DIET AND PREY SELECTION OF BREEDING GOSHAWKS (*ACCIPITER GENTILIS*) IN EASTERN NORWAY

DIETT OG BYTTEDYRSELEKSJON HOS HEKKENDE HØNSEHAUK (*ACCIPITER GENTILIS*) I ØST-NORGE

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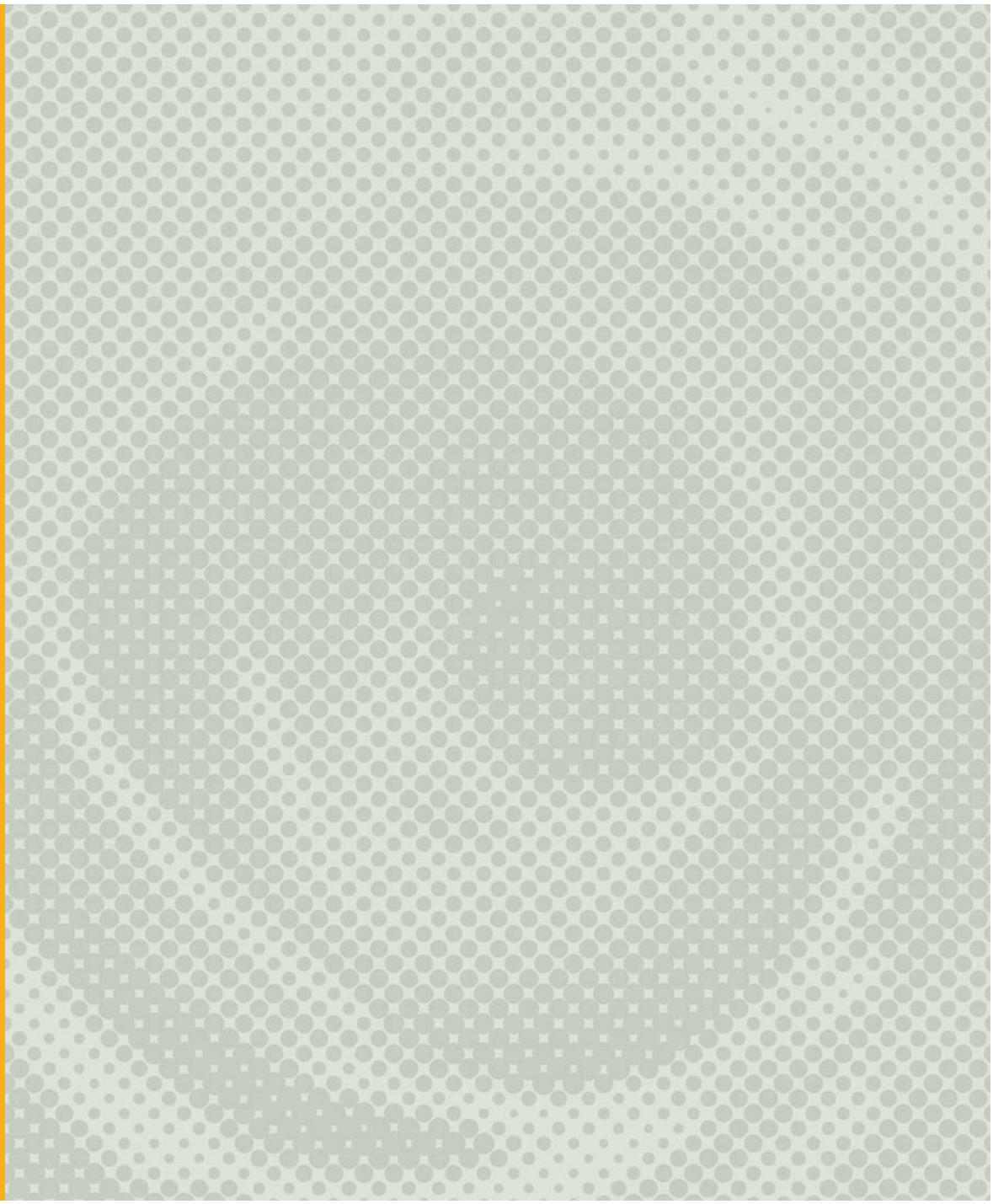

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Abstract

Diet and prey selection of a raptor is connected to the abundance and size of its prey. But prey selection is also influenced by handling time, the accessibility, and the prey's vulnerability to predation. Availability of its main prey is also important. In this study I revealed the diet of the goshawk (*Accipiter gentilis*) by video monitoring seven goshawk nests during the nestling period from eastern Norway 2005. I also estimated the numeric availability of avian prey within each goshawk home range by conducting bird surveys the same year. Applying the compositional analyse, avian prey preference were estimated. A total of 146 prey items were recorded, of which 95% were birds, and 5% red squirrel (*Sciurus vulgaris*). Among the avian prey, thrushes (*Turdus*) were most important considering the numeric proportion (55% of all prey), while corvids (*Corvidae*) were the most important prey group considering the biomass proportion (46%). The average body mass of all prey was 168g. The highest preferred prey group were corvids, and secondly the tetraonid species (*Tetraonidae*), but their mutual ranking was not statistically different. There was also a significant negative correlation between the species diversity and the proportion of corvids in the diet. The third most preferred prey group were thrushes, utilised more often than expected from their abundance within the home ranges of the goshawk. The next prey groups were as follows, with decreasing ranking: pigeons (*Columbidae*), other birds and small birds. All three groups were utilised less then expected. The three most preferred prey groups constituted bird species that had an average body mass similar to, or heavier than a redwing (*Turdus iliacus*). They also represent species that mainly inhabit the forest, and species that mainly forage on the forest floor. The three least preferred prey groups were mostly small bird species, or species that forage mostly in open land.

Sammendrag

Diett og byttedyrseleksjon hos en rovfugl er knyttet til mengden av byttet og byttets størrelse. Men byttedyrseleksjon er også avhenging av byttets håndteringstid, adgang til byttet og hvor utsatt det er for predasjon. Tilgjengelighet av dets hovedbytte er også avgjørende. I denne undersøkelsen har jeg sett på dietten til hønsehauken (*Accipiter gentilis*) ved å filme sju hønsehaukreir i ungeperioden. Jeg har også estimert den antallmessige tilgjenglighet av fugler innenfor haukens jaktområde ved å gjennomføre fugletakseringer det samme året. Byttedyrpreferanse ble beregnet ved å ta i bruk en metode beskrevet som "The compositional analyses". Total ble 146 byttedyr registrert, hvorav 95% var fugler, og 5% var ekorn (*Sciurus vulgaris*). Blant de byttedyr som var fugler, utgjorde troster (*Turdus*) den viktigste gruppen antallmessig (55% av det totalt antall byttedyr), mens kråkefugl (*Corvidae*) var den viktigste gruppen med hensyn på vekt (46%). Gjennomsnittlig vekt på et byttedyr var 168 g. Den mest prefererte gruppen av byttedyr var kråkefuglene. Deretter kom skogshønsefuglene (*Tetraonidae*), men deres innbyrdes rangering var ikke signifikant forskjellig. Det var også en signifikant negativ korrelasjon mellom artsdiversiteten og andelen kråkefugl i dietten. Den tredje mest prefererte gruppen av byttedyr var trostene, mer utnyttet som bytte enn forventet i forhold til tilgjengligheten av trost i jaktområdene til hønsehauken. De neste byttedyrgruppene var som følger, med synkende rangering: Duer (*Columbidae*), andre fugler og småfugl. Alle tre gruppene ble utnyttet mindre enn forventet. De tre mest preffererte byttedyrgruppene besto av fuglearter som var på størrelse med en rødvingetrost (*Turdus iliacus*) eller større. De representerer også arter som først og fremst er knyttet til skog, og arter som hovedsaklig søker næring på bakken i skog. De tre minst prefererte byttedyrgruppene var først og fremst små fugler, eller arter som er knyttet til åpent landskapet.

Table of contents

Introduction

The goshawk (*Accipiter gentilis*) is a medium-sized raptor with a large sex-dimorphism (Cramp and Simmons 1980). The mean weight of Swedish goshawks is 855 g for males, and 1374 g for females (Marcström et al. 1990). The nominate race, *Accipiter gentilis gentilis* is distributed over most of the Western Palaearctic, were it inhabits the forests (Cramp and Simmons 1980). It typically hunts in mature forests using a short-stay, perched technique (Kenward 1982, Widén 1989, Beier and Drennan 1997). In some regions, the goshawk prefers forest edges when foraging (Kenward 1982). It is adapted to hunt medium sized to large prey, and has a broad spectre of species in the diet, especially during the breeding season (Cramp and Simmons 1980, Widén 1987, Marcström et al. 1990). In Fennoscandia, avian prey is most important, but red squirrel (*Sciurus vulgaris*) and mountain hare (*Lepus timidus*) could also be important during the winter (Tornberg et al. 2006, and references therein). Goshawk populations in Fennoscandia have declined during the last decades (Tornberg et al. 2006), especially in Norway (Grønlien 2004) and the species is entered as vulnerable on the Norwegian red list (Kålås 2006). The forestry in Norway is therefore ordered to show consideration towards goshawk nests and not clear-cut forest stands close to the nests. Goshawk is also maybe the raptor that has been most extensively persecuted in the past, but also at present time (Cramp et al. 1980 and Grønlien 2004). However, goshawk management requires knowledge to the species´ diet and prey preference, i.e. which prey or group of prey is most important.

