Diet of goshawk (*Accipiter gentilis*) nestlings in south-eastern Norway: A comparison of farmland- and forest-dominated areas

Dietten til reirunger av hønsehauk (*Accipiter gentilis*) i Sørøst-Norge: En sammenligning av jordbruksdominerte og skogs-dominerte områder

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PREFACE

This thesis completes my Master degree in Natural Resource Management at the Department of Ecology and Natural Resource Management. Fieldwork was done during spring of 2005 and the thesis was written during spring of 2006.

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ABSTRACT

Video recording was used to record prey items delivered to the nests by seven different goshawk (*Accipiter gentilis*) pairs in two areas in south-eastern Norway during the breeding season of 2005. A total of 146 prey deliveries were recorded. In addition, 144 prey items identified from prey remains were used as a supplement in parts of the analyses. The prey items identified were used to compare the goshawks' diet in a farmland-dominated habitat type in Akershus County to the goshawks' diet in a forest-dominated habitat type in Buskerud County. Thrushes (*Turdus* spp.) and corvids (*Corvidae* spp.) were the two dominating prey groups in both areas. I found higher dietary diversity in the diets in Buskerud, but I also found high dietary overlap between Akershus and Buskerud (Morisita's index = 0.93). The high dietary overlap was most likely due to the dominance of thrushes in the diets in both areas. Diet composition in Akershus differed significantly from that in Buskerud ($P < 0.05$) when testing for differences in both prey group composition and forest versus farmland species. However, no difference was found between the two areas by means of prey weight categories. Data from the prey remains revealed a significant negative relationship between grouse in the diet and proportion of farmland ($P < 0.05$). Further, pooled data from video recording and prey remains showed a significant positive relationship between the groups of "farmland corvids" and the proportion of farmland, and again a significant negative relationship between grouse and the proportion of farmland ($P < 0.05$). My study therefore indicates that the goshawk diet reflects the habitat within the home range, and consequently that there is a dietary difference between goshawks in forest- and farmland-dominated areas. Grouse may not be the most important prey in all areas in Fennoscandia. Therefore, one should also think of farmland areas as potential goshawk habitat.

SAMMENDRAG

Videokameraer ble brukt til å registrere byttedyr brakt til reirene av syv hønsehaukpar (*Accipiter gentilis*) i to forskjellige områder i sørøst Norge, i løpet av hekkesesongen 2005. Totalt ble 146 byttedyrleveringer registrert, og i tillegg ble det brukt 144 byttedyr identifisert fra rester som et supplement til deler av analysene. De identifiserte byttedyrene ble brukt til å sammenligne hønsehaukens diett i jordbruksdominerte områder i Akershus med skogsdominerte områder i Buskerud. Trost (*Turdus* spp.) og kråkefugl (*Corvidae* spp.) var de to dominerende byttedyrgruppene, uavhengig av lokalitet. Jeg fant høyere artsdiversitet blant byttedyrene i Buskerud, men samtidig høy diettoverlapp mellom Akershus og Buskerud (Morisitas indeks = 0,93). Stor andel trost i dietten hos hønsehaukene i begge områder kan være forklaringen på den høye diettoverlappen mellom Akershus og Buskerud. Da jeg testet forskjellen i gruppesammensetningen av byttedyr og skogsarter kontra arter forbundet med jordbruk, fant jeg signifikante forskjeller mellom Akershus og Buskerud ($P < 0,05$). På en annen side fant jeg ingen forskjell mellom de to områdene når det gjaldt byttedyrvekt. Det var en signifikant negativ sammenheng mellom antall hønsefugl i dietten og andel jordbruksland i hønsehaukenes hjemmeområder ($P < 0,05$) basert på data fra byttedyrrestene. En sammenslåing av byttedyr registrert fra videofilmingen med byttedyrrester viste en signifikant positiv sammenheng mellom kråkefugl og andel jordbruskland, og igjen en signifikant negativ sammenheng mellom hønsefugl og andel jordbruksland ($P < 0,05$). Studiet mitt indikerer derfor at hønsehaukens valg av byttedyr reflekterer habitatet i hjemmeområdet, og at det dermed er en forskjell i dietten mellom hønsehauk i jordbruksdominert og skogsdominert landskap. Hønsefugl trenger ikke være en like viktig del av dietten i alle deler av Fennoskandia. Derfor bør en også vurdere jordbruksområder som potensielle hønsehaukhabitat.

1. INTRODUCTION

The northern goshawk (*Accipiter gentilis*) is a common and widely distributed raptor species throughout the northern hemisphere (Brown & Amadon 1968), with many sub-species (Grønlien 2004) likely reflecting the various environments the goshawk is adapted to. In boreal parts of its range, the northern goshawk (referred to as goshawk in this thesis) is mainly an old forest species, and is considered dependent on this kind of habitat especially for nesting sites and hunting area (Widén 1989, Penteriani 2002). During the past decades, the goshawk populations have declined throughout most of their northern ranges. Possible reasons for those declines are legal and illegal hunting, pesticides and intensive forestry (Grønlien 2004). In Norway, the goshawk has a status as vulnerable (Norwegian Directorate for Nature Management 2006a), but today the population trajectory is still debated (Grønlien 2004, Gundersen *et al*. 2004). Recent population estimates for boreal and boreo-nemoral forests in Norway indicate approximately three pairs per 100 km^2 of forested areas (Bergo 1992, Widén 1997).

Food is an important limiting factor of most raptor species (Newton 1979). For individual goshawks this factor is more important than processes acting over large spatial and temporal scales, such as large scale modern forestry and climate change. The feeding ecology of goshawks has therefore engaged ornithologists for over 80 years (Opdam *et al*. 1977), and is well studied throughout Europe (e.g. Kenward *et al*. 1981, Selås 1989a, Tornberg 1997, Toyne 1998). A wide range of different techniques have been used to study their diet, i.e. direct observations from blinds (e.g. Toyne 1998), pellet analysis (e.g. Selås 1989a), stomach analysis (Hagen 1952), radio-monitoring (e.g. Widén 1987), prey remain analysis (e.g. Tornberg 1997), and video recordings of nests (e.g. Grønnesby & Nygård 2000). Video recording is a direct method of assessing diet of raptors. It is therefore a recommended method because it is thought to provide the least biased data (e.g. Grønnesby & Nygård 2000, Lewis *et al*. 2004a, Rogers *et al*. 2005).

In Northern Europe, studies have indicated that goshawk diet consists mainly of avian prey like grouse (*Tetraonidae* spp.), thrushes (*Turdus* spp.), corvids (*Corvidae* spp.), and pigeons (*Columbidae* spp.), but also mammals like red squirrels (*Scirius vulgaris*), and lagomorphs (*Lagomorpha* spp.; Kenward *et al*. 1981, Selås 1989a, Tornberg 1997). The prey species may thus vary greatly in size from small mammals weighing 5 g up to the size of hares and capercaillie cocks weighing 4 kg. The diversity of prey in goshawk diets may mostly depend on the abundance and availability of the local bird and mammal fauna, which varies geographically (Salafsky *et al*. 2005). For example, in Canada studies indicate that the goshawk population responds mostly to just one species, the snowshoe hare (*Lepus americanus*; Doyle & Smith 2001). Further south in North America, however, the dietary diversity increases to 14 dominant species (Reynolds *et al*. 1992).

Landscape structure influences the abundance and distribution of the goshawk's prey (e.g. Saunders *et al*. 1991, Andrén 1994). In more southern parts of its range in Europe, the goshawk is found in human-influenced habitats such as farmlands, parks, and urban areas. Their diet therefore likely varies accordingly (Berg 2002). Most goshawk diet studies in Fennoscandia are conducted in boreal forests where grouse seem to be their preferred prey throughout the year, including the breeding season. However, as the grouse populations have declined markedly during the past decades (Tornberg *et al*. 1999) and much of the older, multilayered boreal forests are converted to even-aged stands, it is important to investigate goshawk diet in other habitats to gain knowledge about their ability to adapt despite changes in their original habitat in Fennoscandia. By such, few have studied the diet in areas located in and close to open farmland during the breeding season in Fennoscandia.

This study investigates the diet of seven goshawk pairs nesting in two separate landscapes in south-eastern Norway. Whereas one of the study areas was dominated by farmland, the other was dominated by middle-boreal coniferous forest. The main aim of my study was to document the breeding diet of goshawks in the two study areas. I expected that goshawk diet in the forest-dominated areas was dominated by large forest species like grouse, jay (*Garrulus glandarius*), woodpeckers (*Picidae* spp.) and red squirrel. In the farmland-dominated area the expected prey composition would be dominated by typical farmland species like corvids and pigeons. First, I will investigate diet diversity in the two study areas and diet overlap between the two areas. Second, I investigate diet similarity between all nests regardless of landscape type. Third, I examine possible diet differences between the two study areas. Fourth, I relate diet to farmland land cover within the home ranges. Finally, I briefly discuss some implications for defining goshawk diet and habitat during the breeding season.

