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Goshawk diet during the nestling period in farmland and forest-dominated areas in southern Norway

Hilde Marie Johansen, Vidar Selås*, Kristine Fagerland, Jon Trygve Johnsen, Bjørn-Arild Sveen, Luis Tapia & Ronny Steen

H. M. Johansen: Department of Ecology and Natural Resource Management, The Norwegian University of Life Sciences, P.O. Box 5003, NO-1432 Ås, Norway
V. Selås: Department of Ecology and Natural Resource Management, The Norwegian University of Life Sciences, P.O. Box 5003, NO-1432 Ås, Norway. vidar.selas@umb.no (Corresponding author)*
K. Fagerland: Department of Ecology and Natural Resource Management, The Norwegian University of Life Sciences, P.O. Box 5003, NO-1432 Ås, Norway
J. T. Johnsen: Department of Ecology and Natural Resource Management, The Norwegian University of Life Sciences, P.O. Box 5003, NO-1432 Ås, Norway
B.-A. Sveen: Department of Ecology and Natural Resource Management, The Norwegian University of Life Sciences, P.O. Box 5003, NO-1432 Ås, Norway
L. Tapia: Department of Ecology and Natural Resource Management, The Norwegian University of Life Sciences, P.O. Box 5003, NO-1432 Ås, Norway
R. Steen: Department of Ecology and Natural Resource Management, The Norwegian University of Life Sciences, P.O. Box 5003, NO-1432 Ås, Norway

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During the past decades, goshawk (*Accipiter gentilis*) populations have declined in forest-dominated landscapes in Norway. To reveal the importance of different prey species in forest versus farmland landscapes, we video recorded 146 prey deliveries at four nests in a farmland-dominated area and three nests in a forest-dominated area in south-eastern Norway in June 2005. Thrushes and corvids were the dominating prey in both areas. We found higher diet diversity in the forest-dominated landscape, but we also found high dietary overlap, presumably due to the dominance of thrushes in both areas. Prey composition of forest versus farmland species differed significantly between the areas, mainly due to a higher proportion of corvids and a lower proportion of grouse in the farmland-dominated area. Goshawk diet thus reflects the habitats within the nesting territory.

1. Introduction

The Goshawk (*Accipiter gentilis*) is a common and widely distributed raptor species throughout the northern hemisphere (Del Hoyo *et al.* 1994). In boreal parts of its range, the Goshawk is associated with mature forest, and is considered dependent on this habitat especially for nesting sites and hunting areas (Widén 1989, Penteriani 2002, Squires & Kennedy 2006). During the past decades, Goshawk populations have declined throughout most of their northern ranges, possibly because of the

Table 1. Information about the Goshawk nests in Akershus (A1–A4) and Buskerud (B5–B7), South Norway, where prey delivery was investigated by use of video recording in June 2005. Approximately hatching date for each of the two recording days is based on estimated nestling age (days) at recording no. 1.

Nest number	Brood size	Hatching date	Nestling age		Total no. of prey
			rec. 1	rec. 2	
A1	4	17 May	18	33	21
A2	4	24 May	10	32	13
A3	3	01 June	7	26	17
A4	3	26 May	14	25	21
B5	2	25 May	20	31	15
B6	3	26 May	16	32	30
B7	4	30 May	17	30	29

negative effect of intensive forestry on hunting habitats and prey populations (Widén 1997, Tornberg et al. 2006). Recent Goshawk population estimates for Norway and Sweden indicate 2–4 pairs per 100 km^2 of forested area (Bergo 1992, Widén 1997, Grønlien 2004).

In Northern Europe, Goshawk diet consists mainly of avian prey like grouse, thrushes, corvids and pigeons, but also mammals like Red Squirrels (*Sciurus vulgaris*) and lagomorphs (e.g. Kenward *et al*. 1981, Widén 1987, Tornberg 1997). The diet depends on abundance, distribution and accessibility of the prey (Salafsky *et al.* 2005, Rutz *et al.* 2006), which at a local scale are influenced by landscape structures (e.g. Saunders *et al.* 1991, Andrén 1994). In Fennoscandia, where most studies have been conducted in boreal forests, grouse seem to be the preferred prey throughout the year, including the breeding season (Lindén & Wikman 1983, Widén 1987, Tornberg 1997).

