum* sp.	*Hordeum vulgare*	Litter
201	0	0,3	0,4	0,6	0	0,0	17,2
202	0	0	2,5	7	0,2	0	20,8
7	0,2	0,1	0	0	0,1	0	28
37	1	0	0	0	0	0	12,9
39	0	0	0	0	0	100	0

Fig. 2. Sward composition (average, percentage) on selected fields on Hvanneyri in September 2005.

The selected fields did not only differ in composition of vegetation but also in size, length and distance to the cause of disturbance. Field 201, a pasture next to the main road, was situated 20m from the road edge and ended 315m away from it. It was sowed with *Phleum* in the years 1974-78 and is about 2 ha in size. Field 202, a pasture 25-375m from the main road, is at the same age and size as field 201. Field 7, a pasture 50-270m from a road and houses, is about 4 ha in size and was sowed with *Phleum* in spring 2005. Field 37, a pasture 35-560m from the main road, has been reseeded with *Phleum* in spring 2002 and is about 2.3 ha in size. Field 39, is a barley field 15-550m from the main road, which is about 2 ha in size and reseeded every spring (Guðmundur Hallgrímsson, farmer on Hvanneyri, interview on 10. April 2006 and Ragnhildur Helga Jónsdóttir, farmer on Ausa, interview on 18. April 2006).

3.1.2 Geese use in relation to vegetation

The relationship between the dropping density and the percentage of the most abundant sward species is shown in Figures 3 - 6. There is a highly significant correlation between geese use and the percentage of *Phleum pratense* ($P < 0.001$) on field 201 and 202. The relationship between dropping density and *Poa pratensis* is not significant anywhere. Field 7 and 37 showed no significant relationship between the vegetation and geese use at all.

Negative relationship on *Deschampsia caespitosa* / *Caryophyllacae* and dropping density has been seen everywhere and approved highly significant for the negative correlation in each one case on fields 201 and 202 (see Figure 3-6.).

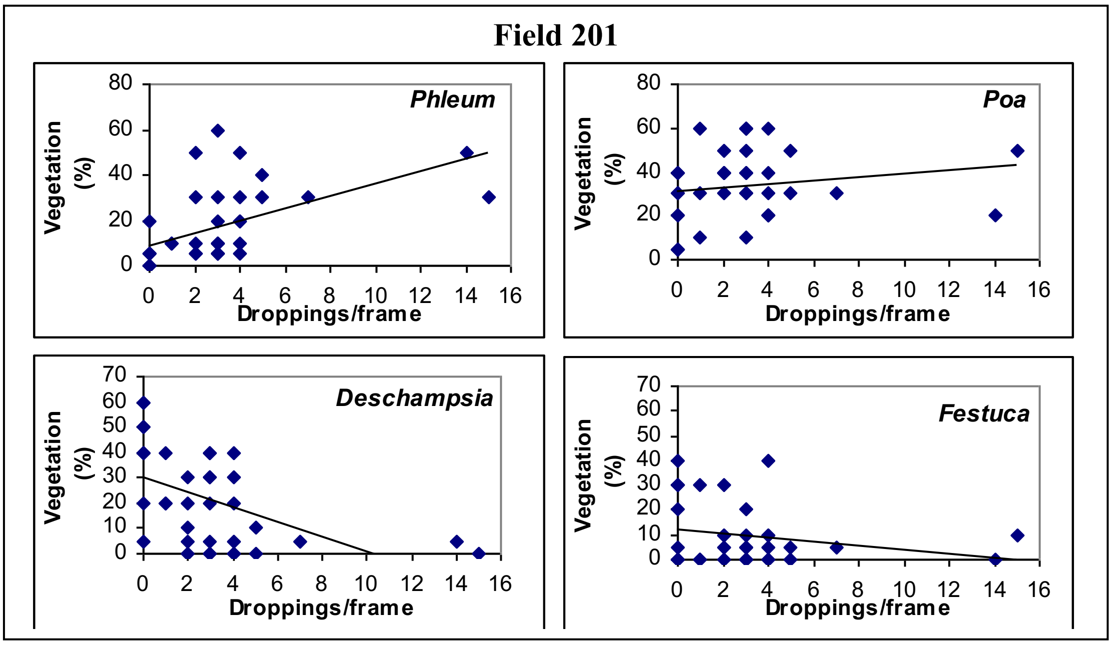

Fig. 3. Regression line of the most abundant plant species versus the dropping density of Greenland White-fronted Geese on Hvanneyri field 201 in autumn 2005. Significant relationship showed up regarding Phleum (r = 0.543, n = 38, P < 0.001) and Deschampsia (r = -0,505, n = 38, P < 0.001), but there was no significance for Poa (r = 0.162, n = 38, P > 0.05) and Festuca (r = -0,215, n = 38, P > 0.05).