2. METHODS

2.1 Study design

Goshawk breeding diet was studied in two areas in south-eastern Norway during the breeding season from 1 June to 1 July in 2005. The two areas, Akershus and Buskerud, were chosen to reflect a difference in land cover and physiographic conditions. Nest selection was based on previous knowledge of breeding territories and availability of the nests. I studied a total of four nests in Akershus, and four nests in Buskerud, by use of video cameras to record prey items the adults delivered to the nest. Prey remains were also collected beneath the goshawk nests and perches. One of the nests in Buskerud failed early in the recording period, and was omitted in all analyses.

2.2 Study area

Akershus

Four nests were monitored within an area in Akershus County. The area (59°45´-59°55´N; 9°35´-10°13´E) is situated in the boreo-nemoral zone (Moen 1998) and is dominated by farmland that alternates with wooded ridges. Grain fields dominate, but grazing land is also common in addition to mosaics of garden fields, parks, mature deciduous and conifer forests, and lowland bogs (Norwegian Directorate for Nature Management 2006b). The climate is characterized by warm and dry summers and mild winters (Norwegian Meteorological Institute 2006a). The mean annual temperature is 5.3 ºC with a minimum of -4.8 ºC in January and February and a maximum of 16.1 ºC in July. Mean annual precipitation is 785 mm with a maximum of 100 mm in October and a minimum of 35 mm in February (Norwegian Meteorological Institute 2006a). Of the four nests in Akershus, three were located in conifer woodlots dominated by Norway spruce (*Picea abies*) and one was located in a woodlot dominated by Scots pine (*Pinus sylvestris*). The main forestry practice involves clear-cuts of different sizes. Older clear-cuts were dominated by birch (*Betula pubescens*). Other common forest tree species in Akershus are elm (*Ulmus glabra*), ash (*Fraxinus excelsior*), lime (*Tilia cordata*), Norway maple (*Acer platanoides*), pedunculate oak (*Quercus robur*) and black alder (*Alnus glutinosa*). High productivity dominates in the area. In terms of age classes a mixture of young and mature forest is common.

Buskerud

Three nests were monitored in Buskerud County. The area (59°45´-59°55´N; 9°35´-10°13´E) is a part of the middle-boreal zone but just below the border of the boreal zone (Moen 1998), and some areas may be classified as boreal forest. The mean annual temperature is 5.0 ºC with a minimum of -6.7 ºC in January and a maximum of 16.5 ºC in July. Mean annual precipitation is 880 mm with a maximum of 110 mm in October and a minimum of 45 mm in February (Norwegian Meteorological Institute 2006b). The area is covered mostly by coniferous forests with Norway spruce and Scots pine as the dominating tree species, and a ground layer of bilberry (*Vaccinium myrtillus*) and heather (*Calluna vulgaris*). Birch is common on open sites following logging. Medium and low productivity dominates, but rich deciduous forests are found in the north of the study area (Norwegian Directorate for Nature Management 2006b). Modern forestry has converted 50% of the area to even-aged stands less than 50 years old. Successional stages were interspersed in a mosaic with patch sizes of 0.5-50.0 ha. Lakes, ponds and rich bogs are scattered features within the home ranges of the studied goshawks in Buskerud.

2.3 Sampling methods

Video study

The system used for recording consisted of a digital camcorder (Canon MV700i), which was equipped with a wired 50 x 45 x 45 mm, 18LED night vision color CCTV lens. The approximately 100 m long connection between the lens and the recorder consisted of a modified RCA video cable with male-to-male connectors on each end. We powered the lens and camera with a 12 V lead battery (10 Ah) each, with a self-constructed voltage converter (from 12 to 8.4 V). The batteries lasted for 12-24 hours, and were recharged with a MC charger (6/12 V).

Before we installed the lens and camera, we made sure that the nestlings had hatched by observing the behavior of the adult goshawks and from evidence beneath the nest (e.g. nestling excreta). Each nesting tree was climbed with the help of climbing equipment and pole climbers. A lens was attached to the nesting tree approximately 1-1.5 m from the nest. The lens was small, easy to handle, and water-resistant and made it possible to change cassettes without climbing the tree and disturbing the goshawks. The lens was aimed down at the nest while another person on the ground directed placement by watching the image on the camera screen. The lens was aimed so that most of the interior bowl of the nest was in focus. Once the location was determined, the lens was affixed to a branch with a screw clamp. When branches were scarce or unavailable, the lens was attached to a pole, and the pole was attached to the tree with straps. The cable connecting the lens and the camera was wired from the tree to the camera that we placed in a tent approximately 50 m away from the nest tree. Inside the tent, each of the observers stayed 6-12 hours by turn, changing tapes every two hours. During the installment of the video equipment the adult goshawks showed evident signs of stress with both sound and behavior, but during the recording process they did not seem to be affected by the presence of recording equipment.

Each of the seven nests was video recorded for two days in two periods, early and late in the nestling period (Table 1). Nestling diet might change as they get older therefore it was important that the recordings were more or less done at the same nestling-age at all seven nests (Cummins & O'Halloran 2002). Each day of recording lasted from 06.00 a.m. to 06.00 p.m., thus we had a total of approximately 336 hours of recording. Goshawks are diurnal raptors and therefore we chose to do the recordings at daytime when the feeding activity is at its highest level.

To identify and document the prey items we viewed the tapes using a video camera connected to a 32-inch color TV (Grundig ST84-794 TOP) after the breeding season. The camera allowed the tapes to be replayed at slow speed and it could freeze one frame at a time to facilitate prey identification. The prey were identified to the lowest taxonomic level possible (Appendix 1), by morphological features such as size, color and texture on feathers or fur, bill, feet and, bone size. A reference collection of stuffed specimens of locally breeding birds and mammals was used to help identify items, and we identified prey by comparing their morphological features with the size of the goshawk's tarsus, toes, and head. The goshawks completely or partially plucked and often parted their prey before delivering them to the nest. Thus some of the prey items were unidentifiable. Most of the unidentifiable items were categorized into a more general category of genus or family, and some items were not possible to identify at all.

Prey remains

Prey remains were collected from beneath the nests, plucking posts, and perches located within 150 m around the nests, and also inside the nest bowl at the same time the camera equipment was installed. Only six nests and nest areas were searched. To avoid double counts,

Table 1. Summary of information about the seven goshawk nests and the nestlings in Akershus and Buskerud. Proportions of farmland within a radius of 2 km around each nest are also given.

Nest no.	Nest location	Brood size	Estimated date of hatching	Nesting tree	Altitude (m a.s.l.)	% farmland	App. nestling age at video recording (days) Period 1	Period 2
1	Akershus	4	17 May	Spruce	93	35.8	18	33
2	Akershus	4(3)*	24 May	Pine	90	42.2	10	32
3	Akershus	3	1 June	Spruce	126	42.7	7	26
4	Akershus	3	26 May	Spruce	93	24.0	14	25
5	Buskerud	2	25 May	Pine	320	0.7	20	31
6	Buskerud	3	26 May	Pine	250	0.7	16	32
7	Buskerud	4	30 May	Spruce	220	0.7	17	30

* Only 3 nestlings fledged.

all remains were collected prior to video recording and also after video recording to register those prey that most likely were caught on tape. Prey remains included feathers, bills, feet, fur and other skeletal parts of both birds and mammals. The identification was based on reference collections of bones and feathers, and the results are listed in Appendix 1. In this study I focused mostly on the prey identified from the video recordings, and used prey remains as supplementary data to increase sample size only when analyzing diet in relation to land cover.

2.4 Dietary diversity and overlap between Akershus and Buskerud

Dietary diversity

For all analyses in this study I have chosen not to distinguish among young versus adult prey. To evaluate how diet varied between the seven nests and between the two study areas, Akershus and Buskerud, I analyzed differences in prey diversity and dietary overlap. Dietary calculations were based on the occurrence of the prey items listed in Appendix 1, and the species and species groups used in the different calculations are summarized in Table 2.

Prey species diversity was calculated using Simpson's Reciprocal Index (*1/D*) which describes the "concentration" of the goshawks prey species (Simpson 1949, Krebs 1999). The index represents the probability that two individuals randomly selected from a sample will belong to the same species (Krebs 1999). This index is also a measure which takes into account both species richness and evenness (Krebs 1999). Evenness is a measure of the relative abundance of the different species making up the richness of an area (Krebs 1999). The Simpson's Reciprocal Index was calculated from the following formula:

$$D = \frac{\sum n(n-1)}{N(N-1)},$$

where n is the total number of prey items of a particular species and N is the total number of prey items of all species (Krebs 1999). All species were used and therefore the index ranged from 1 to 16 species and the higher the value, the higher the species diversity.