A raptor is likely to select prey that gives the highest net energy gain in relation to the costs of prey handling, and to maximize the number of offspring entering the breeding population (Krebs and Davies 1993). One of the main factors affecting the profitability of a prey is its abundance and size in relation to the predator (e.g. Linden and Wikman 1983, Tornberg et al. 2005). Prey abundance is linked to capture time since the chance that the prey and the predator come across increases with increasing abundance of the prey. Handling time is also important, i.e. capture time, preparation time, and ingestion time. The notion "available" is not only connected to their numerical abundance, but also their accessibility (Janes 1984, Widén 1994, Beier and Drennan 1997, Ontiveros et al. 2005), because prey could exist in a part of the environment, for example dense vegetation, that is difficult for the predator to access, or that alter the predators' ability to detect the prey. Prey vulnerability is another important factor, i.e. the prey's ability to escape, to hide, or defence it's self when first detected by a predator (e.g. Quinn and Cresswell 2004). The optimal diet theory predicts

that the predator should utilise the most profitable prey as long as it is abundant, but when densities goes below a certain threshold, it should switch over to alternative and less profitable prey (Krebs and Davies 1993). Since prey switching requires that appropriate alternative prey are present, the response by a predator to declining prey populations may vary both temporally and spatially.

The Goshawk is one of the most studied raptors in the world and several diet studies have been carried out to reveal the diet. Small game species seem to be important prey in most regions, and in Fennoscandia, grouse (*Galliformes*) are most important (Tornberg et al. 2006, and references therein). However, during the last decades, grouse populations have declined. Simultaneously, the proportion of grouse in the diet has decreased, while other groups, like corvids, thrushes and pigeons have become more important. A majority of the diet studies are based on collections of prey remains during the breeding season. The method is likely to underestimate some prey groups, and overestimate other (Rutz 2003, Lewis et al. 2004). Using a direct method is therefore to prefer (Lewis et al. 2004, Rogers et al. 2005). A general diet description should ideally be derived from a selection of nests that best reflect the average goshawk habitat in that region or part of the world (Aebischer et al. 1993). Few studies have applied video equipments to reveal the goshawk diet during the nestling period, and the only such study from Fennoscandia included only two nests (Grønnesby and Nygård).

However, a diet study alone does not necessarily reflect preference. To reveal prey preferences it is necessary to compare diet composition with prey availability within the home ranges. No studies have so fare examined prey selection by goshawk during the nestling period by combining results from diet studies based on video recording (a direct method) with a bird survey within the goshawks´ home ranges. Analysing preference also requires a proper statistic tool, and several methods have been composed. But all have some short comes, described by Aebischer et al. (1993). Simultaneously they showed how to overcome the short comes by applying the compositional analysis.

The aim of my study is: 1) To describe the goshawk diet during the nestling period with regard to both numeric proportion and proportion by weigh of different prey groups based on video monitoring. 2) Applying the compositional analysis, to test if the goshawks selected avian prey from the diet in proportion to the abundance of prey within the goshawk home ranges (opportunistic), or if they had some preferences (selective). I suppose that grouse species are the most important group of prey in the diet, and most preferred. I also suppose that small avian prey are less utilised, and least preferred.

Methods

Study area

The study area is situated in the eastern part of Norway with six nests located in the boreo-nemoral zone and one in the southern boreal zone (Moen 1999). Four nest localities are situated in Akershus County (59º 36´ - 59º 42´ N, 10º 39´ - 10º 52´ E), with three in Ås municipality and one in Frogn municipality. Further, three nest localities are in Buskerud county (59º 40´ - 59º 56´ N, 9º 41´ - 9º 48´ E), with one in Modum municipality and two in Øvre Eiker municipality. The three goshawk nests in Buskerud are located in typical forest-landscapes with norway spruce (*Picea abies*) and scots pine (*Pinus sylvestris*) as the dominant tree species covering most of the area. The nests in Akershus are in a typical agricultural-landscape, with a mixture of fields and forest, and some villages within the home ranges. The forests in Akershus are in general more productive, and the amount of deciduous forest is higher in Akershus compared to the home range areas in Buskerud. We selected four nests from a typical agricultural landscape, and three nests from a typical forest landscape to reflect the different habitat use by breeding goshawks from this region.

Mean January temperature is -6,7 ºC, and mean July temperature is 16,5 ºC in the Buskerud study area (Norwegian Meteorological Institute 2006). In Akershus the mean January and July temperature is -4,8 ºC and 16,1 ºC, respectively. Average annual precipitation is 880 and 785 mm for Buskerud and Akershus, respectively.
The study areas are affected, more or less, by modern forestry activities, with forest stands in different age classes from clear cuts to mature forest. The fieldwork took place during May and June 2005.

Bird surveys

In order to estimate the prey availability, a bird survey was conducted within each goshawk home range. The bird surveys were run twice for each locality, in two separate periods between 16 May and 16 June 2005, except for the Tierud locality that was visited only once, 23 May. The first survey was conducted between 16 May and the 4 June, and the second survey was conducted between 30 May and 16 June. The relative occurrence of the different species in the bird community around each nest was estimated using a point count method (Gregory et al. 2004).

A total of 20 fixed points were laid out on four lines going out from the nest, one line going eastwards, one going westwards, one southwards, and one line going northwards. Birds were counted at five points along each compass direction, with the first one starting 300 m from the nest, and the last one ending 1,5 km from the nest. This making a cross-shaped form of the appraisal route, with the goshawk nest in the middle. The bird survey then represents an estimate from a 5,1 km^2 of the goshawk home range. In one instant, a part of the route went into the sea, and the rout was than changed to follow the shoreline. Binoculars were used to help bird identification.

At each point, birds singing, warning or seen within a 50 m distance from the point, were recorded during a 7-min. period. Every observation was separated into two categories, heard or seen. Birds seen within 50 m from the observer, while walking between the points, were also recorded in an own category, but only observation of a few species in this category were included in the analyses. It was applied for bird species that rarely or never sing when the survey was conducted, and species that respond to humans by being silent and motionless, or leaving the area undetected. This was true for the following species: mallard (*Anas platyrhynchos*), common eider (*Somateria mollissima*), common goldeneye (*Bucephala cleangula*), red-breasted merganser (*Mergus serrator*), eurasian sparrowhawk (*Accipiter nisus*), northern goshawk, capercacaillie (*Tetrao urogallus*), black grouse (*Tetrao tetrix*), hazel grouse (*Bonasa bonasia*), black woodpecker (*Dryocopus martius*), Eurasian jay (*Garrulus glandarius*), hooded crow (*Corvus corone*), and common bullfinch (*Pyrrhula pyrrhula*).

The surveys were conducted by the same two field workers, each doing two lines at each locality, per day. Surveys usually began around 0500 and 0600 h. and were finished between 0800 and 1000 h. A total number of 74 bird species were recorded with 1661 individual observations (Appendix 1). Also two mammal species that are potential as prey, red squirrel and mountain hare, were observed during the survey. But these species were excluded from the analysis because of very few counts, and because of the difficulty comparing bird observations with observations of mammals.

To obtain an estimate of the relative occurrence of the different bird species within each goshawk locality, every observation (seen and heard) for all points were summed up for that locality. For each locality, two identical surveys were conducted (except from the Tierud locality) and data from these two days were also pooled together. Finally, observations from "between the points" were added to the material for those species it was relevant to (see above). The bird species were grouped into six categories for further analyses. The six groups

were: Tetraonids (*Tetraonidae*), Pigeons (*Columbidae*), Thrushes (*Turdina*), Corvids (*Corvidae*), Small birds, and Other birds. The definition "small birds" here is birds with average body mass less than redwing (*Turdus iliacus*), which was the smallest thrush occurring in the group "Thrushes" (63g). The relative occurrences were calculated by dividing the number of observations for each group by the total number of bird observations from that locality.

The video monitoring

The seven nests were video recorded in two periods between 1 June and 1 July, one recording sequence during the first half of the nestling-period, when the nestlings were between 6 and 23 days old, and one in the second half of the nestling-period when they were between 25 and 34 days old. Video monitoring was not conducted the first days after hatching because the goshawk could be vulnerable to human disturbance in this period. Each nest was usually filmed with duration of 12 hours per day, and 12 hours the following day for each period (sometimes spread over three days), making a total of about 48 hour filming for each nest. The total time of filming for all nests was 327 hours.

The nests were monitored with a separate lens mounted on a branch with a screw clamp in the nest tree, in distances from about 0,5 m to 1 m, which gave an image of the whole nest bowl from above. In one instance the lens was mounted on a stick that was placed on a branch from the neighbouring tree and over to a branch on the nest tree in a horizontal manner. And in two cases the lens was mounted in an adjacent tree. The lens used was a 18LED night vision colour CCTV camera, size: 50 X 45 X 45mm, water proof for outdoor use. Two wires were connected to the lens, one electric wire going to a battery underneath the nest tree, a 12 voltages lead battery (10 Ah), and the other, a signal wire, going to a tent/camouflage 50-100 m away from the nest tree.

The camera used for recording was a digital camcorder, a Canon MV700i. It was placed in the tent where the filming was conducted. The camera was connected to a separate battery (a 12 voltages lead battery (10 Ah) with a self-constructed voltage converter from 12 to 8.4 voltages). The battery was situated in the tent/camouflage. The battery life had a duration of 24 h before charging, and the lens battery had a duration of 36 h. The battery to the lens was disconnected during night. Usually the filming was performed with the observer in the tent throughout the whole recording, but sometimes the observer left the tent and nest area during recording, only visiting the tent for shifting cassette every 2nd hour. The cassettes used were some Pansonic miniDV cassettes, put in long play mode of 120 minutes. A total of

four lenses were used for monitoring the seven nests, making it necessary to move the equipment between some of the nests. For nests that were difficult climb, the lenses were kept mounted throughout both filming periods. The mounting were performed by a minimum of two persons, one climbing the tree with the help of climbing irons and/or climbing equipment, and the other controlling the lens installation by watching the screen image while positioning the lens.

The video analyses

The cassettes were played back on a colour TV. Sequences with prey deliveries were played over several times when necessary, and it was also possible to freeze the film to get a still image, or play it in slow motion. The purpose of this analysis was to determine each prey item to species, or to a higher taxonomic group when identification to species level was impossible. Many of the prey items were plucked before delivered to the nest, with few or no feathers left. Identification was then made by factors such as bill size, shape and colour compared to the adult or juvenile goshawks in the nest. Further, leg-size, shape, colour and the general prey size were estimated. Sometimes some body-feathers and wing-feathers were still left on the prey item, and helpful for the identification. To help prey identification, some stuffed birds were placed out on a table for comparison with the video. Also some plucked birds were available for comparison. A team of four to seven people were active in watching and analysing the cassettes, and every scene containing a prey delivery were discussed before the final prey identification was made. A total of 146 prey items were registered by the video recording.