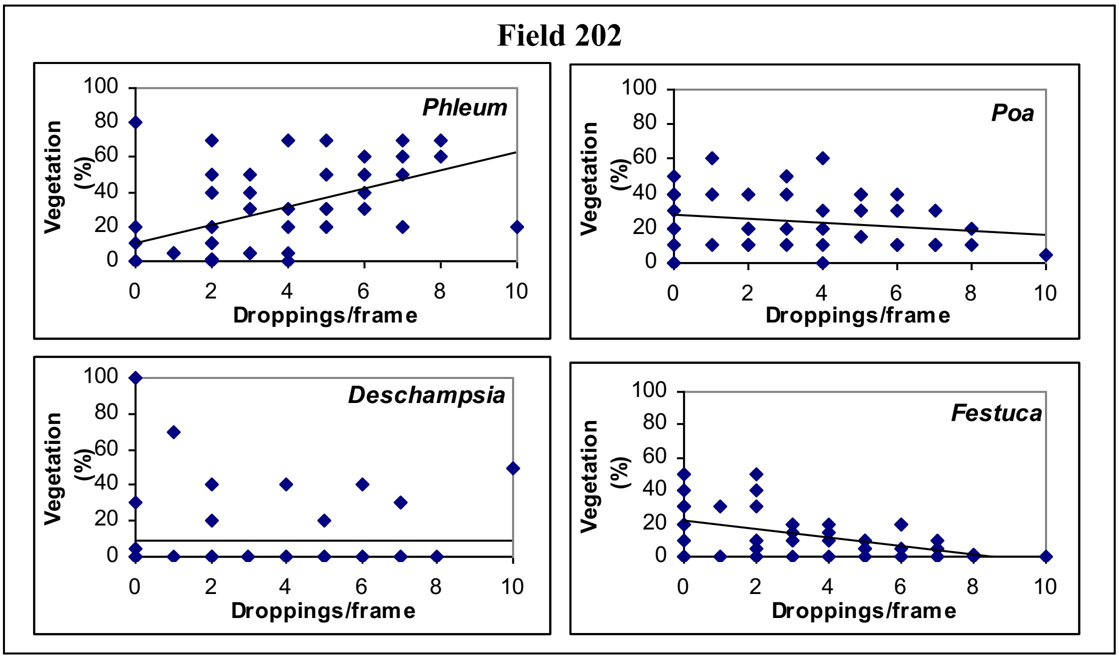

Fig. 4. Regression line of the most abundant plant species versus the dropping density of Greenland White-fronted Geese on Hvanneyri field 202 in autumn 2005. Significant relationship showed up regarding *Phleum* (*r* = 0.552, *n* = 49, *P* < 0.001) and *Festuca* (*r* = -0.454, *n* = 49, *P* < 0.001), but there was no significance for *Poa* (*r* =-0.203, *n* = 49, *P* > 0.05) and *Deschampsia* (*r* = -0.010, *n* = 49, *P* > 0.05).

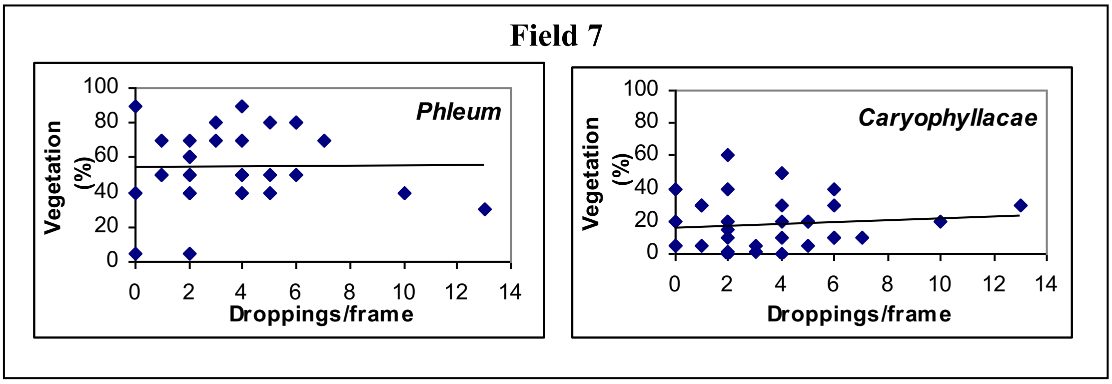

Fig. 5. Regression line of the most abundant plant species versus the dropping density of Greenland White-fronted Geese on Hvanneyri field 7 in autumn 2005. No significant relationship showed up, neither regarding *Phleum* (*r* = 0.023, *n* = 34, *P* > 0.05) nor *Caryophyllacae* (*r* = -0.010, *n* = 49, *P* > 0.05).