In western and central Europe, Goshawks have successfully adapted to breed and hunt in small woods and parks in farmland and urban landscapes, where pigeons and corvids are important prey (Rutz *et al.* 2006). Also in Fennoscandia, such habitats may now be more important for the Goshawk population than in the past, because of marked declines in grouse densities in continuously forested landscapes (Lindén & Rajala 1981, Tornberg *et al.* 1999), where much of the original multi-layered forests have been converted to even-aged stands (Widén 1997). However, even moderate levels of persecution, which still occurs in Norway (Selås 1997), may prevent Goshawks from utilising habitats in close proximity to humans (Rutz *et al.* 2006). It is therefore important to investigate Goshawk use of farmland and urban landscapes also in Fennoscandia.

The main aim of our study was to document the breeding diet of Goshawks in two study areas in south-eastern Norway, one dominated by middle-boreal coniferous forest and one by farmland. We expected that the diet would differ between the two areas, being dominated by forest-dwelling species like grouse and Red Squirrel in the former, and by typical farmland species, such as corvids and pigeons (Berg 2002), in the latter.

2. Methods

The study was conducted in June 2005. Two study areas, one in Akershus County and one in Buskerud County, were chosen to reflect a difference in land cover and degree of humanization. In Akershus, we selected nests with high proportions of farmland in the surrounding landscape, whereas in Buskerud, the criterion for nest selection was that there should be minor areas of farmland within a radius of 2 km from the Goshawk nest. We selected four nests in each county, but one of the nests in Buskerud failed early in the recording period, and was omitted from the analyses.

The study area in Akershus (59°45'–59°55'N; 9°35'–10°13'E) is situated in the boreo-nemoral zone and is dominated by farmland that alternates with wooded ridges. Grain fields dominate the farmlands, but grazing lands are also common.

Other landscape elements include urban areas, villages, garden fields, parks, and lowland bogs. The forests are characterized by high timber production. The main forestry practice involves clear-cutting and planting, and a mixture of young and mature forests is common. Norway Spruce (*Picea abies*) is the most important tree species, but older clear-cuts are often dominated by Birch (*Betula pubescens*). Other common forest tree species are Scots Pine (*Pinus sylvestris*), Aspen (*Populus tremula*) and Pedunculate Oak (*Quercus robur*).

The study area in Buskerud County (59°45'–59°55'N; 9°35'–10°13'E) is a part of the middle-boreal zone, but some areas may be classified as boreal forest. Most areas have medium or low timber production. 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*). Modern forestry has converted 50% of the area to even-aged stands less than 50 years old. Birch and Aspen are common on open sites following logging. Lakes, ponds and bogs are scattered features within the home ranges of the studied Goshawks.

Goshawk diet was studied by 336 hours of video recording (Table 1). Each nest was recorded for two days, each lasting from 06.00 a.m. (ca. 2 hours after sunrise) to 06.00 p.m. (ca. 4.5 hours before sunset), a time period which should be expected to capture a large part of the prey deliveries during that day (Reif & Tornberg 2006). We used an external wired lens (50×45×45 mm, 18LED night vision colours water-resistant CCTV camera) connected with a modified RCA cable (approximately 100 m) to a digital camcorder (Canon MV700i). The lens was attached to a branch in the nestling tree, approximately 1–1.5 m from the nest. The camcorder was placed in a tent approximately 50 m away from the nesting site. Inside the tent, an observer changed tapes (Panasonic miniDV cassettes which constitute 120 min in long play mode) every two hours. The lens and the camcorder were powered with a 12 V lead battery (151×65×112 mm, 10 Ah). The batteries lasted for 12–24 hours, and were recharged with a MC charger, 500mA (12V).