Statistical analyses

In the analysis of prey selection, the compositional analysis was applied (Aebischer et al. 1993). This analyse combines the results from the bird survey, which gave an estimate of the relative occurrence of prey groups, and the results from the video recording, which gave an estimate of the utilisation. By combining these two estimates, it is possible to determine which group of prey was more preferred than other groups by the goshawk. This analysis uses nests as units instead of pooling nests together. The notion of “preference” is only valid on a relative scale since avoidance of one prey group will lead to an apparent preference for other groups. It is only useful when the prey groups are ranked in an order of “most preferred” to least preferred”. The first step in the analyses tests whether overall prey use differ from

random. The next step is to find where use deviates from random, and to rank the prey groups in order of preferences.

In the proportional prey-use and prey-availability for each nest, zero values were substituted with a small positive value since zero values are invalid in the log-ratio transformation. The substituted value was 0.001 for the available data and 0.01 for the use data, a value less then the smallest recorded nonzero proportion value. In three occasions, for the tetraonids category, both available proportion and use proportion contained zero value, and the group should ideally be excluded from the analysis. This would lead to a considerably loss of information, and therefore I assumed that hazel grouse were available in these three home ranges. Arguably because these areas had some amount of productive spruce forest within, and the hazel grouse distribution is mainly connected to this habitat type (Swenson 1994). Sveen (2006) also recorded an individual of capercacaillie as prey remains from one of the localities of concern.

The level of statistical significance was established to $P \leq 0.05$ for the analyses. Squirrels (n = 7) and unidentified birds (n = 3) were excluded from the test. The compositional analysis was conducted in Microsoft Office Excel 2003.
Correlations-test were also performed to see if there were any relationships between the number of goshawk fledglings and the proportion of the different prey groups in the diet, and between the total minimum number of species in the diet for each nest and the proportion of the different prey groups in the diet. I also tested for relationships between the total bird density and the density of corvids within each home range. The tests were run in MiniTab 14. Estimated prey weights are taken from Fagerland (2006).

Results

Diet from video monitoring

A total of 146 prey items were delivered to the seven nests during the video monitoring (Table 1), with a minimum of 16 species identified (Appendix 2). Avian prey was the largest prey group, and consisted 95.2% of the total number of prey items recorded (Table 1). The only mammal species recorded was red squirrel (4.8%). Among the avian prey, thrushes were the dominating prey by number, compromising 54.8% of all prey. Thrushes were recorded as prey from all nests, with proportions varying between 28.6% and 71.4% of the total number. Among the thrushes, the redwing and the song thrush (*Turdus philomelos*) were most numerous, compromising 32.2% of all prey. These two species were difficult to separate in the video analyses, and the majority were identified as redwing/song thrush. Blackbird (*Turdus merula*) was the second most common thrush (11.6%). Furthermore, four individuals of fieldfare (*Turdus pilaris*, 2.7%), and one individual of mistle thrush (*Turdus viscivorus*, 0.7%) were recorded. Two individuals were identified as either blackbird or fieldfare (1.4%), and 10 individuals were identified only to the genus *Turdus* (6.8%).

Corvids constituted 26.7% of the total number, making them the second largest group by number. Corvids were also recorded from all nests, varying between 6.7% and 57.1% in their proportion. Eurasian jay and hooded crow were the dominant prey species in this group, with 17 (11.6%) and 16 (10.0%) individuals, respectively. Further there were four individuals of common magpie (*Pica pica,* 2.7%), and one raven (0.7%). Also one individual was identified as common magpie or house crow (*Corvus monedula*). Tetraonids, the third most common prey category, constituted 5.5% with 8 individuals. Tetraonids were recorded from three of the nests, varying between 0% and 16.7% in their proportion, with three individuals of capercaillie, one hazel grouse, one black grouse, and three unidentified grouse. Among the tetraonid preys, 50% were juveniles. For the group “pigeons”, only one species, common wood pigeon (*Columba palumbus*) was identified, with five individuals (5.5%). Only one prey, a tree pipit (*Anthus trivialis*), was identified to species in the group “small birds”, with a total of three individuals in this group (2.1%). One individual of great spotted woodpecker (*Dendrocopos major*) constituted the group “other birds”. Three prey items could not be identified to any of the prey categories, and were set to the category “unidentified birds”. One

was a mallard or capercaillie female, one was about the size of a hooded crow, and one about the size of a common wood pigeon. Average delivery rate was 0.45 prey items per hour.

Table 1. The percentage by numbers of prey recorded by video monitoring of seven goshawk nests in the eastern part of Norway from 1 June to 1 July 2005.

Prey group	Himsjø	Lurdalen	Løken	Slørstad	Solberg	Tierud	Torsnes	Totale
Squirrel	6.8	0.0	3.4	0.0	7.7	0.0	14.3	4.8
Tetraonids	16.7	13.3	0.0	0.0	7.7	0.0	0.0	5.5
Pigeons	3.3	6.7	3.4	0.0	15.4	0.0	0.0	3.5
Thrushes	63.2	53.3	58.6	52.9	46.2	71.4	28.6	54.8
Corvids	6.7	13.3	27.6	47.1	15.4	23.8	57.1	26.7
Small birds	0.0	0.0	6.9	0.0	0.0	4.8	0.0	2.1
Other birds	0.0	6.7	0.0	0.0	0.0	0.0	0.0	0.7
Unid. birds	3.3	6.7	0.0	0.0	7.7	0.0	0.0	2.1
N	30	15	29	17	13	21	21	146

Diet by biomass

Corvids accounted for 46% of the total prey biomass, making them the most important prey group (Table 2, Fig. 1). Thrushes accounted for 24% of the biomass, i.e. about half the total weight of the corvids. This is in contrast to the numeric proportion where the situation was approximately the opposite for these two categories (Fig. 1). The three next categories were tetraonids (9%), pigeons (9%) and red squirrel (8%). Unidentified birds constituted 4%, but in this group one item was excluded from the analyses, either a mallard or female capercaillie, because of uncertainty about weight.

The average body mass of all prey was 168 g, ranging from 17.4 g (a tree pipit) to 1254 g (a raven), with SE = 14.2. The average body mass is equal to the size of a Eurasian jay, approximately. A total of 24.3 kg of prey were delivered to the nests during video recording with an average of 3473 g for each nest, ranging from 2397 to 4988 g (SE = 447), and with an average of 74 g per hour for all nests.

Table 2. The estimated weight of different prey groups recorded by video monitoring of seven goshawk nests in the eastern part of Norway in the period 1 June to 1 July 2005.

Prey group	Weight in gram	Weight by %
Squirrel	1945	8.0
Grouse	2294	9.4
Pigeons	2176	9.0
Thrushes	5563	24.0
Corvids	11054	45.5
Small birds	23	0.2
Other birds	90	0.4
Unid. birds	866	3.6
Total	24308	100

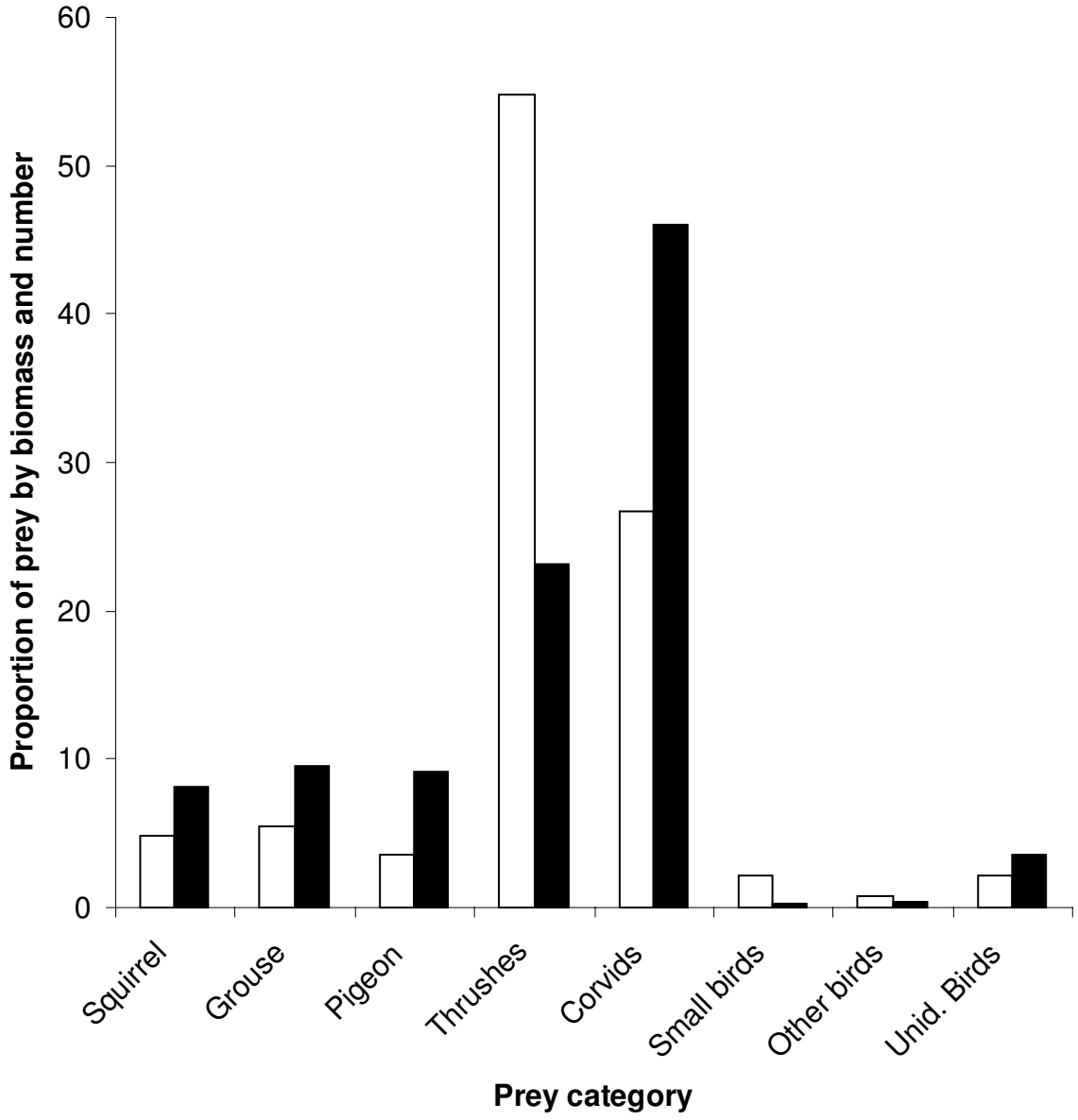


Figure 1. The proportion (%) of different prey groups brought to seven goshawk nests from eastern Norway, determined by video recording. A total of 146 prey items were analysed. The figure shows the proportion by number (open bars), and by weight (filled bars). One prey item (from the unidentified bird group) was excluded from the calculation of biomass.