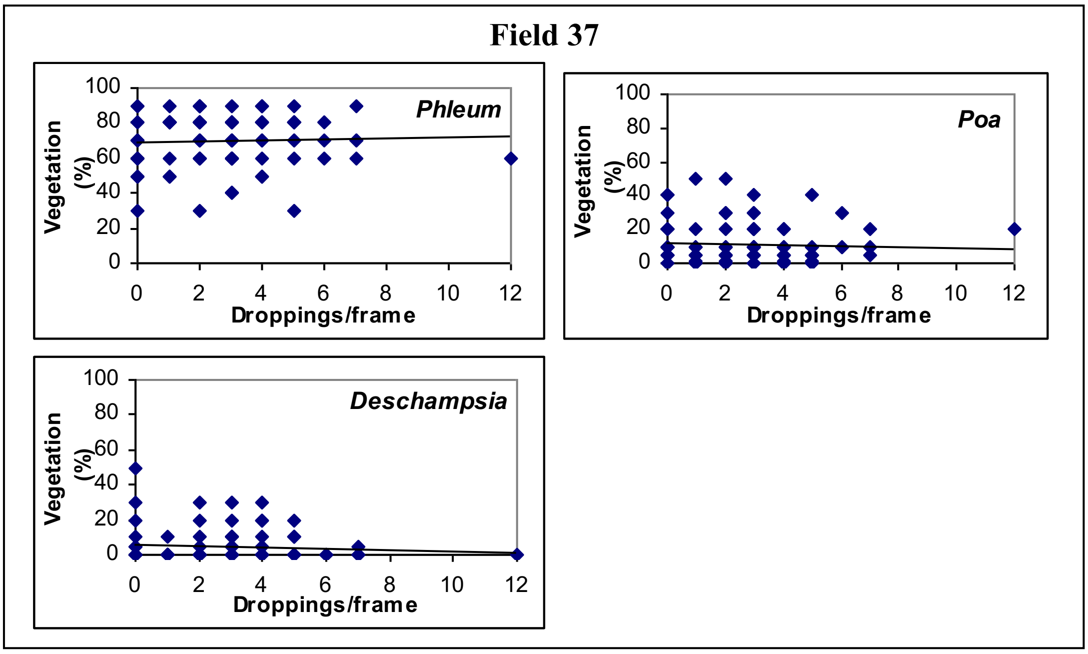

Fig. 6. Regression coefficient of the most abundant plant species versus the dropping density of Greenland White-fronted Geese on Hvanneyri field 37 in autumn 2005. No significant relationship showed up, neither regarding Phleum ($r = 0.044$, $n = 98$, $P > 0.05$), Poa ($r = -0.062$, $n = 98$, $P > 0.05$) nor Deschampsia ($r = -0.080$, $n = 98$, $P > 0.05$).

Figure 7 shows the relation the number of dropping per sample frame and the percentage of the most important grass species on Hvanneyri fields, Phleum pratense, in the different fields studied.

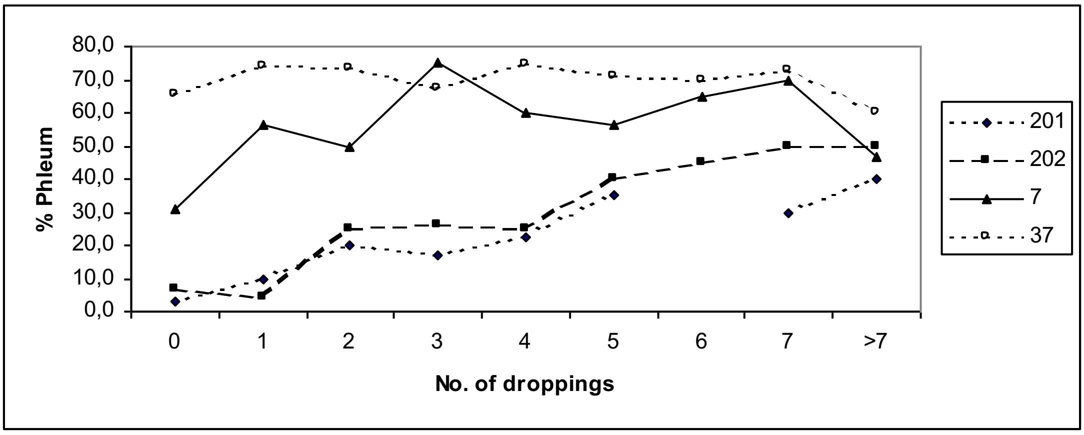

Fig. 7. General dropping density in relation to the existence of *Phleum* (average of sample frames with the same dropping density) on different fields on Hvanneyri, West Iceland, in autumn 2005.

Vegetation composition of different fields on Hvanneyri are presented in Figure 8.