To identify the prey, we viewed the tapes by connecting the camcorder to a 32-inch colour TV (Grundig ST84-794 TOP). Each prey was identified to the lowest taxonomic level possible, based on morphological features such as size, colour and texture of feathers or fur, bill, feet and bone size. The Goshawks completely or partially plucked and often parted their prey before delivering them, thus some of the prey items were unidentifiable. Unidentifiable prey were categorized into a more general category of genus or family, but a few items could only be identified as avian prey of a given size.

For each study area, we evaluated prey diversity by calculating the Simpson's Reciprocal Index, which takes into account both species richness and evenness (Simpson 1949, Krebs 1999). To estimate dietary overlap between the two areas, we used the Morisita's Index, with values ranging between 0 (no overlap) and 1 (complete overlap; Morisita 1959, Krebs 1999). This index gives similarity scores nearly independent of sample size, which was advantageous for our study with low sample size. We used three groups of species and six species to calculate Morisita's index (Table 2).

Quantitative and qualitative similarities in diet between the seven nests were analysed by two cluster analyses. The quantitative analysis reveals the clustering pattern of nests with regard to preference of forest species vs. farmland species (Table 2). This cluster was calculated using average distance coefficients. The qualitative cluster analysis identified the similarity of diets between the nests with regard to "present" and "absent" of all of the identified prey species. This cluster was calculated using Jaccard's coefficient (0–100% similarity), which is a measurement of asymmetric information on these binary variables. Clustering was done with the un-weighted pair-group method (Romesburg 1984), and prey species were selected as variables and the nests were selected as cases. The statistical software used for this analysis was Multi-Variate Statistical Package Version 3.13n (Kovach Computing Services 2006).

We used Chi-square tests to examine differences in prey species composition between Akershus and Buskerud. In the first analysis we grouped all species into farmland corvids, Eurasian Jays (*Garrulus glandarius*), thrushes and other prey to achieve sample sizes of five or above. The Jay was grouped separately from other corvids because it was classified as a forest species. In the second analysis, we grouped the species into forest spe-

Table 2. Classification of prey species identified from video recording at four Goshawk nests in Akershus (A1–A4) and three nests in Buskerud (B5–B7), South Norway. Forest species (FO) are species found mainly in forests. Farmland species (FA) are species found in farmland habitats or species simultaneously using both farmland and forest habitats, but with highest densities in farmland-dominated landscapes. Indet. stands for indeterminable.

Prey species	Habitat type	Number of prey						
		A1	A2	A3	A4	B5	B6	B7
Hooded Crow *Corvus cornix*	FA	7	–	3	2	1	–	2
Common Raven *C. corax*	FA	–	–	–	–	–	–	1
Black–billed Magpie *Pica pica*	FA	–	2	1	1	1	–	–
Eurasian Jay *Garrulus glandarius*	FO	5	–	4	2	–	2	5
Blackbird *Turdus merula*	FO	1	1	4	2	2	6	–
Song Thrush *T. philomelos*	FO	–	2	–	–	–	3	3
Redwing *T. iliacus*	FO	–	–	1	–	–	1	–
Mistle Thrush *T. viscovorus*	FO	–	–	–	–	1	–	–
Fieldfare *T. pilaris*	FA	–	–	–	3	1	–	–
Redwing/Song Thrush	–	5	3	3	6	3	4	13
Blackbird/Fieldfare	–	–	–	–	2	–	–	–
Indet. thrushes	–	–	–	1	2	1	5	1
Tree Pipit *Anthus trivialis*	FO	–	–	–	1	–	–	–
Indet. small passerines	–	–	–	–	–	1	–	2
Great Spotted Woodpecker *Dendrocopos major*	FO	–	–	–	–	1	–	–
Wood Pigeon *Columba palumbus*	FA	–	2	–	–	1	1	1
Indet. pigeon *Columba* sp.		–	1	–	–	–	–	–
Capercaillie *Tetrao urogallus*	FO	–	–	–	–	2	1	–
Black Grouse *T. tetrix*	FO	–	–	–	–	–	1	–
Hazel Grouse *Bonasa bonasia*	FO	–	1	–	–	–	–	–
Indet. grouse	–	–	–	–	–	–	3	–
Indet. large bird (grouse or duck)	–	–	–	–	–	–	1	–
Red Squirrel *Sciurus vulgaris*	FO	3	1	–	–	–	2	1
Total		21	13	17	21	15	30	29