Dietary overlap

To estimate dietary overlap between the nests in Akershus and nests in Buskerud I used Morisita's Index (C) with values ranging between 0 (no dietary overlap) and 1 (complete dietary overlap; Morisita 1959, Krebs 1999). Overlap measures are designed to measure the degree to which two groups of individuals utilize common prey species. Wolda (1981) recommended Morisita's Index as the best overall measure of similarity for ecological use. It has been shown to give similarity scores nearly independent of sample size (Morisita 1959, Krebs 1999) which was advantageous for my study with low sample size. I used three groups of species and six species to calculate Morisita's index (Table 2) with the following formula:

$$C = \frac{2\sum_i^n p_{ij} p_{ik}}{\sum_i^n p_{ij}\left[(n_{ij}-1)/(N_j-1)\right] + \sum_i^n p_{ik}\left[(n_{ik}-1)(N_k-1)\right]},$$

where C = Morisita's index of niche overlap between sample j and k

p_{ij} = Proportion resource i is of the total resources used by sample j

p_{ik} = Proportion resource i is of the total resource used by sample k

n_{ij} = Number of individuals of sample j that use resource category i

n_{ik} = Number of individuals of sample k that use resource category i

N_j, N_k = Total number of individuals in each area in sample

$\sum_i^n = 1 \;\; n_{ij} = N_j, \; \sum_i^n = 1 \;\; n_{ik} = N_k$

2.5 Similarities in diet between all nests

I wanted to analyze how the seven nests were related in terms of the goshawks' diet. Quantitative and qualitative similarities in diet between the seven nests, independent of location, were therefore analyzed by two cluster analyses. A cluster analysis sorts different objects into groups in a way that the degree of association between two objects is maximal if they belong to the same group and minimal otherwise (Statsoft Inc. 2006). The quantitative analysis revealed clustering pattern of nests with regard to presence of forest species vs. farmland species in the diet. The distance ranges from 0 % to 100 % where low distance means high diet similarity and vice versa (Krebs 1999). The prey species were divided into "forest species" (i.e. species most common in forest landscapes; Appendix 1), "farmland species" (i.e. species found in farmland habitats or species simultaneously using both farmland and forest habitats; Appendix 1) or "absent".

The qualitative cluster analysis identified the similarity of diets between the nests with regard to presence or absence of all of the identified prey species. The cluster was calculated using Jaccard's coefficient (measures similarity), which is a measurement of asymmetric information on these binary variables. Jaccard's coefficient ranges from 0 % to 100 %, where 100 % would mean that nests have identical diet. Clustering was done with the un-weighted pair-group method (UPGMA; Romesburg 1984), and prey species were selected as variables and the nests were selected as cases. The results from the cluster analyses were displayed in dendrograms. The branching pattern of the dendrogram illustrates the similarity in diet between the various nests. The statistical software used for the cluster analyses was Multi-Variate Statistical Package Version 3.13n (Kovach Computing Services 2006).

2.6 Differences in diet between Akershus and Buskerud

I wanted to investigate if there were any differences in diet between Akershus and Buskerud. The data were not normally distributed, consequently only non-parametric tests were employed in the prey-difference analyses (Siegel & Castellan 1988, StatSoft, Inc. 2006). To analyze differences in the goshawks' preference of each species between Akershus and Buskerud I used the Mann-Whitney U-test. The prey species were tested separately although the sample size was extremely small and even zero for many species. The species were also grouped into larger groups of thrushes, grouse, "farmland corvids", and jays and their abundances tested with the Mann-Whitney U-test. Jays were grouped separately from "farmland corvids" because they constituted a large proportion of the total number of prey and because they were classified as a forest species (FO; Appendix 1) unlike " farmland corvids" which were classified as farmland species (FA; Appendix 1) and include hooded crow (*Corvus corone cornix*), magpie (*Pica pica*), Jackdaws (*Corvus monedula*), and raven (*Corvus corax*).

Further I investigated whether there were differences in prey species composition between Akershus and Buskerud by using the chi-square test. However, this test does not allow any sample size to be < 5 so I had to group the prey species in more general groups. In the first analysis I grouped all species into "corvids", "jays", "thrushes" or "other prey items" to achieve sample sizes of 5 or above. In the second analysis, I grouped the species into "forest species" or "farmland species" as in the cluster analysis described above. This analysis would discover if there was a difference among the goshawks with regard to presence of forest species versus farmland species in their diets. Lastly, the prey items were grouped into four weight classes from the species mean weight and tested for differences between Akershus and Buskerud. The weight categories were < 70 g, 70-200 g, 201-400 g, and > 400 g. Weight estimates for the prey species found in this study were based on published information (references are given in Appendix 1).

2.7 Relationships between land cover and diet

I examined the relationship between the goshawk's diet and land cover surrounding the nests using Spearman rank correlation analysis (Siegel & Castellan 1988). I chose to correlate number of prey species/groups in the diet with the proportion of farmland within the home range. The maps were obtained from the Norwegian Institute of Land Inventory (NIJOS 2006), and made ready for printing using ArcView 3.3 (ESRI 2002). I chose not to use the proportion of forest because farmland was easier delineated on the maps. Circles were made around the nests with a radius of 2 km (~13 km^2) reflecting their approximate home range. I chose a 2 km radius due to a general rule that goshawks do not breed closer than approximately 5 km from each other (Grønlien 2004). The proportion of farmland was estimated with the help of a grid system placed over the map. The proportion of farmland varied between the home ranges, mainly as a function of the study areas. In Akershus approximately 1/3 of the land cover was farmland, whereas in Buskerud the proportion was less than 1 % (Table 1).

I chose to run the correlation analyses on prey identified from video recordings and prey identified from remains separately at first. Then the data from the prey remains were added to the data from the video recording, and analyzed again with the same procedure. This made it possible to study the effects of large versus small sample sizes in determining the statistical outcome of the study. The grouping of prey items was done as described in Table 2. Spearman rank correlations were performed with the statistical software JMP 4.0.0 (SAS Institute Inc. 2000). All statistical analyses had a significance level set at $\alpha = 0.05$.

Table 2. Summary of all methods and grouping of prey items to analyze goshawk diet in this study. Data retrieved from prey remains were only used in the Spearman rank correlation analysis.

Method	Grouping
Simpson's Reciprocal Index	All species separately.
Morisita's index	Jays, farmland corvids*, fieldfares (*Turdus pilaris*), forest thrushes, wood pigeons (*Columba palumbus*), tree pipits (*Anthus trivialis*), great spotted woodpeckers (*Dendrocopos major*), grouse, and red squirrels.
Cluster analyses	1) Forest species, farmland species, or absent. 2) Species present or absent.
Mann-Whitney U-test	1) All species separately. 2) Thrushes, grouse, farmland corvids*, and jays.
Chi-square test	1) Jays, farmland corvids*, thrushes, and other prey. 2) Forest species or farmland species. 3) Weight classes: < 70 g, 70-200 g, 201-400 g, > 400 g.
Spearman rank correlation	1) Video recording: thrushes, jays, farmland corvids* and other prey items. 2) Prey remains: thrushes, jays, farmland corvids*, grouse and pigeons. 3) Video recording/prey remains: thrushes, farmland corvids*, jays, grouse.

*Hooded crow, magpie, jackdaw and raven.

3. RESULTS

3.1 Identification from video recording and prey remains

A total of 146 prey items were registered from the video recording of the seven nests. The collection of prey remains from six nesting areas resulted in 144 identified prey items. Birds accounted for 95.2% of the items from the video recording and 97.2% from the prey remains, and mammals accounted for 4.8 % and 2.1 %, respectively.

From the video recordings, 89 of 146 prey items (61.0 %) delivered to the nests were identified to species level, 55 (37.7 %) to genus, whereas five (3.4 %) were unidentifiable. Thrushes and corvids were numerically the most important species groups in the goshawks' diets (Fig. 2). Thrushes accounted for 54.1 % of the prey items (50.0 % in Akershus and 62.0 % in Buskerud), and corvids 26.7 % (37.1 % in Akershus and 18.3 % in Buskerud). Within the group of thrushes, redwing (*Turdus iliacus*) and song thrush (*Turdus philomelos*) accounted for 25.3 % of the prey species in total (23.0 % in Akershus and 29.6 % in Buskerud). These two species were difficult to tell apart and were therefore identified as "redwing/song thrush". Identified to the species level, jays were dominant and accounted for 12.3 % of the prey items (16.0 % in Akershus and 9.9 % in Buskerud).

From the prey remains we could identify 143 items to species level and one to genus. As the largest group, thrushes accounted for 37.8 % of the identified prey. Corvids accounted for 21.7 % and were thus the second largest group of identified prey. The dominant prey species was wood pigeon (21.7 %; Fig. 1).

3.2 Dietary diversity and overlap between Akershus and Buskerud

Only the identified prey species from the video recordings were used in the calculations of diet diversity and overlap (16 species in total). The Simpson's reciprocal index gave the values 6.7 for Akershus and 10.0 for Buskerud. Diet diversity in Buskerud was higher than the diversity in Akershus. Dietary overlap between Akershus and Buskerud as two separate areas, indicated a high dietary overlap between the two study areas (93 %; Morisita's index).