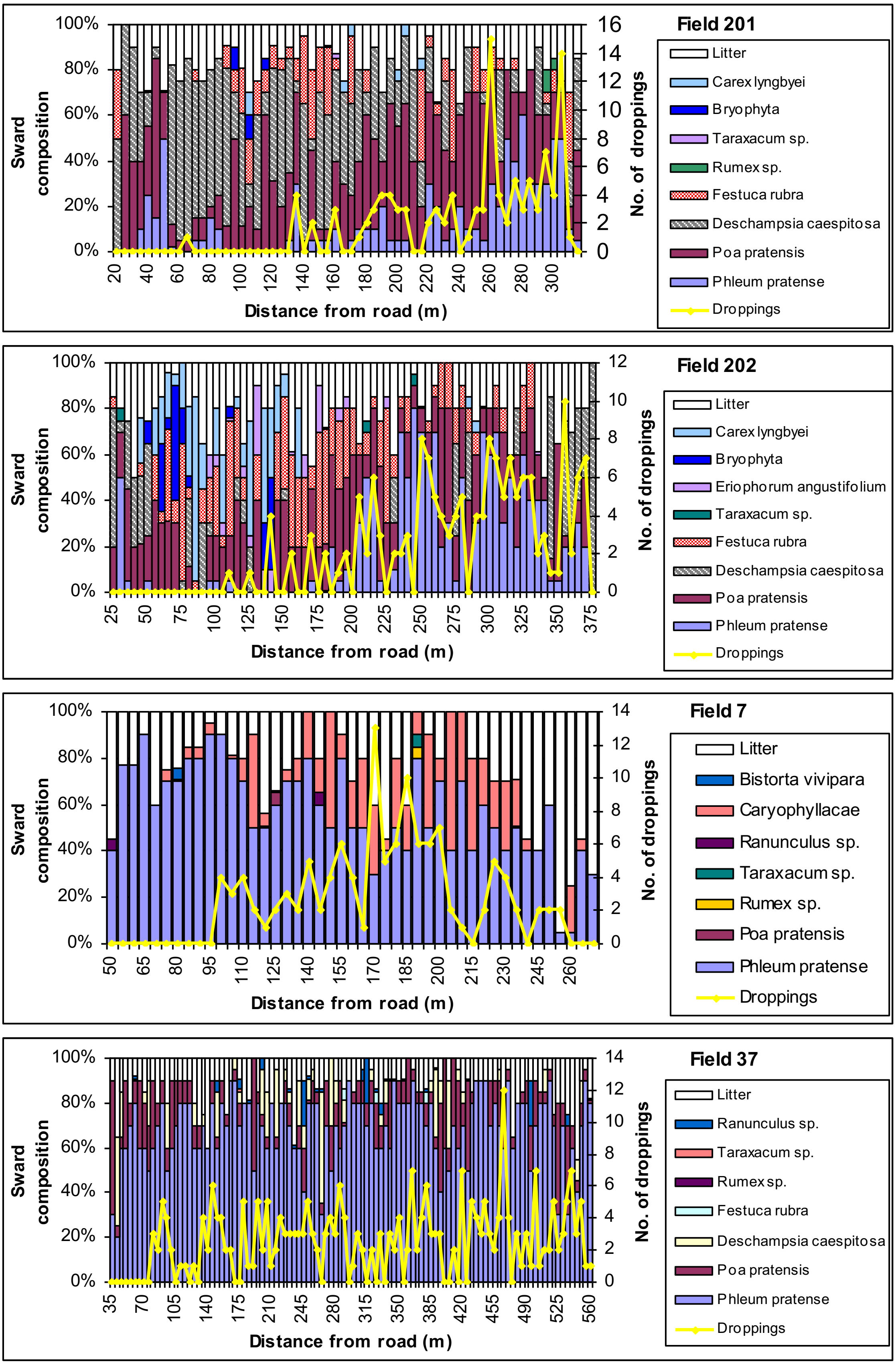

Fig. 8. Dropping density of Greenland White-fronted geese in relation to the sward composition on selected fields on Hvanneyri, West Iceland, in autumn 2005.

3.1.3 Field parameters and dropping distribution in relation to the distance to the road.

Dropping counts on selected days and fields in September 2005 showed different distributions of droppings, as shown in Figure 9.

Droppings were absent in field 201 up to 135m from the road and 140 m from the road in field 202. In contrast, the first droppings were encountered at around 100m in field 7, 80m in field 37 at 80m, and 15 m in the barley field, field 39. Calculating regression and correlation of dropping density versus the distance to the road, starting from the point of the presence of first droppings, a highly significant relationship between the parameters has been examined on fields 201 and 202 ($P < 0.001$). Field 7 and 37 show trend as well but no significant relationship. On field 39, the relationship between the distance to the road and the geese showed to be highly significant for the negative correlation (r = -0,643, $P < 0.001$) (see Figure 9).

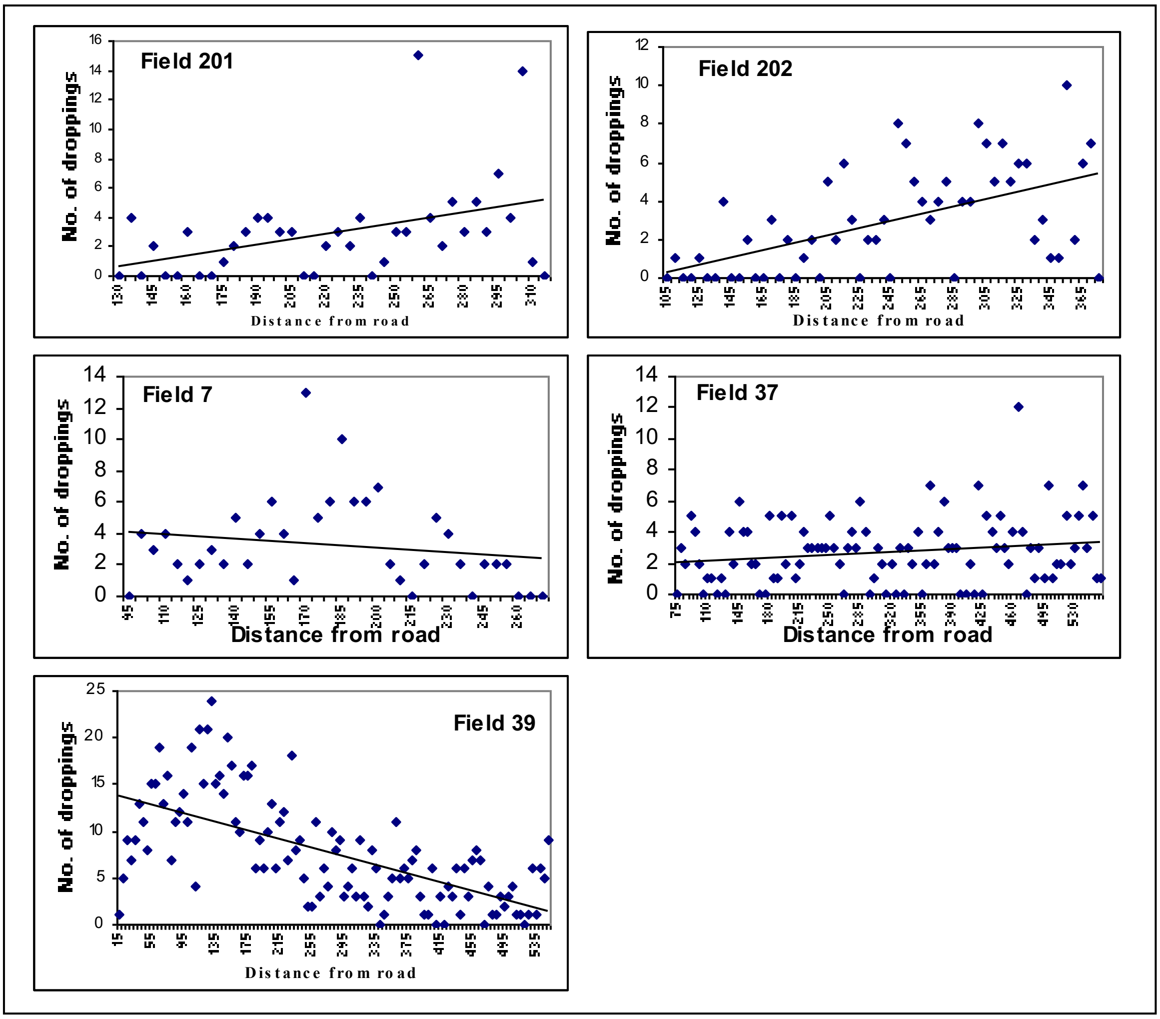

Fig. 9. Relationship between distance to the road and the distribution of droppings of Greenland White-fronted Geese on Hvanneyri fields in September 2005, from the point of the presence of droppings. Linear regression lines are shown (significant correlation between the parameters at field 201, 202 and 39). Different scales have been used that reflect differences in geese use.