cies and farmland species. Lastly, the prey items were grouped into four weight classes based on the species mean weight, taken from Cramp & Simmons (1977), Cramp (1985, 1988), and Cramp & Perrins (1994). The weight classes included < 70 g, 70–200 g, 201–400 g, and > 400 g.

We examined the relationship between the Goshawk's diet and the proportion of farmland surrounding the nests using Spearman's rank correlation (Siegel & Castellan 1988). Circles were made around the nests with a radius of 2 km (mean nearest neighbour distance in both study areas was approximately 4 km). The proportion of farmland was calculated using a grid system on the map. We obtained maps from the Norwegian Institute of Land Inventory (NIJOS 2006), and used ArcView 3.3 (ESRI 2002) for map analysis. The Spearman rank correlations were performed with the statistical software JMP 4.0.0 (SAS Institute Inc. 2000).

3. Results

We documented 146 prey items, and identified 60% to species and 35% to genus (Table 2). Thrushes accounted for 50% of the prey items in Akershus and 59% in Buskerud, and corvids 38% in Akershus and 16% in Buskerud (Fig. 1). Redwing (*Turdus iliacus*) and Song Thrush (*T. philomelos*) accounted for at least 28% in Akershus and 36% in Buskerud. Jays accounted for 15% in Akershus and 9% in Buskerud. The prey diversity was higher in Buskerud (SRI = 10.02) than in Akershus (SRI = 6.68), but the dietary overlap be-

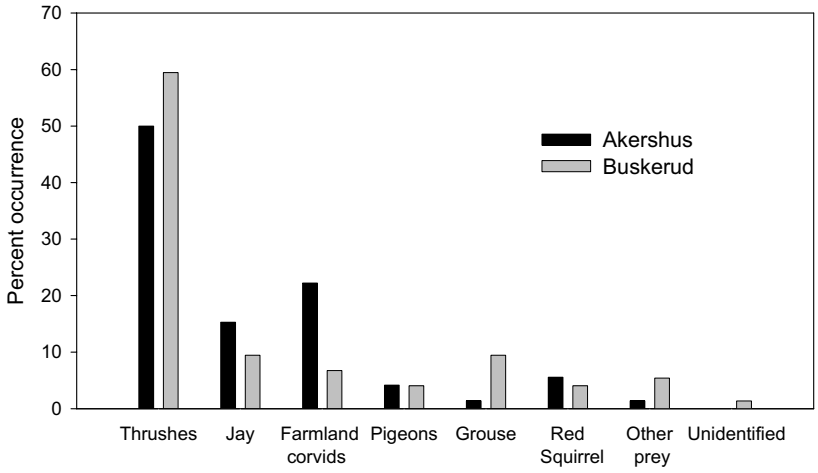

Fig. 1. Proportion of different prey groups identified from video recording at four Goshawk nests in Akershus County and three nests in Buskerud County, South Norway, 2005.