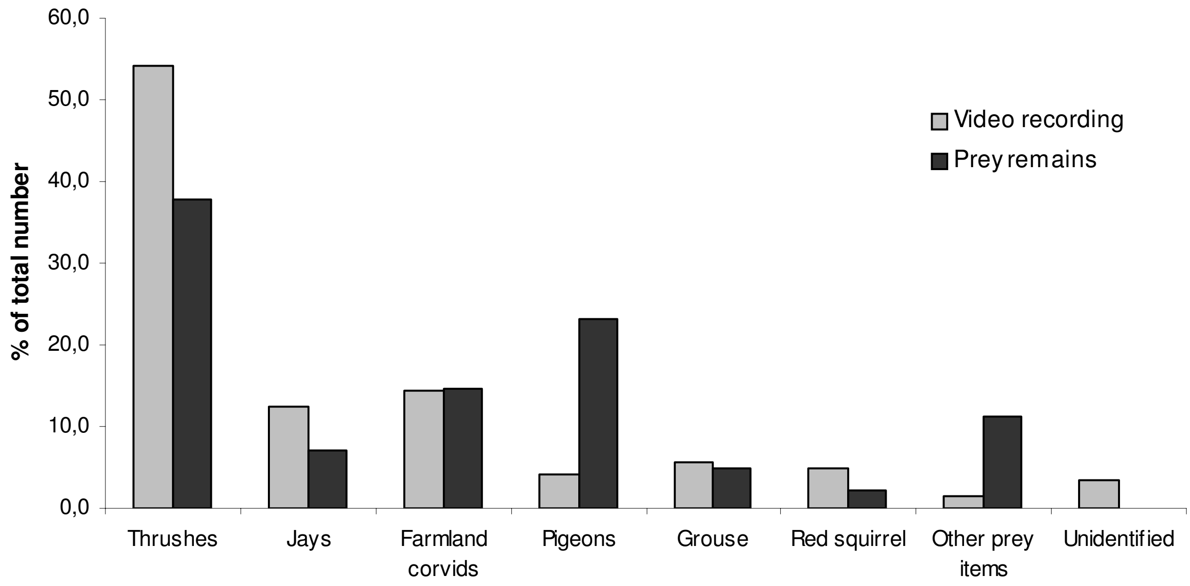

Figure 1. The proportion of different prey groups identified from video recordings and prey remains for all seven goshawk nests in Akershus and Buskerud.

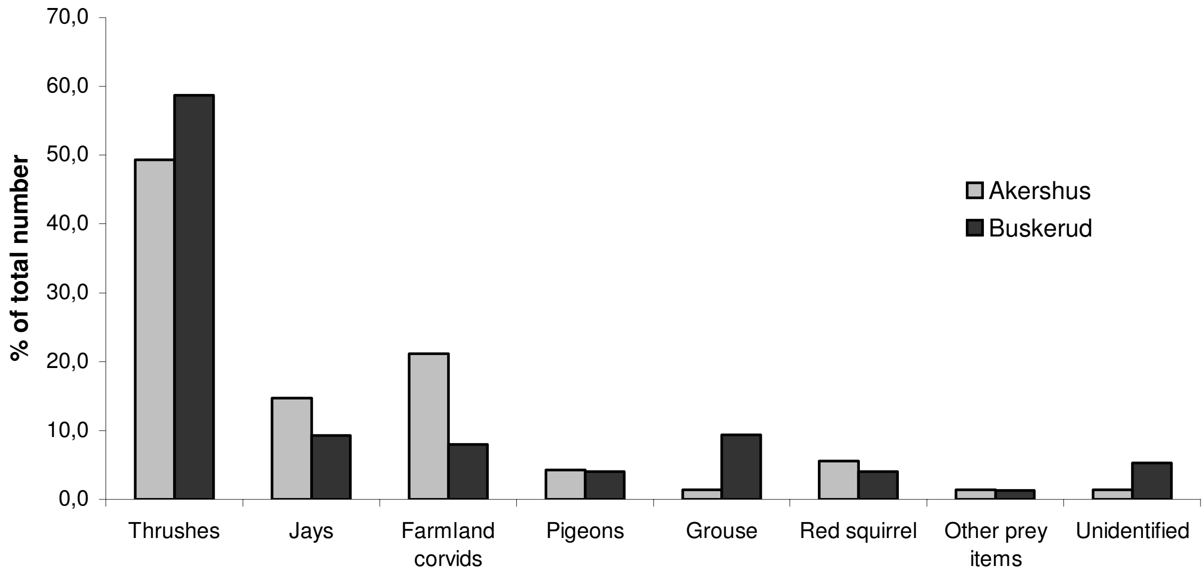

Figure 2. The proportion of different prey groups delivered to seven goshawk nests in Akershus and Buskerud, based on video recording.

3.3 Similarities in diet between all nests

The cluster analyses indicated that there were two groups of nests that showed similar diet composition. Buskerud 6, Buskerud 7, and Akershus 2 were in one group, and Buskerud 5, Akershus1, Akershus 3 and Akershus 4 were in another group (Fig. 3a and b). However, none of the nests had any apparent dietary overlap with one another (Average Distance and Jaccard's Coefficient), and there was no apparent relationship between overlap measures and the location of the nests. The qualitative cluster analysis (Average Distance; Fig. 3a) showed greatest dietary overlap at 56 % (short distance) and occurred between nest one and three in Akershus. The lowest overlap was at 94 % (great distance) and included a total of 12 combinations from both areas (3 Akershus-Akershus; 7 Akershus-Buskerud; 2 Buskerud-Buskerud). The prey species were also analyzed qualitatively (Jaccard's Coefficient; Fig. 3b), and this analysis also showed very little overlap between the nests. The greatest dietary overlap (similarity) was again between nest one and three in Akershus (57 %). The lowest overlap was also the same 12 combinations from both areas (30 %), but diets between the nests were more similar in this analysis than in the quantitative analysis.

3.4 Differences in diets between Akershus and Buskerud

I tested whether there was a difference in number of prey species identified from video recording between Akershus and Buskerud separately using the Mann-Whitney U-test, and found no significant difference between any species. The species were also grouped together (thrushes, grouse, corvids (including jays), jays, and "farmland corvids"). The five groups of prey in Akershus did not differ from that in Buskerud (Table 3). I also compared the relative

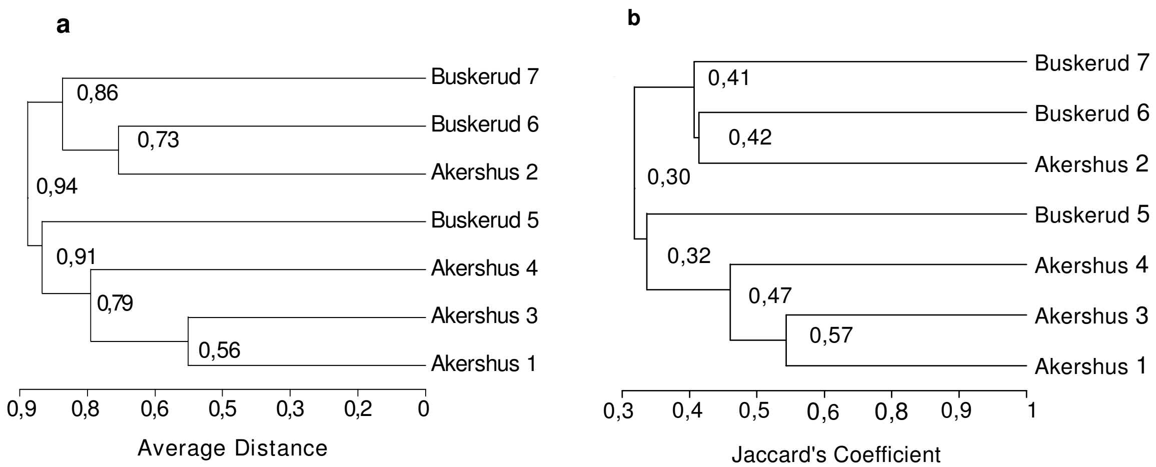

Figure 3. Dendrograms from cluster analyses showing the dietary relationships among the seven goshawk nests in Akershus and Buskerud. Levels of similarity were calculated by using Average Distance (a) and Jaccard's Coefficient (b). The exact order of the cases along the vertical axis is not significant.

abundance of the prey groups which includes thrushes, jays, “farmland corvids” (including hooded crow, magpie, jackdaw and raven), and other prey in diets between Akershus and Buskerud simultaneously (Fig. 2). The difference was significant (χ^2 = 7.95, *DF* = 3, *P* = 0.047). Also when I grouped the prey into forest species and farmland species (Fig. 4) there was a difference between Akershus and Buskerud (χ^2 = 4.61, *DF* = 1, *P* = 0.032). I assigned the identified prey to weight categories and found that there was no significant difference in the distribution of prey in weight categories between the two areas (χ^2 = 1.14, *DF* = 3, *P* = 0.768; Table 4).

Table 3. Results of Mann-Whitney U-tests on differences in the occurrence of different prey species in the goshawks’ diets in farmland dominated area of Akershus (four nests) and forest dominated area in Buskerud (three nests), based on video recording.