The bird survey

A total of 74 avian species were recorded during the bird survey, varying from 26 species (Løken) to 49 (Solberg), with a total of 1540 individual observations used in the analyses. Ten species occurred with only one registration. (Appendix1)

The two most frequent species recorded were willow warbler (*Phylloscopus trochilus*) and common chaffinch (*Fringilla coelebs*), constituting 14.6% and 11.2% of the

total number of observations respectively. Among the ten most common species, seven belonged to the group "small birds". The three other species were red wing (4.5%), blackbird (3.5%), and wood pigeon (3.3%). In the prey category "tetraonids", two individuals of capercaillie were observed at the Løken locality, and one singing black grouse from Himsjø. Although not recorded during the survey, one individual of capercaillie was observed while walking away from the survey rout at Lurdalen, but within the home range of the goshawk (less then 2 km from the nest), and also some black grouse were heard singing from a count point from this locality, but not within the 50 m distance. In the group "pigeons", wood pigeons were dominating (n = 51), observed from all localities, but varying from one to 24 by number. Also feral pigeons (*Columba livia*) were commen (n = 33), but only from one locality with one observation of a flock with 31 individuals.

The thrushes were abundant, recorded from all localities, varying from 7.4% to 23.3% in proportion. Red wing was most common (4.5%), followed by blackbird (3.5%), song thrush (2.7%), and fieldfare (1.8%). Among the corvids, the hooded crow was most common with 11 individuals (0.7%). Further, six Eurasian jays (0.4%), and four magpies (0.3%) were recorded. The group "other birds" included many species, but the most important were lapwing (*Vanellus vanelellus*) (1.6%), starling (*Sturnus vulgaris*) (1.4%), common eider (0,5%), black-headed gull (*Larus ridibundus*) (0.3%), herring gull (*Larus argentatus*) (0,5%), green sandpiper (*Tringa ochropus*) (0.5%), and great spotted woodpecker (0,5%). Commen eider and herring gull were only recorded from one locality (Solberg).

Prey selection

The goshawk utilised avian prey non-randomly, i.e. the proportion of different prey categories in the diet were not proportionally to the proportions available within the home range (Wilk`s $\Lambda = 0.0107$, $\chi^2 = 31.75$, $P < 0.001$). Corvids were the most preferred group of prey utilised by the goshawks (Table 3), with the highest rank in the compositional analysis. The corvids were significantly more preferred than all other groups of avian prey, except from the tetranoids (Table 3). The tetranoids was the second most preferred group. They were significantly more utilised than pigeons, small birds, and other birds. The tetraonids were ranked above thrushes in the analyses, but the difference was not significante ($P = 0.053$, table 3). The thrushes were the third most preferred group, significantly more utilised than "other birds" and "small birds". Pigeons and other birds were the fourth and fifth most preferred groups, respectively. These two prey categories were slightly less utilised than expected from the bird survey (Fig. 2), but their mutual ranking did not differ significantly. The less

preferred prey category was small birds, significantly less utilised than all other groups of prey. Grouse, corvids and thrushes were caught more often than expected according to their proportion in the bird community, and pigeons, other birds and small birds were caught less often then expected (Fig. 2).

Table 3. Selection of different groups of avian prey by seven breeding goshawk pairs from eastern Norway in 2005. The results are based on comparing proportional avian prey availability from bird surveys in the home range for each goshawk pair, with proportional prey utilisation from video monitoring. The upper right of the table gives the mean log-ratio differences (mean ± SE) when comparing two and two prey groups against each other. The lower left gives the corresponding p-values (significant values in bold). The rank column ranks the prey groups according to relative preference, a high value indicate a high preference, while a low value indicates a low preference.

Prey group	Tetranoids	Pigeons	Thrushes	Corvids	Small birds	Other birds	Rank
Tetranoids		2.44 ±0.85	1.26 ±0.54	-0.86 ±1.11	6.61 ±0.94	4.26 ±0.72	4
Pigeons	0.025		-1.18 ±0.65	-3.30 ±0.83	4.18 ±0.78	1.83 ±0.46	2
Thrushes	0.053	0.124		-2.12 ±0.66	5.36 ±0.43	3.01 ±0.46	3
Corvids	0.461	0.005	0.015		7.48 ±0.49	5.13 ±0.57	5
Small birds	<0.001	0.001	<0.001	<0.001		-2.35 ±0.61	0
Other birds	<0.001	0.006	<0.001	<0.001	0.006		1

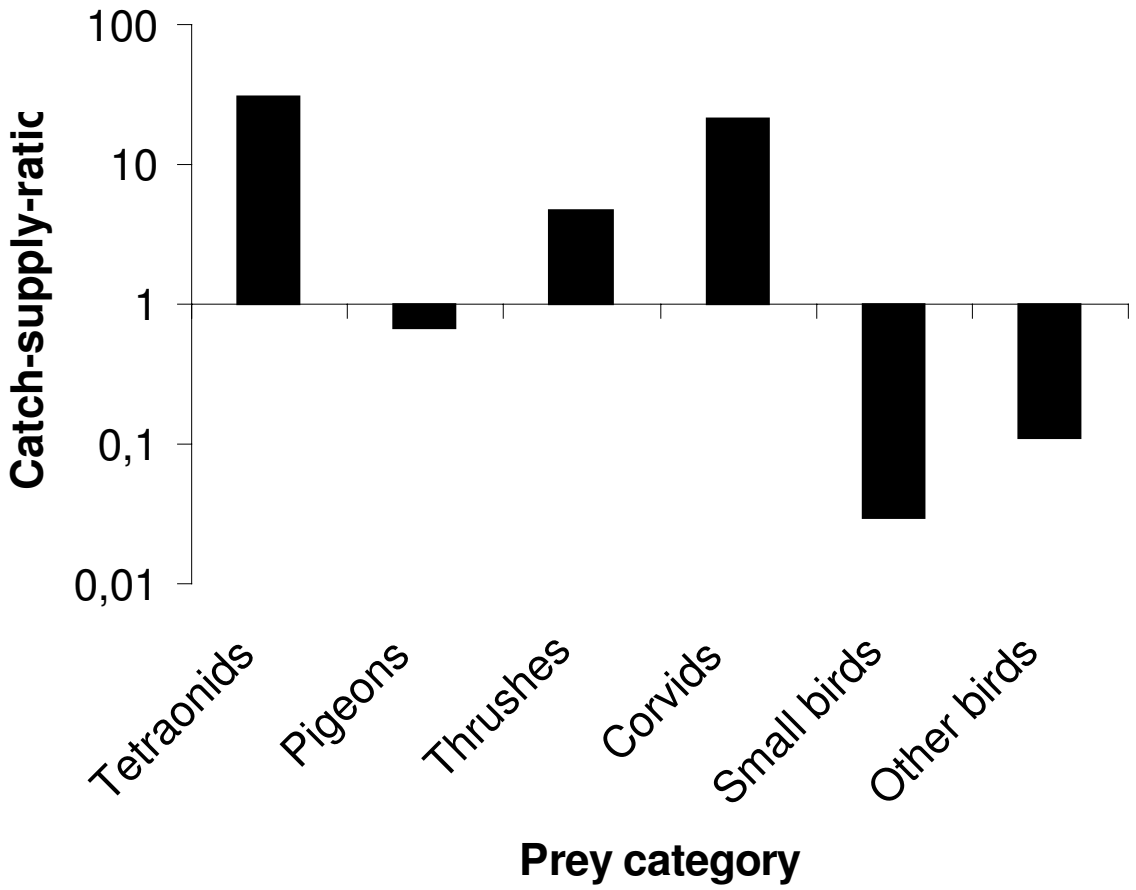
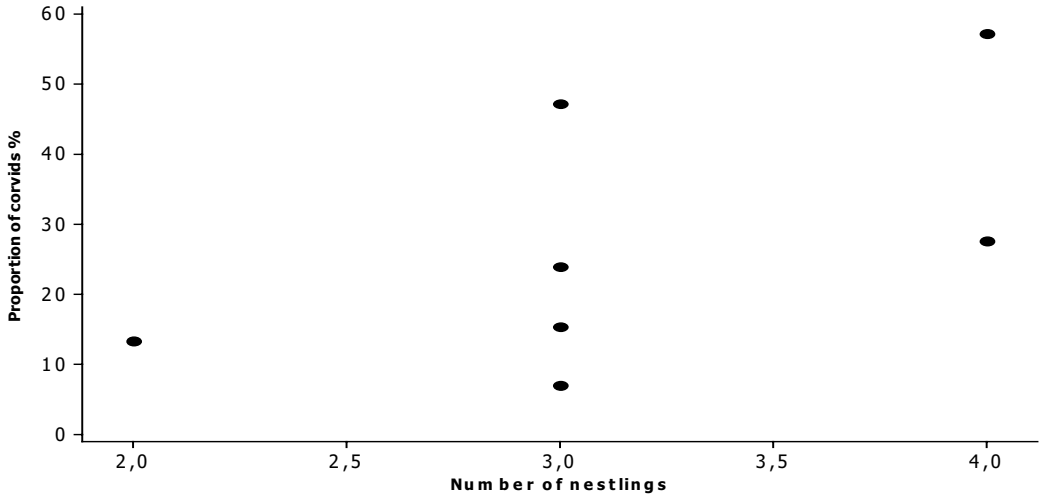


Figure 2. Catch-supply-ratio (CSR) showing the relationship between the numeric proportion of different prey groups in goshawk diet, estimated from video recording, and the proportion in the bird community, estimated from bird surveys. The data are based on studies of seven breeding goshawks pairs from eastern Norway in 2005. CSR < 1 when a prey group is caught less than expected, and CRS > 1 when a prey group is caught more often than expected. CRS is calculated by dividing the use proportion with the available proportion.