3.1.4 Dropping density and sward length

Evaluation of correlations between sward height on the different fields and dropping density showed highly significant significant negative relationships in three cases (field 201, 202 and 37) and an obvious negative trend on field 7 (see Figure 10).

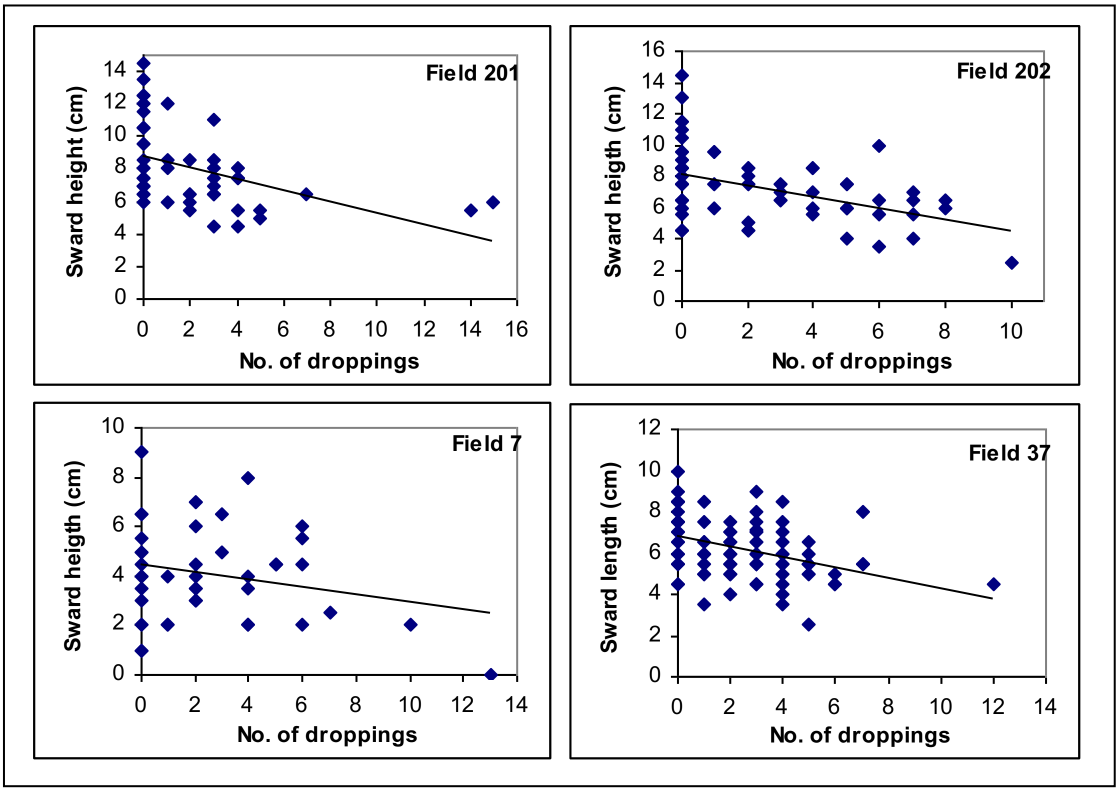

Fig. 10. Relationship between dropping density of Greenland White-fronted geese and sward length (cm) on selected fields at Hvanneyri, West Iceland, in autumn 2005. Regression lines are shown. Negative significant relationships appeared on fields 201 (r = -0.421, n = 59, $P < 0.001$), 202 (r = -0.442, n = 71, $P < 0.001$) and 37 (r = -0.394, n = 106, $P < 0.001$), but not on field 7 (r = -0,220, n = 45, $P > 0.05$).

3.1.5 Dropping density on different fields

Field	***201*** mixed sward	***202*** mixed sward	***7*** *Phleum* dominated	***37*** *Phleum* dominated	***39*** Barley
Droppings	111	159	118	267	829
no. quadrates	60	71	45	106	108
Droppings/m^2	**2.62**	**3.17**	**3.72**	**3.57**	**10.88**

Fig. 11. Average dropping density of Greenland White-Fronted geese, counted on selected fields on Hvanneyri, West Iceland, in autumn 2005. Each quadrate is 0.7056m^2 in size.

A One-way anova of the dropping density/sample quadrate on the different fields showed a significant difference (P<0.001) between the groups (7, 37, 201, 202 versus 39).

3.2 Study no. 2

3.2.1 Classification of fields

The classification of the fields for the second study of this study refers to the sward determination shown in 3.1.1. and an interview with the local farmer. Field 37 is a *Phleum* dominated pasture, sowed in spring 2002, whereas field 38 is a young *Phleum* dominated field, reseeded in spring 2005. Field 39 is an acre exclusively dominated by *Hordeum vulgare* (barley), and field 39b is natural bog land, among others dominated by *Carex lyngbyei*.