Species group	No. of prey, Akershus	No. of prey, Buskerud	*U*	*P*
Thrushes	35	44	3.5	0.368
Grouse	1	7	2.5	0.172
Corvids (all)	26	13	3.5	0.354
Jays	11	7	5.5	0.856
Farmland corvids	15	6	4.0	0.471

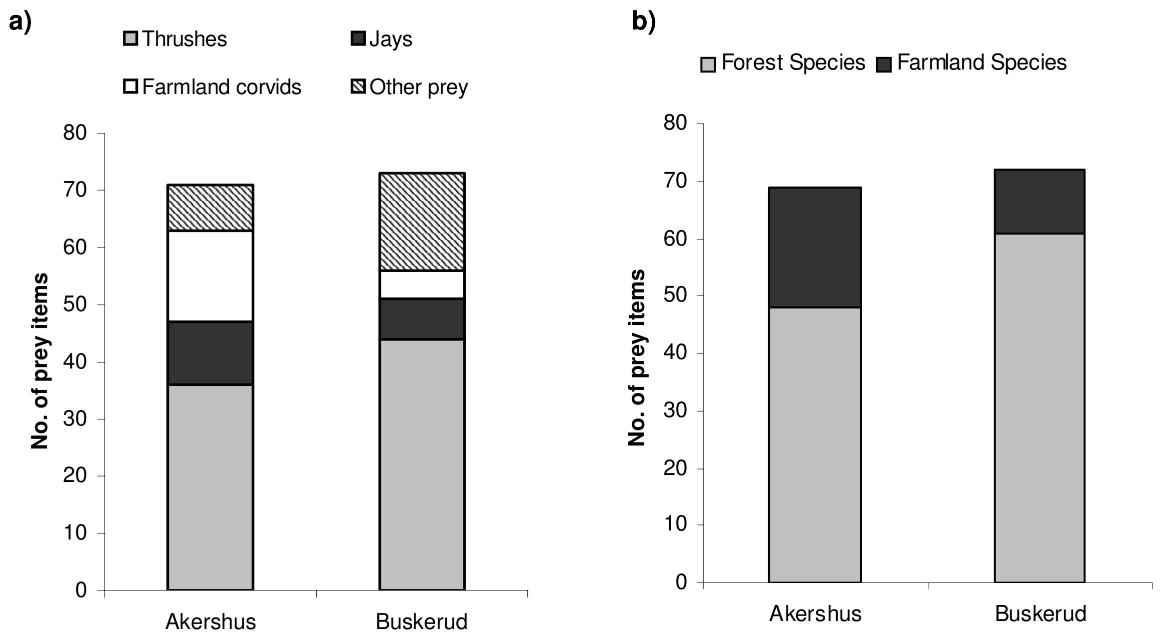

Figure 4. Number of prey items, identified from video recording of seven goshawk nests in Akershus and Buskerud. The prey items are grouped into thrushes, jays, “farmland corvids” and other prey (a) and farmland and forest species (b). For classification, see Appendix 1.

Table 4. Number and percent of total biomass of goshawk diet categorized into four different prey weight categories.

	Akershus		Buskerud	
Weight category	n	% of total biomass	n	% of total biomass
< 70 g	18	8.2	22	5.3
70-200 g	29	24.2	30	11.2
201-400 g	8	15.4	5	4.7
>400 g	15	52.2	14	78.9

3.5 Relationships between land cover and diet

None of the prey groups in diet identified from video recordings (thrushes, jays, "farmland corvids" and other prey items) showed any significant relationship with the proportion of farmland within the home ranges (Fig. 5; Table 5). The number of grouse identified from prey remains showed a significant negative relationship with the proportion of farmland (r_s = -0.89, P = 0.017; Fig. 5; Table 5). The rest of the prey groups from the remains (thrushes, jays, "farmland corvids", pigeons, and other prey items) were not significantly related to the proportion of farmland (Fig. 5; Table 5). The registered prey items from the video recordings and prey remains were finally pooled and correlated with the proportion of farmland (Fig 6). Diet that consisted of thrushes, jays and pigeons did not show a significant relationship with proportion of farmland, whereas "farmland corvids" showed a significant positive relationship (r_s = 0.89, P = 0.017) and grouse a negative relationship (r_s = -0.96, P = 0.003; Fig. 6; Table 5).

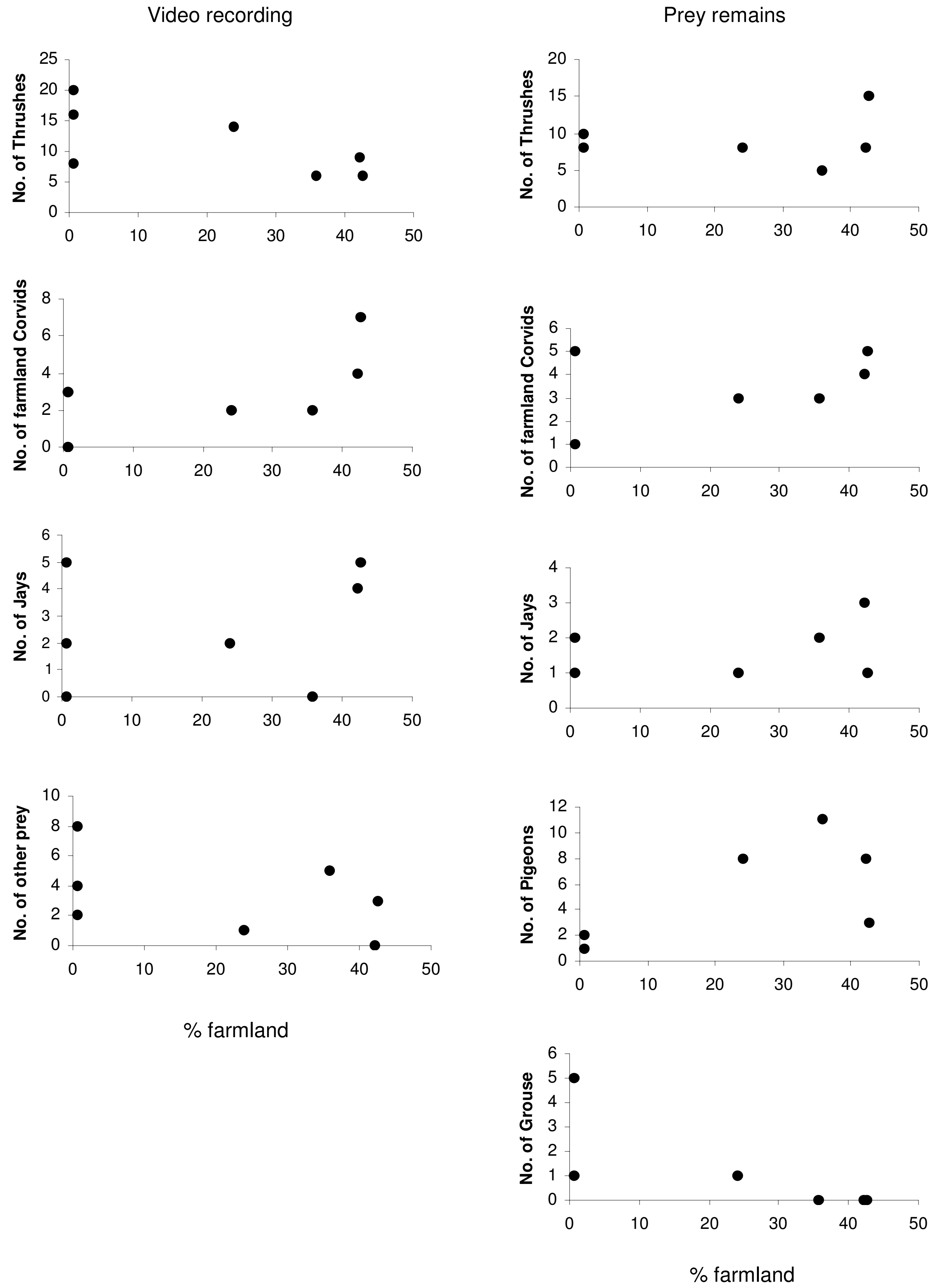

Figure 5. The relationship between the number of items of different prey species/groups identified from video recording (7 nests) and from prey remains (6 nests), and the proportion of farmland within 2 km from each goshawk nest.