There was a tendency for relationship between the number of fledglings in a goshawk nest, and the proportion of corvids in the diet (Fig. 3a). There was a significantly negative correlation between the number of species in the goshawk diet, and the proportion of corvids in the diet (Fig. 3b), $p = 0.019$. There also was a significant positive correlation between total bird density and density of corvids within the home range (Fig. 4).

a)



b)

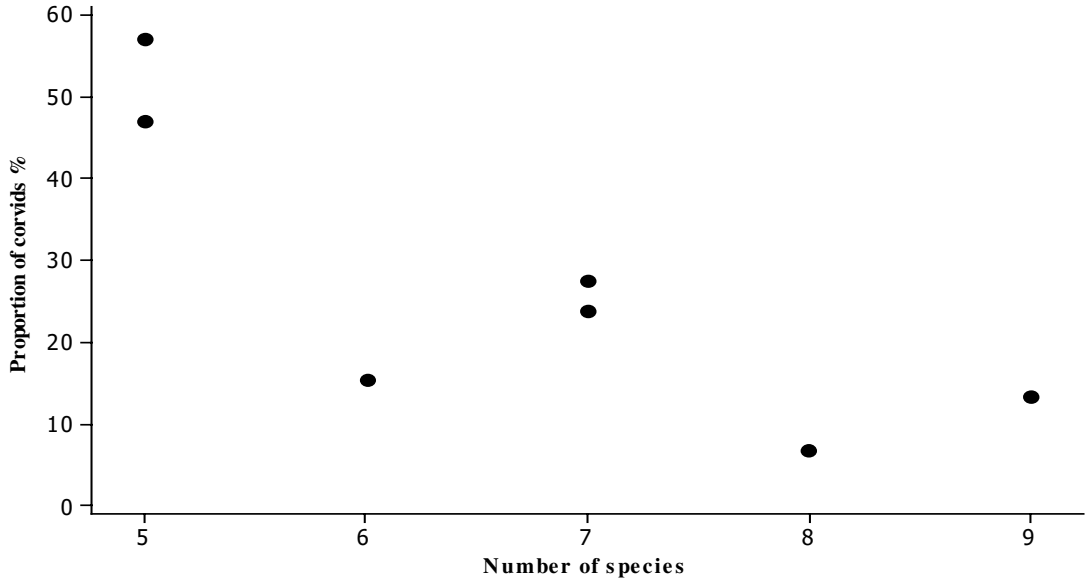


Figure 3. The proportion of corvids in the diet in relation a) to the number of nestlings (R_{ho} = 0.68, p = 0.095), and b) the minimum number of prey species brought to the nest (R_{ho} = -0.84, p = 0.019). Each plot represents a nesting site.

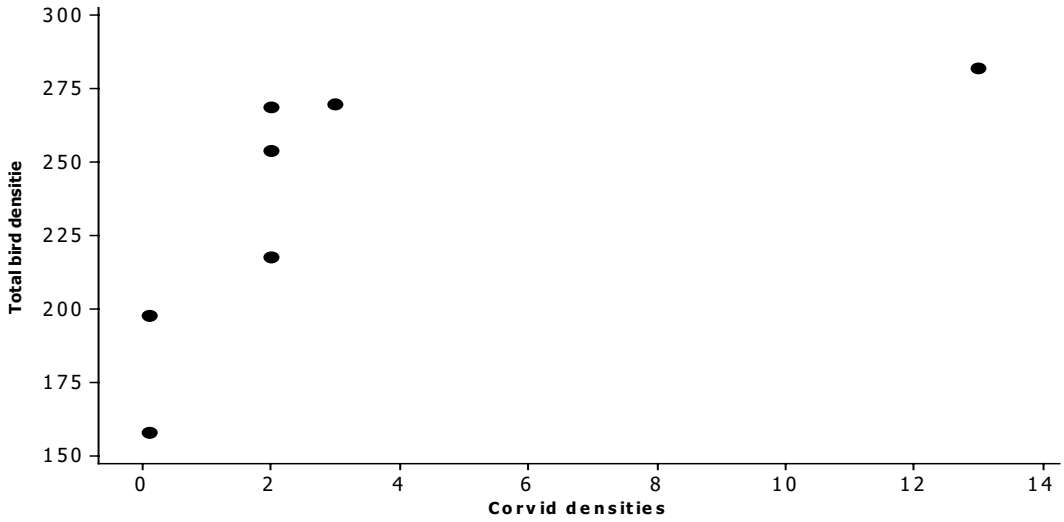


Figure 4. The relationship between the total bird density and total corvid density (number of observations) within the home range of the goshawk ($R_{ho} = 0.95$, $p = 0.001$). Each plot represents a nesting site.

Discussion

Diet during the nestling period

Avian prey constituted 95% (by number) of the prey delivered to the seven goshawk nests. Red squirrel was the only mammal recorded. Among the avian prey, thrushes and corvids were most important, contributing more then 50% of the diet, both by number and biomass. The thrushes were most important by number (55%), while the corvids were most important considering biomass proportion (46%).

My results differ from that of several other studies on goshawk diet during breeding season in northern Europe (Wikman 1977, Lindén and Wikman 1983, Nielsen 1986, Widén 1987, Selås 1989b, Overvoll 1999, Tornberg 1997, Grønnesby and Nygård 2000, Tornberg et al. 2006), where large birds like pigeons and grouse have been more important. But this could at least partly be due to the methods applied. The majority of the goshawk diet studies from northern Europe are based on prey remains collected around goshawk nest sites, and from the nests. This method could be biased, because the remains of some prey items are easier to detect than others (Selås 1989a, Rutz 2003, Lewis 2004 et al, Sveen 2006). It is also important to consider the difficulties by comparing different diet studies when the methods bias the proportions of different prey groups, because over- or underestimation of one group will influence the proportions of the other groups. But other factors should also be considered, like the effect of different habitat types between different study areas, and the composition of prey species within the home range of the goshawk.

Another diet study based on direct observation of the nest, using a time-laps video, was carried out in Central Norway (Grønnsby and Nygård 2000). Their findings were more similar to my results with regard to the proportion of grouse and thrushes, but they found a considerable lower proportion of corvids. A reason for the differences could be that the results from Central Norway were derived from only two nest localities. This low sample size could as a consequence lead to diet estimates reflecting single hawks hunting habits, more than the average hawks. Anyway, the similar result from this study and my study could indicate that grouses have been overestimated and thrushes underestimated in previous diet studies based on prey remains.

Widén (1987) estimated goshawk diet by collecting prey remains during the breeding seasons 1977-1981 in the south central part of Sweden. The most frequent prey category recorded were corvids with 28%, which is very similar to my result (27%). No other studies

from Fennoscandia, to my knowledge, have showed a similar high proportion of corvids in the goshawk diet (Tornberg et al. 2006 with references therein). This could, however, be because many of the studies were conducted in the periods when grouse densities were in general higher. In northern Finland, Tornberg and Sulkava (1991) found that goshawk attempt to switch to preying more on corvids, thrushes and pigeons when there were low densities of grouse.

I found that grouse constituted only 5.5% of the total prey number and that they were clearly less important than thrushes and corvids. In contrast, grouse have been the most important prey in several other studies (Tornberg 1997, Tornberg et al. 2006 with references therein), where they have made up 14% to 54 % of the total number of prey during the nestling period. When considering their proportion by biomass, their importance has been even higher. The proportion of grouse in the diet has to be considered in relation to the number of grouse available within the goshawk home range. In my study, four out of seven nests were located in a dominating agriculture landscape less suitable for grouse. The number of grouse is also known to fluctuate considerable from one year to another, and the proportion of grouse in the goshawk diet will then fluctuate. In southern Finland, the biomass of grouse and pheasant (*Phasianus colchicus*) in the diet varied from 13 % to 49 % between years (Lindén and Wikman 1983), and from southern Norway, the annual proportion of adult black grouse in the diet varied from 9.5% to 17.1% during 1989-1996 (Selås 2003).

Pigeons made up 3.5% of the total number of prey in my study, a proportion considerably lower than many studies based on collecting prey remains, excluding studies from Finland. Nilsen (1986) found a proportion of pigeons in the diet of 41.5% in Denmark, and Widen (1987) a proportion of 28.3% in Sweden. Overvoll (1999) found a proportion of 44.4%, 15.9%, and 5.5% from three different study areas respectively in western Norway. I suggest that pigeons are easy to overestimate when making diet estimates from plucking prey remains. Sveen (2006) conducted simultaneously with my work a comparison between the two methods (prey remains versus video recording) for assessing the goshawk diet, and his most important finding was the overestimation of pigeons by the prey remains method. The pigeons were significantly overestimated above all other prey groups. From the prey remains method, pigeons constituted 22.9 % of the total number (n = 144), compared with 4.3 % in the video analysis (n = 117).

Thrushes made up a large part (by number) of the goshawk diet in my study (54.8%). Thrushes are relative small prey items, and are likely to be underestimated from prey remains methods (Newton 1979, Selås 1989a, Sveen 2006). To my knowledge, the only other study

that has found a similar high proportion of thrushes is that of Grønnsby and Nygård (2000). Their results support the assumption of thrushes being an important part of the goshawk diet during the breeding period.