3.2.2 Dropping distribution in relation to the distance to the ditches

The observing days for each field 37, 38 and 39 were counted together. Since no droppings were found on field 39b, this was not taken into account.
Interaction effect between the fields and the distance to the ditches were not significant (P > 0.05), but the difference between both the fields and the distance to the ditches showed up as highly significant (P <0.001).
Concerning the variability of dropping density in relation to the distance to the ditches, the field boundaries in immediate proximity to the ditches (0m) pointed noticeably out. A comparison of the number of droppings there with the average numbers on the other spots could explain 74% of the variability (if the original data was used) and even 95% of the variability explained while using the logarithmic projection of dropping density.

4. Discussion

4.1 Study no. 1: The effect of roads on goose utilisation

4.1.1 Field and diet selection

In this study, three different vegetation types of different importance for the grazing Greenland White-fronted Geese have been compared: *Phleum* dominated, recently reseeded fields (7 and 37), old fields with mixed sward (201 and 202) and the barley field 39. It is known from earlier researches that geese favour *Phleum* over all other existing grass species on Hvanneyri (Nyeland, 2001) and that they go for energy-rich food like barley as well.

The results of the present study confirm these from earlier results of e.g. Nyegaard et al. (2001): the geese choose *Phleum* over *Poa* and even avoid zones with high percentage cover of *Deschampsia* and *Caryophyllacae* in mixed sward fields. It is notable that the only statistically significant results were found on field 201 and 202, the old pasturages with mixed swards.

The reason why there are no significant relationships on the fields dominated by *Phleum* is the high percentage of their favourite food. Figure 7 shows that the geese respond by selecting for *Phleum* on the mixed swards, but on the fields where it's percentage is already more than 50% of the sward, the preferred species is so common throughout the distribution of droppings show no spatial response. This explains why there are no significant relations on field 37 and 7: the higher the percentage of energy rich food species is within the fields, the less the birds show any spatial response to *Phleum* abundance in the sward composition.

Comparing the average density of droppings per square metre on the different fields, we come to the following results: the geese usage per frame seems to be quite similar on the four grass fields (2.62 to 3.72 droppings/m^2) but were more than tripled in the barley field (10.88 droppings/m^2) (see Figure 11). This conforms to the optimal foraging theory, which suggests that animals are able to distinguish between different quality and quantity of food and select the best (Kristiansen, Fox & Nachman, 2000). The one-way ANOVA affirmed those numbers and showed a significant difference between the four grass fields and the barley field. The geese therefore used the barley field significantly more than the grass-fields.

An interesting fact revealed during an interview with the local farmer Guðmundur Hallgrímsson that was done on the 10. April 2006. He mentioned that he had scared the geese off from the barley field by driving a vehicle on field 38, firing shots into the air and even fireworks to keep them away from barley field 39 in the weeks before the harvest. This does not affect the results from field 39, because the main usage there has been the days after the barley had been cut when geese were feeding on spilled grain after the harvest, when they would not have been disturbed by Guðmundur. However, this does affect the data collected for field 37, which was collected two days after the cut of barley and lies in direct proximity to it. This explains why the average usage shown in Figure 11 is the lowest recorded: the geese obviously react to the unusual levels of disturbance next to field 39. It is very likely that geese usage would have been much higher on field 37 and the results different without this additional disturbance. In the absence of this effect, perhaps a significant difference between goose usage on mixed swards and *Phleum* dominated fields would have shown up.

Evaluation of correlations between sward height on the different fields and dropping density showed simply that the dropping density corresponds with the average sward height and that grazing occurred. The more droppings the less organic matter was found on average within the frames. However, a confounding effect can be that geese prefer short nutritious grass swards over longer ones of higher biomass but lower food quality (e.g. van der Graaf et al., 2002).

4.1.2 Avoidance towards roads

Animals respond to disturbance from humans in the same way as they respond to the risk of predation: they avoid areas of high risk, either completely or by using them for limited periods (Gill, Sutherland & Watkinson, 1996). Therefore, in the case of even habitat quality, geese will show reduced exploitation rates of areas subject to high disturbance compared to those experiencing less disturbance. As expected and demonstrated in earlier researches, the geese show total avoidance of parts of the fields closest to the roads and keep at least 100m distance. After that, the response is a gradually increasing with greater distance from the road. Most grazing takes part on the opposing side of the field from the road. As in the case of field 201 and 202, the geese show complete avoidance for the first 130 m followed by a linear incline out to about 280 m after which the field use keeps on a stable level. Field 37 shows no significant difference, but the distribution of droppings suggests at least a trend of avoiding the road as a reaction to probably disturbance. In field 7 is obviously an effect of the other side of the field. There is no potential source of disturbance on the other side, but the curvilinear response can be explained by varying vegetation composition. As shown in figure 8, the favoured plant species *Phleum* decreases on field 7 from about metre 200 to the end, which leads to a decrease in goose utilisation as well and may explain this apparent anomaly in goose use of the field furthest from the road.

The barley acre 39 shows the most unexpected reaction of the geese towards disturbance: here we got a highly significant result for the negative correlation, which means: the geese seemed to be attracted by the road and avoid the relatively undisturbed far end of the field. The enormous concentration of droppings near the road is hard to explain because it conflicts with all expectations. The first conclusion would be that the birds seem to be more tolerant to disturbance in this field because barley is the most energetic food they can get on Hvanneyri farmland, and because there is only a very limited amount existing for a very short time. It seems to be likely that the distribution of droppings corresponds with the distribution of barley-grain within the field. One potential explanation for the very high densities of droppings at intermediate distances up the field would be that the farmers seem to have been loading the barley in the area 50-150 m up from the road, which would be a possible explanation for the unequal distribution of both barley and geese. Another possibility would be an unequal maturity of the barley at the time of the cut: the ground could have been dryer close to the road. The consequence would have been that the barley on dryer ground would maturate earlier and be looser, which could have led to an increased loss of grain short before and during the cut. In the interview on 10. April 2006, the local farmer Guðmundur Hallgrímsson dismissed this theory. He has of course no data to confirm this, but he felt that the field was quite homogeneous, except for a spot of several square metres close to the road. But this area is far too small to explain the unexpected distribution of barley and geese.