Pooled data from video recording and prey remains

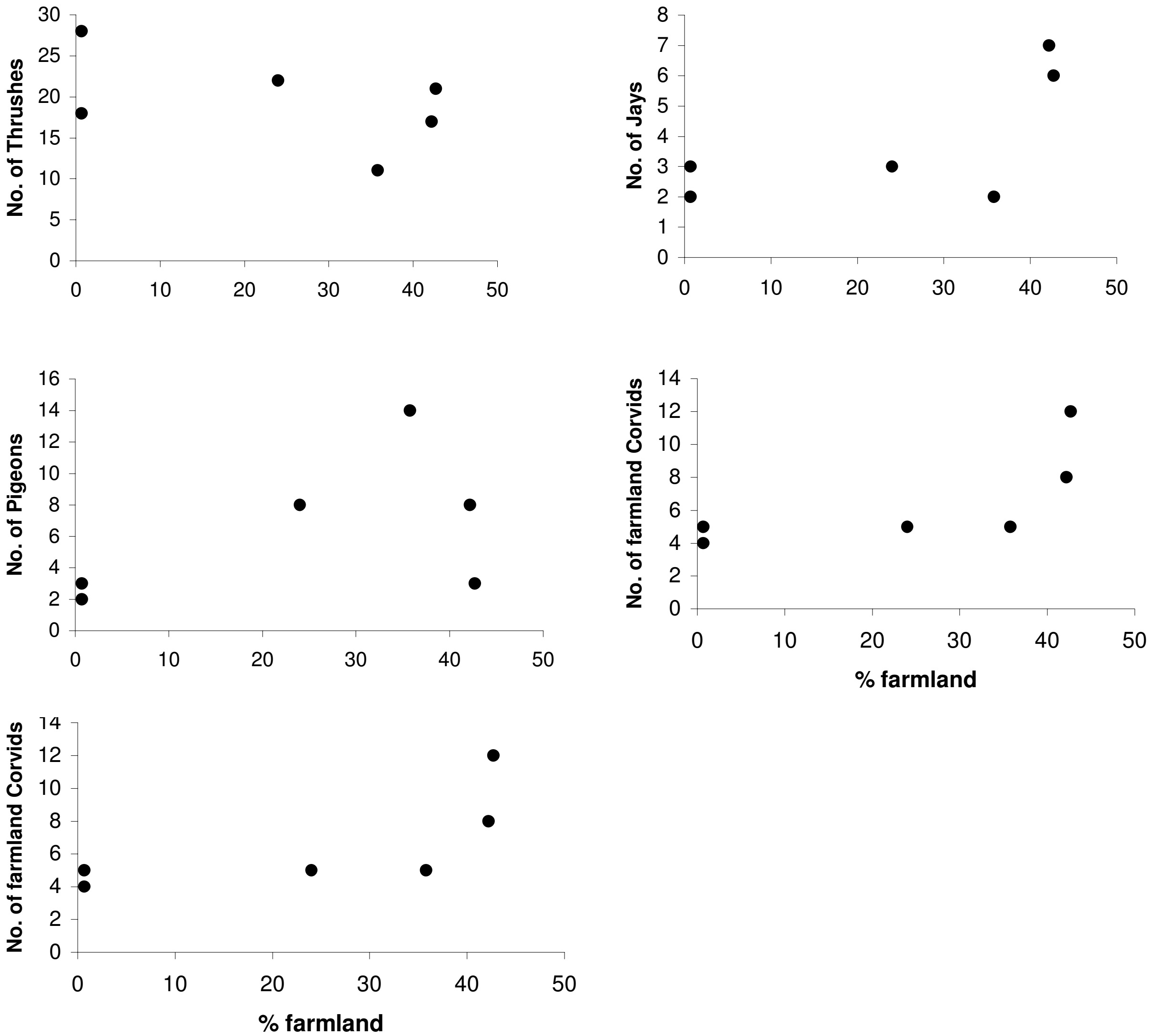

Figure 6. Number of different prey groups identified in diet with pooled data from video recordings (7 nests) and prey remains (6 nests) in relation to the proportion of farmland within 2 km from each goshawk nest.

Table 5. The results from Spearman rank correlations where the number of individuals of different prey species/groups was correlated with the proportion of farmland within a 2 km radius from each goshawk nest. The r_s denote the Spearman rank-order correlation coefficient. Bolded *P*-values denote significant relationships.

Method	No. of prey	Prey species/group	No. of nests	r_s	*P*
Video recording	79	Thrushes	7	-0,67	0,097
	18	Jays		0,31	0,506
	21	Farmland corvids*		0,59	0,160
	23	Other prey items		-0,37	0,413
Prey remains	54	Thrushes	6	0,15	0,771
	10	Jays		0,14	0,790
	21	Farmland corvids*		0,40	0,428
	33	Grouse		-0,89	**0,017**
	7	Pigeons		0,53	0,280
	19	Other prey items		0,65	0,165
Video recording and prey remains	117	Thrushes	6	-0,41	0,425
	23	Jays		0,63	0,183
	39	Farmland corvids*		0,89	**0,017**
	15	Grouse		-0,96	**0,003**
	38	Pigeons		0,40	0,428
	41	Other prey items		-0,39	0,439

*Hooded crow, magpie, jackdaw, and raven.

4. DISCUSSION

4.1 Limitations and Biases

Technical limitations

The results of this study need to be interpreted cautiously because of the biases associated with the small sample size (Bissonette 1999). The findings in my study derived from seven nests and over one breeding season only. Therefore there is a larger chance that individual variations among the goshawk parents may have caused slightly different results than with more nests to investigate. Several factors affect the parents hunting success and consequently diet, e.g. foraging skills, time of day, weather conditions, geographical location, habitat and the quality of the home ranges, abundance and availability of prey, hunting techniques, number of prey deliveries, size of prey, the parents' total presence time in the nest, and time spent hunting. The importance of each of these factors varies, but nevertheless they act and interact to shape the composition of the diet (Grundel & Dahlsten 1991, Lemon 1993, Smart *et al*. 2000, Garcia & Arroyo 2005).

All methods for quantifying diet have limitations (e.g. Selås 1989b), even video recording, despite its many recommendations (e.g. Lewis *et al*. 2004b). First we could only observe what was delivered to the nests. Items consumed away from the nest would not be registered (Sonerud 1992). This did not affect the diet of the nestlings, but may affect which prey were delivered to the nest by the parents. Second, we had some difficulties in interpreting the recordings. A typical situation was when the parents blocked the view and the prey was consumed before we got a chance to identify it. Prey were often decapitated and plucked when they were delivered to the nest and this made identification even harder, especially early in the nestling period (Selås 1989b). Smaller items were more difficult to identify to species, and items not identified to species level were grouped into more general categories. Appropriate image quality was essential to identify prey items and this was dependent on good light conditions, which varied throughout the day.

It is impossible to find remains from absolutely all prey delivered to the nest or plucking perches. Large remains (e.g. wood pigeon) and birds with conspicuous or bright feathers (e.g. jays) are more conspicuous for the observer than small remains, and some prey do not even leave remains. This typically results in overestimation of large prey and consequently an underestimation of small prey (Selås 1989b, Rutz 2003, Lewis *et al.* 2004a).

Ecological biases

Some limitations apply regardless of method (video recording or prey remains). For example, female goshawks are distinctly larger than male goshawks, and due to this large size difference one could expect divergence in the diets of the two sexes (Reynolds 1972). As the female basically stay in or nearby the nest, prey delivered to the nest may only reflect prey choice of the male, especially in the first period of the breeding season (Newton 1979, Selås 1989b), which increases the small sample size problem (Bissonette 1999). Toyne (1998), however, found that there was no difference between male and female prey choice late in the breeding season when both parents hunt.

Prey delivered to the nests may not be representative for the actual diet during the breeding season (Newton & Marquiss 1982). If the distance to the nest is large, due to the load-size effect, small prey may not be worth carrying to the nest if the energetic cost is higher than the energy gained from the prey (Stephen & Krebs 1986, Sonerud 1992). Thus, the parent has to maximize the rate of delivery of prey to the nestlings (Krebs & Davies 1993). The parents will most likely consume the small prey their selves and this would lead to an overestimation of larger prey (Sonerud 1992). If this is the case, prey groups like small passerine birds will be underestimated. Prey may also be too heavy for transportation over long distances, and therefore plucked, or consumed at capture site.

Variation in age among the goshawks may explain variation in diets. Rutz *et al.* (2006) found that diet composition changed significantly within individuals as they got older and that the proportion of feral pigeons in the diet of breeding goshawks increased with male age. Age-dependent diet choice in breeding goshawks can be explained first of all by improvements in hunting abilities with age, and hawks may become more able to target and catch maneuverable prey (Rutz *et al.* 2006). My study was a short-term observational study, and obviously it cannot provide a strong basis for estimating goshawk's diet in similar areas. Numbers and availability of prey do affect the goshawk's diet, and fluctuations in the availability of prey species might have influenced the prey composition the year of my study. However, this kind of observational study may be a valuable first step in the formulation of ecologically interesting hypotheses about goshawks diet in relation to land cover (Bissonette 1999).

4.2 Diet composition

Video recordings of goshawk diet showed a high dependence on thrushes and corvids in all nests. Thrushes were the absolute dominant prey group both in Akershus and Buskerud, with redwing and song thrush appearing to be the most important species in terms of number delivered. Corvids were second in terms of number delivered, and together thrushes and corvids constituted approximately 80 % of all prey. In contrast, the total proportions of grouse and pigeons were low (6 % and 3 %, respectively) compared to several studies made in northern Europe (e.g. Lindén & Wikman 1983, Tornberg 1997, Toyne 1998).

Diet depends on physiographic context

The high proportions of thrushes and corvids, and the low number of grouse and pigeons are not in accordance with earlier studies on goshawk breeding diet in the forests of Fennoscandia. Many studies on goshawk diet in Fennoscandia have emphasized the importance of grouse as main food supply also during the breeding season (south-boreal forest in Finland; Lindén & Wikman 1983, boreal forests of central Sweden; Widén 1987, boreal forests of Finland; Tornberg 1997). These studies indicate quite clearly that goshawks do not prefer small prey species and that prey groups like thrushes, corvids and wood pigeons are complementary prey rather than main prey.