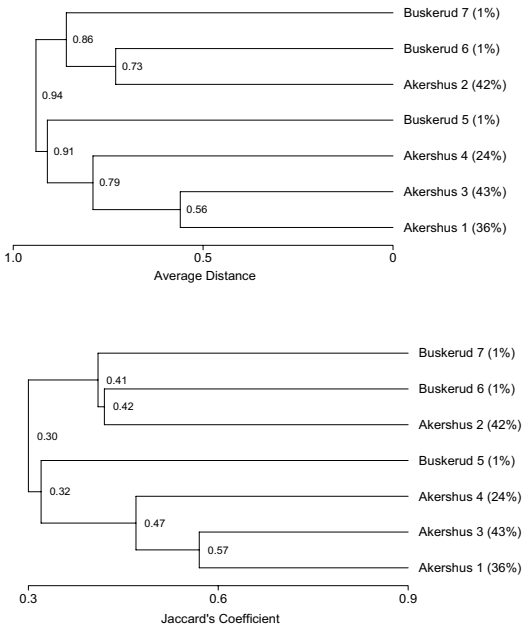

Fig. 2. Dendrograms from cluster analyses showing the dietary relationships among the seven Goshawk nests in Akershus and Buskerud, South Norway, 2005 (percentage of farmland within the home ranges in parentheses). Levels of similarity were calculated using Average Distance and Jaccard's Coefficient, and clustering was calculated by the Unweighted Pair Group Method with Arithmatic Mean (UPGMA) method. The exact order of the cases along the vertical axis is not significant.

tween the two areas was high (93%; Morisita's index).

The cluster analyses indicated that there were two groups of nests that showed similar diet composition, but there was no apparent relationship between these groups and nest location or proportion of farmland (Fig. 2). The quantitative cluster analysis (Average Distance; Fig. 2a) 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. The qualitative cluster analysis (Jaccard's coefficient; Fig. 2b) gave very similar results, but the differences between the nests were less than in the quantitative analysis.

There was a significant difference in the relative abundance of the prey groups thrushes, Jays, farmland corvids and other prey between Akershus and Buskerud ($\chi^2 = 7.95$, d.f. = 3, P = 0.047). The two areas also differed with regard to the proportion of forest and farmland prey species ($\chi^2 = 4.61$, d.f. = 1, P = 0.032), but not with regard to the proportion of different weight classes of prey ($\chi^2 = 1.14$, d.f. = 3, P = 0.768). The proportion of farmland corvids was positively related to the proportion of farmland within 2 km from the goshawk nest (Spearman $R_{ho} = 0.89$, P = 0.007; Fig. 3). For the other prey groups, there were no significant relationships with the proportion of farmland.

4. Discussion

Video recordings of Goshawk diet showed a high proportion of thrushes in all nesting territories. By use of time-lapse video monitoring, Grønnesby

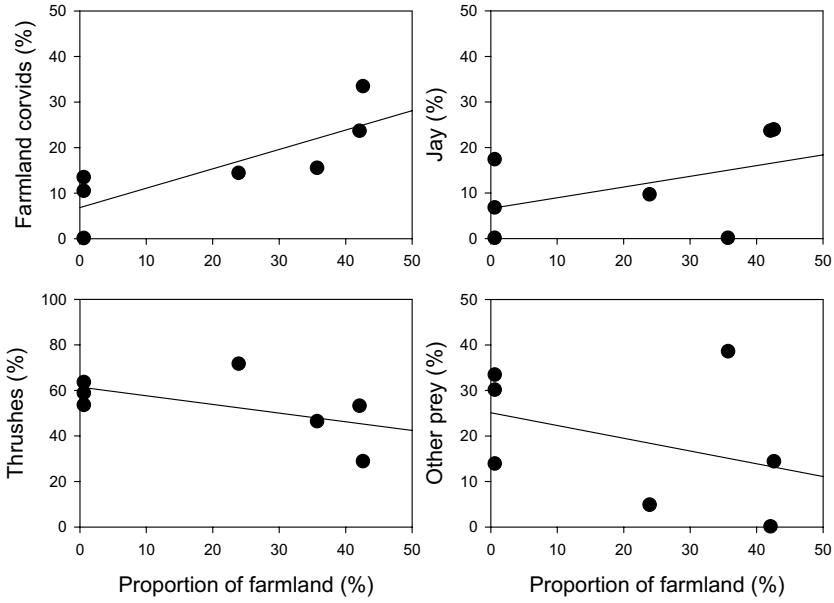

Fig. 3. Proportion of different prey groups among the total number of prey identified with video recordings at seven Goshawk nests in South Norway 2005, compared with the proportion of farmland within 2 km from each Goshawk nest.