Moreover, it could have been that the results on the barley field may have been influenced by a higher rate of reaction to disturbances. As the geese moved closer towards the road, they were probably reacting more towards disturbance, resulting in more movements within the area. It is known, that geese often defecate when flying up **(REFERENCE)**; so even short flights within the area could have led to an accumulation of droppings that does not reflect the real geese use.

Therefore, further investigation of the precise distribution of the spilled grain and the goose droppings would be necessary to find a satisfying answer. Nevertheless, it might be expected that patterns of goose exploitation of this food source may differ from grass feeding, because of the very high profitability of the barley compared to all other forage available to the geese.
It seems to be obvious that the geese take more risks as more they can profit from their food sources. On the old mixed swards, the total avoidance distance is 130-135m. On the *Phleum* dominated pastures, the distance is 80-100m, and goes down to only 15 in case of the barley field. These discovery fits with those of other studies, as to name Owen (1971 & 1972), Nyegaard et al. (2001) or Gill, Sutherland & Watkinson (1996). It is though necessary to mention, that it is not known whether there is any cost to the geese of feeding on grain versus grass or wetland plants in terms of their energetic and nutritional needs.

As vegetation is the factor that affects goose usage most, choosing the fields and determination of the sward composition are extremely important in a study like this. This may be a helpful hint for similar future studies.

How long the depressing effect of the roads on goose utilisation reaches within the fields is hard to say. As Madsen (1985) found out in a study named the Impact of Disturbance on Field Utilization of Pink-footed geese in Denmark, roads with a traffic volume of 20-50 cars per day had a serious depressing effect on goose utilisation in a range of 0-500m from the road. His results were also, that the disturbance tolerance of geese increases as soon as the space of habitat decreases.
In the present study, only field 37 and 39 reached 500m in length; the others were shorter. Both field 39 and 7 had unexpected outcomes, affected by other factors. The comparison of field 201 and 202, with regard to field 37 (see Figure 12), suggests that the geese graze mostly undisturbed at distances around 300m and more from the road. But this is only a very vague assumption; it is necessary to compare a larger quantity of fields that are both similar in size and sward composition to come to a firm conclusion. Nevertheless, the assumption of Madsen parallels the findings of the present study and suggests that geese could be less disturbed by the road traffic in Iceland than in Denmark (Madsen, 1985) or Wexford (Walsh, 1991) because of smaller field units and lower levels of disturbance. Furthermore, spring staging geese in Iceland need to build up fat reserves quickly, which could cause a more tolerant reaction towards disturbance.

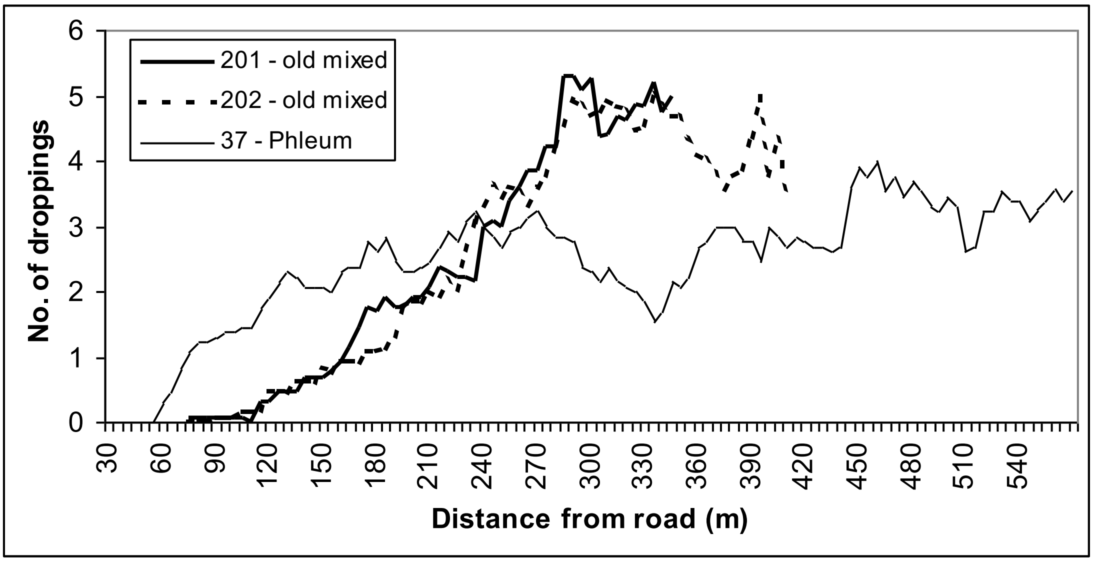

Fig. 121. Distribution of droppings of Greenland White-fronted Geese on selected Hvanneyri fields, Iceland. Smooth-Data (average of 13 numbers) from autumn 2005.

4.2 Study no. 2:The effect of ditches on goose utilisation

4.2.1 Avoidance towards ditches

As far as the author knows, no data is existing concerning the reaction of Greenland White-fronted Geese to ditches on Icelandic fields. It is however known that geese avoid potentially disturbing landscape elements, for example high-power lines, windbreaks, roads and settlements (Larsen & Madsen, 2000), all types of cover that would potentially hide a predator. Geese react in avoiding these objects and ultimately in terms of under exploiting a resource in close proximity to such features (Gill, Sutherland & Watkinson, 1996). The avoidance distances are highly dependent on the given conditions (Larsen & Madsen, 2000).