Apart from studies in boreal forests, studies of goshawk diet in "warmer" vegetation zones and physiographic settings in Fennoscandia report a dominance of other prey items. These areas are more frequently under agricultural land uses than boreal forest areas in the interior and further north. For example, Selås (1989a) found that thrushes was the absolute dominating prey group (32 % of total) in a coniferous forest dominated area located in the boreo-nemoral zone of southern Norway. Grønnesby and Nygård (2000) also found that thrushes were the dominant group in two home ranges with different proportions of farmland (2 % and 44 % farmland) in the middle- and southern-boreal zone in Trondheimsfjorden in central Norway. They also found a low proportion of large prey like grouse in both home ranges.

An evident pattern is that the prey registered in the different studies reflects the location of the study areas. Further south in the temperate zone of central Europe where goshawks occur in urban landscapes, pigeons, corvids, and thrushes dominate their diets (e.g. Opdam *et al.* 1977, Rutz 2003, Toyne 1998). The large span of diets reported in various studies call upon an explicit description of the kind of habitat and vegetation zone where the study was conducted, and makes any extrapolation and generalization of goshawk diet to the entire Fennoscandian population doubtful.

Grouse in goshawk diet

Many recent studies suggest that the proportion of grouse in the goshawks' diet has decreased during the last 50 years (Tornberg 1997, Tornberg *et al*. 1999), and most researchers agree that this is caused by the decrease of grouse populations since the 1960s (Lindén & Rajala 1981). This could explain the low proportion of grouse in my study in contrast to earlier studies. Tornberg (1997) suggested that the decrease in grouse numbers could have resulted in a dietary shift to alternative prey species during the breeding season in modern time. For example, some studies have indicated that goshawks hunt corvids to a larger extent today than earlier, and that they may have been able to compensate for the loss of grouse by switching to alternate prey found near human settlements (Tornberg & Sulkava 1991). This could mean that the large proportion of small-sized birds like thrushes in the goshawks' diets was due to a low occurrence of more preferred prey like grouse, as also reported by Selås (1989a) and Grønnesby & Nygård (2000). This view has received increased support in North America, where goshawks have the ability to switch to alternative prey species when densities of their main prey species are reduced (Doyle & Smith 1994).

Another explanation for the low proportion of grouse in my study versus earlier studies could be the different methods used to obtain data. My findings and the findings of Grønnesby and Nygård (2000) were retrieved from video recording, and as discussed earlier, this method does not have the same problem with underestimating small prey like thrushes as identification from prey remains does. Consequently, studies from other parts of Fennoscandia which have identified prey through prey remains might therefore have overestimated the proportion of grouse and underestimated the proportion of thrushes.

Grouse is undoubtedly an important part of the goshawk's diet where grouse is available. Their importance, however, may also fluctuate during the season. Lindén & Wikman (1983), Widén (1987), and Tornberg (1997) reported high proportions of grouse in goshawk diets prior to hatching of their young and a marked decrease in the proportion during June when the diet becomes more diverse as the goshawks turn to other species like migratory birds, and especially young corvids. This could also explain the low proportion of grouse found in my study and in the study of Grønnesby and Nygård (2000), where video recording was carried out only during the nestling period in June.

4.3 Summary of analyses

My two study areas differed by means of dominant land cover and vegetation zones. Based on the above discussions, one would expect the goshawk diets to differ accordingly. I investigated diet diversity and overlap between Akershus and Buskerud, prey similarity among all nests, diet differences between Akershus and Buskerud, and diet in relation to land cover among all home ranges. Several methods were employed and the results may seem contradictory at first glance. However, inclusion of several tests made it possible to discuss goshawk diet in relation to its ecology to a deeper extent than would be possible from a limited set of tests. This approach also made it possible to overcome and reveal weaknesses in the analytical methods (such as sample size and large influence of certain prey groups).

The tests and indices can be categorized into two main groups: dependent on nest location (Akershus or Buskerud), and independent of nest location (Table 7). Whereas the U-tests and Morisita's index indicated no difference between diets in Akershus and Buskerud, the chi-square tests revealed a significant difference between the two locations for prey group composition and forest versus farmland species. Simpson's reciprocal index showed higher prey diversity in Buskerud than in Akershus. Independent of location (Akershus or Buskerud), correlation analyses revealed a positive association between proportion of farmland in the home range and the "farmland corvids", and a negative association towards grouse. For none of the analyses did the nests cluster according to their location.

I have chosen to rely mostly on the chi-square and correlation analyses for examining diet differences between the two landscape types. Chi-square tests made it possible to analyze groups simultaneously and not separately like the U-test. Chi-square tests are probably more ecologically relevant than the U-tests because diet should be treated as an entity by which the composition is more interesting. Although taxonomic resolution increased by testing the species separately this lead to an extremely low sample size and low statistical power. This difference in perspective may thus have caused the difference in the outcome and I therefore chose to disregard the U-test. Apart from "pure" diet analyses, the correlation analyses of diet in relation to farmland cover are perhaps more applicable to managers because they allow a visualization of goshawk diet in relation to land cover. Morisita's index indicated high dietary overlap between Akershus and Buskerud (93 %). However, this could be a result of the high abundance of thrushes and corvids in the diets in both areas, as also found by Garcia & Arroyo (2005) and Smithers *et al*. (2005).

The cluster analyses categorized the nests into two distinct groups, but not "correctly" by means of their true geographic locations. However, the nests that were in the "wrong" clusters (Akershus 2, Buskerud 5; Fig. 3) were the two with the most and the least forest covers in Akershus and Buskerud, respectively. Akershus 2 had a lot of forest and was clustered with Buskerud 6 and 7, which were the nests with the least human influence in Buskerud. Buskerud 5 clustered with Akershus 1, 3, and 4. Buskerud 5 had the highest human influence of the Buskerud nests. From the home range border there was only three km to the nearest town, and two km to a large contiguous farmland area. It was the only home range in Buskerud with infrastructure and human settlement. Even though the findings from the cluster analyses are not completely similar to the chi-square tests and the correlation analyses, they have a plausible explanation, and may act as auxiliary explanations of the differences in diets between Akershus and Buskerud.

4.4 Differences in diet between Akershus and Buskerud

Kenward and Widén (1989) argue that the preferred prey within a physiographic region may not be the most important ones elsewhere. There are four properties of a prey that explains the goshawk's diet (Tornberg 1997): 1) the weight of the prey, 2) the population density of the prey, 3) a combination of density and weight (biomass in the field), and 4) the proportion of the prey by weight in the diet (importance). Goshawks may for example consume more mammals than birds in some areas due to their availability and sizes relative to those of local birds (Widén 1987, Doyle & Smith 1994).

I found that both the relative abundances of prey groups and the relative proportions of forest and farmland prey species in the diets differed significantly between goshawks in Akershus and Buskerud. The proportion of "farmland corvids" was more than twice as high in Akershus than in Buskerud, and probably was the single most important factor in creating the difference in prey group compositions. Although the numbers of grouse were low in both areas, it is important to point out that the proportion of grouse in Buskerud was almost seven times higher than in Akershus. Grouse constituted the greatest proportion of "other prey items" in the analysis, and probably the species that caused the observed diet difference for the group "other prey", which was evidently higher in Buskerud (Fig. 4a). This is in accordance with the study of Grønnesby and Nygård (2000), who found the proportion of grouse to be larger in the home range with only 2 % farmland, and the proportion of corvids to be larger in the home range with 44 % farmland.

A high proportion of pigeons was expected in both areas, but few pigeons were registered from the video recordings. Tornberg (1997) found that the proportion of wood pigeons in the diet peaked in July. This may explain the low numbers of pigeons registered in the video recordings from June in my study. On the other hand, a high proportion of pigeons was registered from the prey remains (22 %), and more pigeons were found in Akershus (mean number = 7 per nest) than in Buskerud (mean number = 1.5 per nest). An explanation for this difference could be that especially wood pigeons feed on newly sown cereal seeds on open fields early in the spring and therefore are more vulnerable to goshawk attacks in areas like Akershus.

4.5 Relationships between land cover and diet

The correlation analyses made it possible to get an indication of the cause of the differences in diet compositions (both prey groups and forest versus farmland species). Data from prey remains revealed a significant negative relationship between grouse and the proportion of farmland in the home ranges (Fig. 5). Further, the pooled data from the video recordings and the prey remains revealed a significant positive relationship between "farmland corvids" and farmland. Again, it also showed a significant negative relationship between proportion of grouse in diet and farmland (Fig. 6). These findings are especially reasonable when compared to the results from the chi-square tests, in that "farmland corvids" and grouse (the dominant species in the group "other prey") were the principal drivers of dietary differences between Akershus and Buskerud. The analyses with pooled data showed the strongest evidence that there was a difference in the goshawks diet between the forest-dominated home ranges and the farmland-dominated home ranges. To pool the data from the video recordings and the prey remains, however, is not unproblematic. The identified prey from the prey remains covered only six nests, four in Akershus and two in Buskerud. Therefore, there was a higher likelihood that individual variations (e.g. hunting technique) may have affected the results from Buskerud more strongly than Akershus.