Prey selection, limitations and biases

One possible limitation with the video monitoring is that small prey are more likely to be eaten by the goshawk away from the nest area, since the energy profit gained from a small prey is small compared to the energy cost of bringing the prey to the nest (Newton 1979, Sonerud 1992). It is also important to emphasize that the method is only useful as a description of the diet during the nestling period, when mostly the male is responsible for hunting, and hence, the prey selection (Selås 1989a). The video recordings did not include the very early phase of the nestling period, when nestling were younger than six days old.

Also the bird survey is likely to contain biases (Sutherland et al. 2004). The species differ with regard to ecology and behaviour, which could lead to differences in detect ability. Most of the observations during the bird survey represent singing males, and the survey is likely to underestimate birds that rarely or never sing. Other factors affecting the detect ability is how the bird react towards the observer, it might leave the area undetected, keep silent and motionless, stop singing, or start making warning calls. A few species sing only very early in the season, by night, or to a very restricted time of the day, and the count point method may not be appropriate for species with clumped distribution. For some species occurring at very low densities with few counts, like the tetraonid species, the survey might have been too small to give an appropriate estimate. In the preference analyses, grouping the species could be a problem if the group constituted species with considerable different preference value.

Grouping the species into prey categories may overcome some of the biases, but for two of the prey categories, grouses and corvids, the biases were assumed to be considerable. Therefore observations between the points were applied for some of these species in order to correct for their low detect ability. This may have reduced the bias problem, but it is not expected to be an exactly correction of proportion relative to the other prey groups.

Ideally the bird surveys should have covered the exact goshawk home ranges. Other studies, using radio telemetry, have shown that the size and shape of the home range during the nestling period varies considerably between individual goshawks (Donald et al. 1994, Nygård et al. 1998). However, goshawks do not utilise their home range evenly (Donald *et al*. 1994), but might spend more time hunting close to their nests during the breeding season, and seldom move several kilometres away. According to the optimal diet theory (Krebs and

Davies 1993), prey close to the nest has higher value than prey farther away, because flying between the nest and the hunting area is energy consuming for the goshawk.

Although it might be unrealistic to assume that the goshawks utilized only the 7 km² areas where the bird surveys were conducted, these area should have high forage value during the breeding season.

The prey selection

The goshawk did not utilise the prey species proportionally to their estimated numeric availability. Tetranoids, corvids and thrushes were caught more often than expected, and pigeons, other birds and small birds less often. The most preferred prey group was the corvids, but their ranking above the grouse species was not statistically significant. It is important to have in mind that these are relative preferences because avoidance of one group of prey will almost invariably lead to an apparent preference for other groups.

The optimal diet theory predicts that the diversity in the diet should increase as the abundance of the most profitable prey decreases and vice versa (Krebs and Davies 1993). In agreement with this theory, I found that there was a significant negative correlation between the species diversity in the goshawk diet, and the proportion of corvids in the diet. There was also a tendency for a positive relationship between the number of fledglings produced and the proportion of corvids in the diet, but this could be due to the significant correlation between the density of corvids and total bird density. This is probably because the more productive agriculture landscape has a positive effect on both the total bird density and the density of corvids. Slafsky (2005) found a positive correlation between the number of nestlings produced and the total prey density within the home range of the goshawks. Anyway, Beier and Drennan (1997) showed that forest structure were more important than prey abundance when goshawk selected foraging sites.

A majority of other studies from Fennoscandia have regarded grouse species to be the most important prey group, contributing a high proportion of the diet during the breeding season, and seemingly the most preferred prey group (Tornberg 2006 and references therein). Lindén and Wikman (1983) found an increasing proportion of hazel grouse in the goshawk diet as the population of hazel grouse increased. They also found a significant negative correlation between species diversity among goshawk prey, and the population size of hazel grouse, indicating that hazel grouse was the main prey species in this study. A long time-series from north Finland also show that the proportion of grouse in the spring diet has decreased simultaneous with the decrease of the grouse population (Tornberg et al. 2006). In

contrast, Widén (1987) found no significant variation in the proportion of black grouse in the diet between years, or a correlation with grouse density, but this might be because the grouse population did not occur with densities below the threshold during the study period.

The previous findings of grouse as preferred prey are partly inconsistent with my results. However, the goshawk has a broad spectre of prey species in the diet, and is likely to switch to alternative prey species, or forage in other areas, when the preferred prey species becomes scarce (Rutz and Bijlsma 2006, Tornberg et al. 1999). Tetranoid populations are usually fluctuating greatly between years in Fennoscandia, and switching to alternative prey would probably influence an analysis of prey preference. When tetraonids occur in middle to high densities, they might be the most preferred prey, but when densities turn below a certain threshold, hunting grouse may be less profitable, and a switch to an alternative prey, such as corvids, may occur. According to the optimal foraging theory (Krebs and Davies 1993) the time spent searching for the main prey by the goshawk might be energy unprofitable if grouse densities are too low.

How the goshawks respond to changes in the number of preferred prey, or local densities, will probably depend on the availability of alternative prey species. Within the study area in Akershus, where densities of tetraonids are low, corvids are likely to be the most preferred prey group. Tornberg and Sulkava (1991) and Tornberg et al. (1999) reported a shift in the goshawk diet as the populations of grouse decreased, and the main prey groups compensating for grouse included corvids. Götmark (1997) provided evidence for frequency-dependent prey selection by goshawks. His experiments showed that jays were more vulnerable to attacks when they occurred at high densities. Hence, the goshawk may adopt a search image (Krebs and Davies 1993) and actively choose to forage upon prey that is locally abundant at a given time.

The goshawk diet during the nestling period have a high proportion of nestlings and fledglings, because they are numerous and vulnerable to predation at that time. Different ecology of juvenile grouse and corvids may explain the preference for corvids during the nestling period. Juvenile corvids are probably more accessible because they are bound to a nest, or close to it, just before and after fledging (Cramp et al. 1994). When a nest has been detected by the goshawk, it could return by several visits to capture more nestlings without spending energy on searching for new prey. Fagerland (2006) found that the type of prey delivered to the nest was influenced by the previous delivery, with a higher probability of a species or group of species occurring at a raw. Teraonid chicks are not confined to a nest-structure and its surroundings, but are constantly at move on the forest floor which is covered

with ground vegetation that reduces predation (Sonerud 1985, Bergerud and Gratson 1998, Wegge et al. 2005). The nestlings of the corvids are also more vocal compared to grouse chicks when they utter begging calls from the nest, which is likely to attract predators like the goshawk (Tornberg 1997).

One other factor likely to explain a higher preference for corvids than grouse during the nestling period, (also concerning the other prey species), is that many of the juvenile corvids recorded as prey had reached a weight almost similar to the adult birds. In contrast, the estimated weights of juvenile grouse preys were 100-200 gram, far from the adult weights. Hence, the corvids may be more profitable as prey during the nestling period because their availability considering biomass is relative higher than their numeric proportion. When considering the proportion of the diet by biomass, Tornberg (1997) found that the corvids had a peak during the nestling period of the goshawk, while the grouse had a peak later in the season, as they grow.

Hooded crow made up a bulk of corvids in the diet of goshawk in my study. The hooded crow typically build its nest close to forest edges and forest patches, and hooded crow densities are positively correlated to the amount of agricultural land mixed with forest (Andrén 1992, Tømmerås 1994, Lund 1996). Although the species rarely inhabit deep forests, it was recorded as prey also at two goshawk nests situated about 3 km away from agricultural land, indicating a preference for this species, considering the energy cost of transporting this relative large prey back to the nest. The habitat preference of the hooded crow separates this species from grouse, which space their nests more randomly in the forest landscapes, although the chicks have some habitat preference (Wegge et al. 2005). Selection of hooded crow could therefore be profitable, because the goshawk then can forage selectively in forest edges. Kenward (1982) found that goshawks in Central Sweden hunted more in forest edges than expected from the availability, but this may have been related also to a high availability of pheasants.

The most important corvid by number in the diet was the jay, with a total of 18 individuals (12.3% of the diet). The species was seldom observed during the bird survey (0.4 % of birds observed), and seems thus to be strongly preferred. However, the jay may have been underestimated in the bird survey, because of its anonymous behaviour (Cramp et al. 1994, Løfaldli 1994). I suggest that the preference for jay by the goshawk is linked to its profitable size, its abundance throughout the forest, and its habit of moving around searching for food. The jay is a bird with a relative slow flight (pers. obs.), and when first detected by

the goshawk, it may have problems with escaping from the more fast flying and manoeuvring goshawk, unless dense vegetation is close by, which could function as a hide.

Winter and early spring have been revealed as a critical period for the goshawk, because many of the prey species have migrated out of the area, like most thrushes and wood pigeons, and nestlings are no longer available. Also resident species will occur in lower densities because of mortality. During this critical period, grouse, mountain hare and red squirrel are important food sources (Tornberg et al. 2006, and references therein). Given that the summer and winter home range for the goshawk are the same, and that corvids are less accessible during the winter, the goshawk may gain a benefit by selecting corvids, thrushes and pigeons during summer, if this results in higher population levels of preys that are important during winter and early spring. Besides, as the corvids are predators on grouse eggs and chicks, they may have a negative impact on the grouse population in an area. If goshawk predation on corvids during the breeding season reduces the predation by corvids on grouse eggs and chicks, this may contribute to increase the winter population of grouse.

The third most preferred prey group was the thrushes, significantly less utilised than the corvids, but not significantly less than tetraonids. They were utilised more than expected from the bird survey and were more important by biomass than the tetranoids (23% vs. 10%). The thrushes are far more abundant than many of the other species, and during the nestling period of the goshawk, many young thrushes are available as fledglings with poor flying skills, making them vulnerable to predation by the goshawk. In Wales, Toyne (1998) found that 46% of all thrush preys during March-September were fledglings, and thrushes were also the prey group with the highest proportion of fledglings occurring in the diet. Song thrush, redwing and blackbird usually have two broods during the breeding season (Bentz 1997), making the juvenile proportion of the total thrush population high compared to other avian prey groups. This will probably also affect the preference rating since the availability is mainly based on singing males, and hence the true preference for thrushes may have been lower.