and Nygård (2000) also found that thrushes were the dominant prey group in two Goshawk territories in central Norway. Several previous studies have reported a higher proportion of large prey (e.g. Lindén & Wikman 1983, Tornberg 1997, Toyne 1998), but this may be because small prey like thrushes are underrepresented in studies based on identification of prey remains (Rutz 2003, Lewis *et al.* 2004, Tornberg & Reif 2007). However, as we conducted all recordings in June, we may have missed changes in the relative importance of prey of different sizes over the season (see Tornberg 1997, Lewis *et al.* 2006). Furthermore, the long-term decline in grouse numbers may have contributed to a higher proportion of small prey in recent studies (c.f. Tornberg 1997, Tornberg *et al.* 1999).

We found the highest prey diversity in the forest-dominated area, but there also was a high dietary overlap, presumably because of the general importance of thrushes and corvids. Farmland corvids appeared to be the single most important factor in creating differences in prey group compositions between areas or home ranges with high or low proportions of farmland. Few pigeons were delivered, possibly because they are a less important prey item in June (Tornberg 1997). Furthermore, the proportion of grouse among prey was low in both study areas, but was almost seven times higher in the forest-dominated area. Grønnesby and Nygård (2000) also found the highest proportion of corvids and the lowest proportion of grouse among prey in the goshawk home range with most farmland.

Goshawk reproduction reflects variations in prey numbers (e.g. Salafsky *et al.* 2007), and several studies have suggested that the breeding success in Fennoscandia depends on the abundance of grouse (Linden & Wikman 1983, Widén 1987, Sulkava *et al*. 1994, Tornberg 1997). In our study, the mean number of nestlings was relatively high (e.g. Reynolds & Wight 1978), despite the low proportion of grouse delivered at the nests. Hence, at least in the nestling period, Goshawks seem to be able to compensate for low availability of grouse by hunting other prey, as also suggested by Tornberg and Sulkava (1991) and Tornberg (1997). It should be remembered, however, that the ratio of alternative prey numbers to Goshawk numbers will increase if Goshawk breeding densities decline in accordance with declines in grouse populations.

Although the Goshawk is better adapted for hunting large avian prey in forests than any sympatric raptor species, our study supports the view that Goshawks are adaptable to alternative habitats (e.g. Tornberg 2000, Kudo *et al*. 2005), such as woodland and woodland edges in farmland and ur-

ban areas. Here, high numbers of both farmland corvids and jays, which prefer dense spruce-dominated stands (Andrén 1990) commonly found in mixed farmland-forest landscapes, may offer a stable and predictable food source throughout the year. Studies in England and southern Sweden have registered high Goshawk densities in areas with small and scattered but old woodlands (Kenward 1982, Kenward & Widén 1989). Hence, as long as there are sufficient amounts of old woods for hunting and nesting, farmland landscapes may provide important habitats for Goshawks, and act as a buffer against the negative effect of forestry on goshawk populations in northern Europe.

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Kanahaukkojen ravinnonkäyttö pesäpoikasaikana Etelä-Norjan maatalousympäristöissä ja metsissä

Kanahaukkapopulaatiot ovat pienentyneet viimeisten vuosikymmenten aikana Norjan metsissä. Selvittääksemme metsä- ja maatalousympäristöissä pesivien yksilöiden eroja ravinnonkäytössä videoimme 146 saaliin tuonnin pesille kolmella metsäreviirillä ja neljällä maatalousympäristön reviirillä kesäkuussa 2005. Rastaat ja varislinnut muodostivat molemilla reviirityypeillä suurimman osan saaliseläimistä.

Metsäreviireillä saaliseläimet vaihtelivat enemmän kuin maatalousympäristössä, joskin molemmilla reviirityypeillä rastaiden osuus oli varsin suuri. Maatalousympäristössä sijainneilla reviireillä varislintujen suhteellinen osuus oli suurempi kuin metsäreviireillä. Metsäreviireillä taas kanalintujen osuus oli suurempi. Kahaukkojen ravinnonkäyttö kuvastaa reviirin laatua.

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