The findings are supported by Toyne (1998) who investigated the relationship between forest patch size and goshawk diet. He found that goshawks caught more squirrels in small patches, and concluded that there was a relationship between forest size and diet. Grouse, including capercaillie, black grouse, and hazel grouse, are found in continuous forests in Fennoscandia (Swenson & Angelstam 1993, Svensson *et al*. 2004). Their ecology supports the negative trend between grouse found in the goshawks' diets and proportion of farmland, and therefore the result was not surprising. Hooded crows, magpies and jackdaws are typical farmland and urban birds (e.g. Svensson *et al.* 2004), so the positive trends indicated by the correlation analyses were also expected. Consequently, these results are in accordance with my hypotheses and suggest that goshawks take advantage of the prey species available in their home range.

Jays were analyzed as a separate group and their number from both video recording and prey remains showed no relationship to the proportion of farmland in the home ranges (Fig. 5). This could be owing to the fact that jays nest in all kinds of forests and parks (Svensson *et al*. 2004) so that they are abundant no matter what kind of land cover that dominates the goshawk home range. The equal number of jays in the goshawks diets in Akershus and Buskerud may be explained by jay density. The boreo-nemoral forests in Akershus are more productive and contain more deciduous trees than the forests in Buskerud, and this might result in a higher density of jays per forest area in Akershus.

4.6 Implications for defining diet and habitat in the breeding season

The goshawk is a widely distributed species radiated into several subspecies, and therefore likely to adapt to local conditions. Clearly, generalizations about their habitats in Fennoscandia are likely as doubtful as those for their diets, when considering the wide range of habitat conditions in which goshawks live.

My study supports the view that goshawks are more adaptable to alternative habitat and alternative prey species than previously thought (e.g. Tornberg 2000). There are potential advantages for goshawks to breed in such landscapes because of predictable food sources. For example, grain fields are sources of food that can attract many bird species (wood pigeons, feral pigeons (*Columba livia 'domestica'*), hooded crows, magpies, jackdaws, starlings (*Sturnus vulgaris*)), and therefore make high concentrations of several species of prey available in one area, whereas in the forest the food sources are scattered and so are the prey species. Studies in productive areas in England and southern Sweden have registered high goshawk densities in areas with small and scattered, but old woodlands, which imply a high availability of both woodland edges and prey (Kenward 1982, Kenward & Widén 1989). The studies emphasized the value of woodland edges for hunting hares, pheasants (*Phasianus colchicus*), and wood pigeons which all may feed in open land, but close to the forest for refuge.

5. CONCLUSION

From the video recordings of seven goshawk nests in two areas in south-eastern Norway I found that thrushes were the absolute dominant prey group and corvids constituted the second largest group in both study areas. Diets in Buskerud were more diverse than diets in Akershus. On the other hand, the two areas had high dietary overlap, presumably due to the high proportions of thrushes and corvids in both areas. I found a significant dietary difference between Akershus and Buskerud with respect to prey group composition and farmland species versus forest species, where the group "farmland corvids" was the most important factor. The number of "farmland corvids" and grouse in the diets were the only groups showing a positive significant relationship and a negative significant relationship, respectively, to proportion of farmland within the goshawk home ranges. These findings suggest that so-called alternative prey like thrushes and corvids are important food sources for goshawks in the nestling period, also in forest-dominated areas in Buskerud. The analyses also indicate that, despite the large proportion of thrushes, goshawk diet reflects the habitat within its home range. Consequently, there is a dietary difference between goshawks in forest- and farmland-dominated areas. It is important to have a broad perspective on goshawk diet, and to think of goshawks in Fennoscandia as raptors whose main prey may be other species than grouse in areas where there is little or no grouse. Goshawk conservation should therefore also focus on human influenced areas, such as productive lowland agricultural areas, as potential goshawk habitat.

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Appendix 1. Number of goshawk prey items identified from video recording and from prey remains. Mean weight and the associated habitat type for each prey are presented. Forest species (FO) include species mainly associated with forest habitats, and farmland species (FA) include species associated with farmland, and both farmland and forest (Berg 2002).

			Number of prey items													
			Video recording							Prey remains						
Prey species	Mean weight (g)	Habitat type	1	2	3	4	5	6	7	1	2	3	4	5	6
Hooded crow *Corvus corone cornix*	500[1]	FA[6]	7	-	3	2	1	-	2	1	-	-	-	-	4
Common raven *Corvus corax*	1254[1]	FA[7]	-	-	-	-	-	-	1	-	-	-	-	-	-
Black-billed magpie *Pica pica*	213[1]	FA[6]		2	1		1			4	2	4	3	1	1
Jackdaw *Corvus monedula*	235[1]	FA[6]	-	-	-	-	-	-	-	-	1	-	-	-	-
Magpie/Jackdaw *Pica pica/Corvus monedula*		FA[6]	-	-	-	-	1	-	-	-	-	-	-	-	-
Eurasian jay *Garrulus glandarius*	161[1]	FO[6]	5		4	2	-	2	5	1	2	3	1	2	1
Blackbird *Turdus merula*	95[2]	FO[6]	1	1	4	2	2	6	-	3	4	2	4	4	4
Song thrush *Turdus philomelos*	74[2]	FO[6]	-	2	-	-	-	3	3	1	-	-	1	2	1
Redwing *Turdus iliacus*	63[2]	FO[6]	-	-	1	-	-	1	-	2	-	-	1	-	-
Mistle thrush *Turdus viscovorus*	119[2]	FO[5]	-	-	-	-	1	-	-	-	-	-	-	-	1
Fieldfare *Turdus pilaris*	105[2]	FA[6]	-	-	-	3	1	-	-	9	1	6	2	3	2
Blackbird/Fieldfare *Turdu merula/pilaris*			-	-	-	2	-	-	-	-	-	-	-	-	-
Redwing/Song thrush *Turdus iliacus/philomelos*		FO[6]	5	3	3	5	3	5	13	-	-	-	-	1	-
Thrushes *Turdus* spp.			-	-	1	2	1	5	-	-	-	-	-	-	-
Starling *Sturnus vulgaris*	70[3]	FA[6]	-	-	-	-	-	-	-	1	1	-	-	-	-
Wood pigeon *Columba palumbus*	495[5]	FA[6]	-	3	-	-	1	1	1	3	10	7	8	2	1
Feral pigeon *Columba livia domestica*	302[1]	FA[7]	-	-	-	-	-	-	-	-	1	1	-	-	-
Sky lark *Alauda arvensis*	37[2]	FA[6]	-	-	-	-	-	-	-	-	-	1	-	-	-
Chaffinch *Fringilla Coelebs*	24[3]	FO[6]	-	-	-	-	-	-	-	-	-	2	-	-	-
Wood nuthatch *Sitta europaea*	24[5]	FO[6]	-	-	-	-	-	-	-	-	-	-	1	-	-
Tree pipit *Anthus trivialis*	23[2]	FO[6]	-	-	-	1	-	-	-	-	-	-	1	-	-
Great spotted woodpecker *Dendrocopos major*	90[5]	FO[6]	-	-	-	-	1	-	-	-	1	1	-	2	-
Black woodpecker *Drycopus martius*	380[1]	FO[7]	-	-	-	-	-	-	-	-	-	-	1	-	-
Capercaillie *Tetrao urogallus*	1985[5]	FO[7]	-	-	-	-	2	1	-	-	-	-	1	2	-
Black grouse *Tetrao tetrix*	925[5]	FO[7]	-	-	-	-	-	1	-	-	-	-	-	2	1
Tetraonids *Tetraonid* spp.		FO[7]	-	-	-	-	-	3	-	-	-	-	-	-	-
Hazel grouse *Bonasa bonasia*	372[5]	FO[7]	-	1	-	-	-	-	-	-	-	-	-	1	-
Grey heron *Ardea cinerea*	1547[4]	FO[7]	-	-	-	-	-	-	-	-	-	-	1	-	-
Mallard *Anas platyrhynchos*	1029[4]	FO[7]	-	-	-	-	-	-	-	1	-	-	-	-	-
Domestic duck *Anas* spp.		FA	-	-	-	-	-	-	-	-	1	-	-	-	-
Red squirrel *Sciurus vulgaris*	300[5]	FO[8]	3	1	-	-	-	2	1	1	-	1	1	-	-
Mountain hare *Lepus timidus*	3350[5]	FO[9]	-	-	-	-	-	-	-	-	-	-	-	-	1
Total			21	13	17	19	15	30	26	27	24	28	26	22	17
Total no. of species			5	6	5	6	9	8	7	11	10	10	13	10	10

[1]Cramp 1985, [2]Cramp 1988, [3]Cramp & Perrins 1994, [4]Cramp & Simmons 1977, [5]Selås 2001, [6]Berg 2002, [7]Svensson *et al*. 2004, [8]Andren & Delin 1994, [9]Bjärvall & Ullström 1997.