Pigeons were utilised less than expected from the bird survey. They were not significant less preferred than thrushes, but significantly less preferred than corvids and tetranoids. This is somewhat unexpected since the size of the wood pigeon resembles the size of the two most preferred prey groups (corvids and grouse), and since wood pigeon nests are often situated in forest edges as for the hooded crow (Inglis et al. 1994). However, the wood pigeon has a rapid flight, and healthy birds can outfly a goshawk in open terrain (Kenward 1978). Woodpigeons forage mainly in flocks in open fields (Cramp 1986, Viker 1994), a habit

that makes them less vulnerable to goshawk predation (Kenward 1978). The nests are often placed in dense spruce forests (Viker 1994), which might be too dense for the goshawk to manoeuvre proper. Until the nestlings are 8-10 days old they are fed only twice by day, and the parent will often forage fare away from the nest (Cramp 1986). The nestlings are usually silent and motionless between each feeding, and when a nest is disturbed, the adults generally leave the area without showing any mobbing behaviour against the predator. This assumingly makes it difficult for a goshawk to detect a wood pigeon nest.

Toyne (1998) found that only 13% of the wood pigeon preys in June were fledglings, less than all other groups of prey. However, this has to be considered in relation to the relative small clutch size of the wood pigeon, compared to other species. Usually they lay two eggs in a brood, with 1-2 broods in a year (Viker 1994), and thereby, the proportion of young birds in the population is relative small. Since the species will be overestimated in the availability estimates due to the low output of young, the true preference may have been higher than indicated by my analysis.

The next prey group with regard to preference was “other birds”. This exhibited many different bird species but few occurred as prey. The group were significantly less utilised than all other groups ranked above, but significantly more preferred than “small birds”. Many of the species occurred by low number, but if we assume goshawks to be size selective, preferring large and medium-sized birds, I would expected to find some of the species of concern in the group “other birds” in the diet. But this was not true for ducks (Anatidaea) gulls (Laridae), lapwing (*Vanellus vanellus*), and starling (*Sturnus vulgaris*), which occurred by 1.04%, 0.97%, 1.56%, and 1.36% from the bird surveys respectively. These species occur mainly in open landscapes, and do not inhabit the forests. Starling and lapwing are strongly connected to the open fields, while ducks and gulls are connected to open water habitats and the water surface in lakes, rivers and sea (Gjerdshaug 1994). The main reason why these species are being poorly utilised is probably that the goshawk seldom forage in open landscapes, but prefer to forage in forest and forest edges (Kenward 1982).

The last group in the prey selection analysis was small birds, significantly less utilised than all other groups. The group consisted of many different bird species, and was the most frequent group from the bird survey, with 75% of the total number, but hardly utilised by the goshawk since only 3 prey items were recorded (2.1%). I suggest the main reason for the low preference was the small size of these birds. The goshawk is a relative large raptor, not adapted for hunting small birds. However, the preference for this group may have been

underestimated because small preys are less likely to be transported to the nest (Sonerud 1992).

The goshawk hunts mostly in forests using a technique best described as “short-stay perched-hunting” (Kenward 1982). It means that the goshawk scan the surroundings for prey from a perch in a tree at fairly short intervals (3-4 min), and then fly to another perch close by (about 200 m) repeating the process. Most attacks are initiated straight from the perch with the hawk surprising the prey by diving, gliding, or flapping close to the ground (Kenward 1982, Marcström et al 1990). This behaviour could indicate that prey occurring at the forest floor are especially vulnerable to attacks from the goshawk and hence most preferred. This assumption could also be supported by my findings. Most of the species occurring in the preferred prey groups from my study have a behaviour that includes spending a lot of time at the forest floor. Included in the group “corvids”, jays and hooded crows were most important as prey. The jay is distributed throughout the forest, also in its inner part, and during the breeding season, it principally forages on ground, where bugs are commonly utilised, but also eggs and fledglings are a part of the diet (Cramp et al. 1994, Løfaldli 1994).

In the group “tetranoids”, seven out of eight prey items were juvenils or females. During the nestling period of the goshawk, these birds spend almost all of their time on the forest ground, when the juvenile birds are incapable of flying properly (Wegge et al. 2005). This is also true for the juvenils in the group ”thrushes”, but also adult thrushes spend a lot of their time on the forest floor when foraging at earthworms, snails and other invertebrates (Cramp 1988). In contrast to ground dwelling birds, the crossbills (*Loxia* sp.) forage mainly in the forest canopy. These species are slightly less than a redwing (40-50 g), but even though they occurred by fairly large numbers in the bird survey (Appendix 1), they were not represented in the diet.

Conclusion

From this study I have found that thrushes and corvids are the most important prey groups in the diet during the nestling period of the goshawk. Thrushes were the most important prey considering the numeric proportion, and corvids were most important considering biomass proportion. Compared to the numeric availability of prey within the home ranges, corvids and tetraonids were most preferred. Small birds were least preferred. My findings, based on video monitoring, differ from that of several other diet studies from Fennoscandia that have found a much higher proportion of grouse species and pigeons in the diet. My findings also show that the goshawk have prey preference, and hence, forage selectively. And further, the most preferred prey groups consist of bird species that mainly forage on the ground in the forests.

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Appendix 1. Bird observations within the home range of the goshawk

Locality	**Himsjø**		**Lurdalen**		**Løken**	
Species	Point counts	Between points	Point counts	Between points	Point counts	Between points
Mallard *Anas platyrhnchos*	0	2	0	0	0	0
Common Eider *Somateria mollissima*	0	0	0	0	0	0
Red-breasted Merganser *Mergus serrator*	0	0	0	0	0	0
Common Goldeneye *Bucephala clangula*	0	0	0	1	0	0
Eurasian Sparrowhawk *Accipiter nisus*	0	0	0	0	0	0
Northern Goshawk *Accipiter gentilis*	0	0	0	0	0	0
Capercaillie *Tetrao urogallus*	0	0	0	0	0	2
Black Grouse *Tetrao tetrix*	0	1	0	0	0	0
Eurasian Oystercatcher *Haematopus ostralegus*	0	0	0	0	0	0
Northern Lapwing *Vanellus vanellus*	0	0	0	0	0	0
Common snipe *Gallinago gallinago*	0	0	1	0	0	0
Common Sandpiper *Actitis hypoleucos*	0	2	0	0	0	0
Eurasian Woodcock *Scolopax rusticola*	0	0	1	2	0	0
Green Sandpiper *Tringa ochropus*	1	0	5	2	1	1
Black-headed Gull *Larus ridibundus*	0	0	0	0	0	0
Herring Gull *Larus argentatus*	0	0	0	0	0	0
Common tern *Sterna hirundo*	0	0	0	0	0	0
Common Wood Pigeon *Columba palumbus*	1	0	1	1	1	2
Feral Pigeon *Columba livia*	0	0	0	0	0	0
Common Swift *Apus apus*	0	0	1	0	1	0
Green woodpecker *Picus viridis*	0	0	0	0	1	0
Black woodpecker *Dryocopus martius*	1	0	1	0	0	0
Great Spotted Woodpecker *Dendrocopos major*	1	0	2	0	1	0
Eurasian Wryneck *Jynx torquilla*	0	0	0	0	1	0
Sky Lark *Alauda arvensis*	0	0	0	0	0	0
House Martin *Delichon urbica*	0	0	0	0	0	0
Barn Swallow *Hirundo rustica*	0	0	2	0	0	0
Tree Pipit *Anthus trivialis*	16	3	18	0	5	1
Grey Wagtail *Motacilla cinerea*	0	0	0	0	0	0
White Wagtail *Motacilla alba*	1	0	4	0	0	0
Dunrock *Prunella modularis*	4	0	5	0	4	0
Winter Wren *Troglodytes troglodytes*	0	0	2	0	5	0

Common Redstart *Phoenicurus phoenicurus*	0	0	2	0	0	0
European Robin *Erithacus rubecula*	13	0	25	1	16	0
Winchat *Saxicola rubetra*	0	0	0	0	0	0
Song Thrush *Turdus philomelos*	3	0	3	0	10	0
Redwing *Turdus iliacus*	7	0	8	0	16	1
Fieldfare *Turdus pilaris*	2	1	2	0	4	0
Common Blackbird *Turdus merula*	6	0	7	1	7	0
Garden Warbler *Sylvia borin*	0	0	5	0	4	0
Blackcap *Sylvia atricapilla*	2	0	0	0	0	0
Lesser Whitethroat *Sylvia curruca*	0	0	1	0	0	0
Common Whitethroat *Sylvia communis*	0	0	0	0	0	0
Marsh Warbler *Acrocephalus palustris*	0	0	0	0	0	0
Wilow Warbler *Phylloscopus trochilus*	35	0	44	0	23	0
Common Goldcrest *Regulus regulus*	10	0	7	0	8	0
Spotted Flycatcher *Muscicapa striata*	0	0	0	0	0	0
Pied Flycatcher *Ficedula hypoleuca*	1	0	0	0	2	0
Great Tit *Parus major*	5	0	3	1	6	2
Blue Tit *Parus caeruleus*	1	0	0	0	1	0
Coal Tit *Parus ater*	0	0	5	0	1	0
Crested Tit *Parus cristatus*	7	0	6	0	1	0
Marsh Tit *Parus palustris*	0	0	0	0	0	0
Willow Tit *Parus montanus*	2	0	5	0	1	0
Long-tailed Tit *Aegithalos caudatus*	0	0	0	0	0	0
Wood Nuthatch *Sitta europaea*	0	0	0	0	0	0
Eurasian treecreeper *Certhia familaris*	0	0	0	0	0	0
Red-backed Shrike *Lanius collurio*	0	0	0	0	0	0
Black-billed Magpie *Pica pica*	0	0	0	0	0	0
Eurasian Jay *Garrulus glandarius*	0	0	2	0	0	0
Hooded Crow *Corvus corone*	0	0	0	0	0	0
Common Starling *Sturnus vulgaris*	0	0	0	0	0	0
House Sparrow *Passer domesticus*	0	0	0	0	0	0
Eurasian Tree Sparrow *Passer montanus*	0	0	0	0	0	0
Chaffinch *Fringilla coelebs*	24	1	29	0	35	0
Brambling *Fringilla montifringilla*	1	0	0	0	0	0
Common Redpoll *Carduelis flammea*	2	0	0	0	0	0
European Greenfinch *Carduelis chloris*	0	0	1	0	0	0
Eurasian Siskin *Carduelis spinus*	2	0	11	0	1	0
Common Bullfinch *Pyrrhula pyrrhula*	0	2	0	0	0	0