Although ditches do not rise above the surrounding landscape, they can hide predators and are a potential threat to the birds. This suggests we could make the assumption that geese will avoid ditches as well. In the present study, the geese did show avoidance, especially in the range 0-5m distance from the ditches. Because data was collected at an interval of five metres, it is not possible to measure the effect to a finer level. A more detailed research with samples every metre would have been more helpful, which should be taken into account with a view to future studies.

On the other hand, geese can be frequently seen walking down into the ditches to drink, so they cannot be that frightened of the cover. It is likely that the vegetation in the strip nearest to the ditches experience drier soils compared to greater distances from the ditch edge. It is therefore possible that the results are greatly affected by differences in vegetation composition at the field boundaries, so that the reduced usage there could be explainable through vegetation. Therefore, it would have been useful to have undertaken a more detailed classification of the sward composition and dropping densities in the narrow band close to the ditches to fully understand these patterns.

4.2.2 Rotational grazing

Another objective of the second study was to show if the geese would change their behaviour towards the ditches over time. It is known that birds select feeding sites on

the sward level, feeding on the most profitable plant species, but also taking those parts of plants of the highest nutritious value. Since the growing meristems of grasses lie at the base of the leaves, removal of a grass leaf does not stop that leaf growing and elongating, ready to be harvested by the geese again after a short period. This leads to a sequential use of individual fields and parts of fields, which is called rotational grazing and has been discussed explicitly elsewhere (Nyeland, 2001 and Fox & Stroud, 2002). It has also been found that geese take more risks (with regard to potential predation hazards) when food is limiting (Owen, 1972) so that the logical conclusion is that they become less wary to ditches or other disturbing factors towards the end of the season when food becomes depleted or exhausted.
Alas, two unfortunate events made it impossible to come to any usable conclusions. Time series of five counts were scheduled, but interrupted after the third count, because of the farm management. The collection of data was therefore suspended. More studies through the season are essential to measure the effects of food depletion through the autumn. A better communication between the researcher and the farmers / land owners would have been helpful.
The second part which had not the desired outcome was the measurement of the sward length. Here, a more careful collection of data would have been advisable. Instead of measuring always at exactly the same spot or even determine the exact growth of single blades of grass (as in Nyeland, 2001), measurement took place somewhere within the sample frame. This may be correct for single measurement, but not if the aim is to compare the growth rate of exactly the same spot in time series.
Furthermore, no allowance was made for the weather conditions, which were different from time to time during data collection. The first measurement was done in dry and mild weather, ground frost took place on 5 October and rain varied the results on October 14th.
All this affected the outcome, so that the author decided to not take the collected data into statistical consideration.

Data collection and the technique used for estimating the collected data in both studies may be subject to errors from several sources, e.g. inaccuracy in estimating numbers or that no account is taken to other disturbing factors that might have been. It has to be mentioned as well that Greylag Geese (*Anser anser*) were grazing on the same fields as the Whitefronts, though in minor quantity.

5. Conclusions

One of the main results of the present study is, that the presence of the road demonstrably affects the behaviour of the geese much more than the ditches do. Ditches seem to affect goose use over a distance of 0-5 metres, whereas the frequently used roads on Hvanneyri have a serious depressing effect on goose utilisation over a range of 0-300m.
The other important conclusion appears to be that the disturbance tolerance of geese increases with the increasing quality of food. The most reaction to disturbance is shown on fields 201-202 where *Phleum* coverage is less than 50%. The geese come closer to the road on the *Phleum*-dominated fields 7 and 37, and showed no avoidance response at all in the barley field 39, although this may be due to differential food availability because of unknown patterns in spilled grain.

Concerning the conflict between increasing human activity on Hvanneyri and the site's international importance for the population of Greenland White-fronted Geese, this study gives a good and interesting perspective. The birds are highly dependant on the farm, the local wetlands and the energy-rich grass species which are cultivated on the fields. What is significant is that the geese show avoidance to human activity and do not use the fields at all in an area up to 100m from the road and show reduced use of the fields up to a distance of at least 300m. Despite the very large field size, this represents a substantial area of "effective habitat loss", which means that there is good available goose feeding habitat which is not exploited because of human activities. This response is only to relatively infrequent walkers, horse riders and cars using the roads on the farm. The disturbance distances could be potentially far greater to settlements, where more frequent human activity could represent a much stronger quasi-predation stimulus. That implies that the expansion of settlement and human activities will potentially result in increased under-exploitation by geese using the fields within area of 0-500m distance to the source of disturbance.
On the other hand, geese seem to adapt and are apparently willing to tolerate disturbance to a greater extent if the quality of food is higher than usual. From this study there is no information about the extent to which the geese would habituate to disturbance within and between seasons.

If the number, size and quality of the fields at Hvanneyri remain at the present level, increased disturbance at the farm will probably result in a decrease in the effective carry capacity of the farm as a whole. This means that for no agricultural change, fewer geese can be accommodated on the reserve because of their avoidance of disturbance. This is critical because Hvanneyri is one of the very few hunting free areas in Iceland in autumn.
One possible solution to this conflict is that geese seem to be more willing to suffer similar levels of disturbance on better quality feeding habitat. This and other studies show that geese exploit spilled barley and *Phleum* in densities far higher than on native grasses. Therefore, one possible management option would be to increase the extent of these habitats on the farm relative to the present day. It would be a possibility to offset the loss of carrying capacity from increased disturbance by increasing the effective carrying capacity of the fields, for example by more frequent reseeding of *Phleum* and/or by growing more barley.

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