Hawfinch *Coccothraustes coccothraustes*	0	0	0	0	0	0
Crossbill sp. *Loxia sp.*	44	13	55	0	0	0
Reed Bunting *Emberiza schoeniclus*	0	0	0	0	0	0
Yellowhammer *Emberiza citrinella*	1	1	4	0	0	0

Locality	**Slørstad**		**Solberg**	
Species	Point counts	Between points	Point counts	Between points
Mallard *Anas platyrhnchos*	1	0	0	0
Common Eider *Somateria mollissima*	0	0	8	0
Red-breasted Merganser *Mergus serrator*	0	0	4	0
Common Goldeneye *Bucephala clangula*	0	0	0	0
Eurasian Sparrowhawk *Accipiter nisus*	0	0	0	0
Northern Goshawk *Accipiter gentilis*	1	0	0	0
Capercaillie *Tetrao urogallus*	0	0	0	0
Black Grouse *Tetrao tetrix*	0	0	0	0
Eurasian Oystercatcher *Haematopus ostralegus*	0	0	0	1
Northern Lapwing *Vanellus vanellus*	8	1	4	0
Common snipe *Gallinago gallinago*	0	0	0	0
Common Sandpiper *Actitis hypoleucos*	0	0	0	0
Eurasian Woodcock *Scolopax rusticola*	0	0	0	0
Green Sandpiper *Tringa ochropus*	0	0	0	0
Black-headed Gull *Larus ridibundus*	5	5	3	0
Herring Gull *Larus argentatus*	0	0	7	5
Common tern *Sterna hirundo*	0	0	1	0
Common Wood Pigeon *Columba palumbus*	14	22	12	24
Feral Pigeon *Columba livia*	0	0	33	9
Common Swift *Apus apus*	1	0	9	0
Green woodpecker *Picus viridis*	0	0	0	0
Black woodpecker *Dryocopus martius*	0	0	0	1
Great Spotted Woodpecker *Dendrocopos major*	0	1	2	0
Eurasian Wryneck *Jynx torquilla*	0	0	2	0
Sky Lark *Alauda arvensis*	45	4	17	2
House Martin *Delichon urbica*	0	0	0	0
Barn Swallow *Hirundo rustica*	3	0	0	1
Tree Pipit *Anthus trivialis*	1	0	0	0
Grey Wagtail *Motacilla cinerea*	2	0	0	0
White Wagtail *Motacilla alba*	2	0	0	1

Dunrock *Prunella modularis*	4	0	2	0
Winter Wren *Troglodytes troglodytes*	3	0	5	0
Common Redstart *Phoenicurus phoenicurus*	0	0	0	0
European Robin *Erithacus rubecula*	1	0	4	0
Winchat *Saxicola rubetra*	5	1	2	0
Song Thrush *Turdus philomelos*	10	0	4	0
Redwing *Turdus iliacus*	10	1	7	0
Fieldfare *Turdus pilaris*	15	2	1	2
Common Blackbird *Turdus merula*	3	3	14	3
Garden Warbler *Sylvia borin*	10	0	8	0
Blackcap *Sylvia atricapilla*	9	0	1	0
Lesser Whitethroat *Sylvia curruca*	2	0	2	0
Common Whitethroat *Sylvia communis*	2	1	1	0
Marsh Warbler *Acrocephalus palustris*	5	0	0	0
Wilow Warbler *Phylloscopus trochilus*	13	0	23	0
Common Goldcrest *Regulus regulus*	6	0	5	0
Spotted Flycatcher *Muscicapa striata*	0	0	0	0
Pied Flycatcher *Ficedula hypoleuca*	3	0	0	1
Great Tit *Parus major*	1	1	8	1
Blue Tit *Parus caeruleus*	1	0	2	0
Coal Tit *Parus ater*	0	0	0	0
Crested Tit *Parus cristatus*	0	0	0	0
Marsh Tit *Parus palustris*	0	0	2	0
Willow Tit *Parus montanus*	1	0	4	0
Long-tailed Tit *Aegithalos caudatus*	0	0	5	0
Wood Nuthatch *Sitta europaea*	2	0	0	0
Eurasian treecreeper *Certhia familaris*	0	0	0	0
Red-backed Shrike *Lanius collurio*	1	0	1	0
Black-billed Magpie *Pica pica*	1	0	3	2
Eurasian Jay *Garrulus glandarius*	0	0	3	0
Hooded Crow *Corvus corone*	2	0	3	4
Common Starling *Sturnus vulgaris*	1	0	0	8
House Sparrow *Passer domesticus*	0	0	0	1
Eurasian Tree Sparrow *Passer montanus*	0	0	1	1
Chaffinch *Fringilla coelebs*	41	0	33	0
Brambling *Fringilla montifringilla*	0	0	0	0
Common Redpoll *Carduelis flammea*	1	0	0	0
European Greenfinch *Carduelis chloris*	7	1	12	1

Eurasian Siskin *Carduelis spinus*	1	0	0	0
Common Bullfinch *Pyrrhula pyrrhula*	1	0	0	0
Hawfinch *Coccothraustes coccothraustes*	1	0	0	0
Crossbill sp. *Loxia sp.*	0	0	5	0
Reed Bunting *Emberiza schoeniclus*	1	2	0	0
Yellowhammer *Emberiza citrinella*	18	5	14	0

Locality	**Tierud**		**Torsnes**	
Species	Point counts	Between points	Point counts	Between points
Mallard *Anas platyrhnchos*	0	0	1	0
Common Eider *Somateria mollissima*	0	0	0	0
Red-breasted Merganser *Mergus serrator*	0	0	0	0
Common Goldeneye *Bucephala clangula*	0	0	0	0
Eurasian Sparrowhawk *Accipiter nisus*	1	0	0	0
Northern Goshawk *Accipiter gentilis*	0	0	2	0
Capercaillie *Tetrao urogallus*	0	0	0	0
Black Grouse *Tetrao tetrix*	0	0	0	0
Eurasian Oystercatcher *Haematopus ostralegus*	0	0	0	0
Northern Lapwing *Vanellus vanellus*	7	0	5	2
Common snipe *Gallinago gallinago*	0	0	0	0
Common Sandpiper *Actitis hypoleucos*	0	0	0	1
Eurasian Woodcock *Scolopax rusticola*	0	0	0	1
Green Sandpiper *Tringa ochropus*	0	2	0	0
Black-headed Gull *Larus ridibundus*	0	0	0	0
Herring Gull *Larus argentatus*	0	0	0	0
Common tern *Sterna hirundo*	0	0	0	0
Common Wood Pigeon *Columba palumbus*	2	2	10	7
Feral Pigeon *Columba livia*	0	0	0	0
Common Swift *Apus apus*	0	0	1	0
Green woodpecker *Picus viridis*	0	0	0	0
Black woodpecker *Dryocopus martius*	0	0	0	0
Great Spotted Woodpecker *Dendrocopos major*	0	1	1	0
Eurasian Wryneck *Jynx torquilla*	0	0	1	0
Sky Lark *Alauda arvensis*	2	0	17	5
House Martin *Delichon urbica*	0	0	1	0
Barn Swallow *Hirundo rustica*	0	0	4	0
Tree Pipit *Anthus trivialis*	3	0	3	0

Grey Wagtail *Motacilla cinerea*	0	0	0	0
White Wagtail *Motacilla alba*	0	0	4	1
Dunrock *Prunella modularis*	6	0	5	0
Winter Wren *Troglodytes troglodytes*	4	0	6	0
Common Redstart *Phoenicurus phoenicurus*	0	0	0	0
European Robin *Erithacus rubecula*	3	0	4	0
Winchat *Saxicola rubetra*	1	0	0	0
Song Thrush *Turdus philomelos*	2	0	10	0
Redwing *Turdus iliacus*	6	0	15	1
Fieldfare *Turdus pilaris*	0	0	3	2
Common Blackbird *Turdus merula*	2	2	15	7
Garden Warbler *Sylvia borin*	2	0	4	0
Blackcap *Sylvia atricapilla*	1	0	4	0
Lesser Whitethroat *Sylvia curruca*	0	0	0	0
Common Whitethroat *Sylvia communis*	0	0	2	0
Marsh Warbler *Acrocephalus palustris*	0	0	0	0
Wilow Warbler *Phylloscopus trochilus*	16	0	19	0
Common Goldcrest *Regulus regulus*	7	0	8	0
Spotted Flycatcher *Muscicapa striata*	0	0	0	1
Pied Flycatcher *Ficedula hypoleuca*	0	0	0	0
Great Tit *Parus major*	3	0	3	2
Blue Tit *Parus caeruleus*	0	0	0	0
Coal Tit *Parus ater*	1	0	0	0
Crested Tit *Parus cristatus*	0	0	2	0
Marsh Tit *Parus palustris*	0	0	0	0
Willow Tit *Parus montanus*	0	0	1	0
Long-tailed Tit *Aegithalos caudatus*	0	0	0	0
Wood Nuthatch *Sitta europaea*	0	0	2	1
Eurasian treecreeper *Certhia familaris*	2	0	0	0
Red-backed Shrike *Lanius collurio*	1	0	2	0
Black-billed Magpie *Pica pica*	0	0	0	0
Eurasian Jay *Garrulus glandarius*	0	1	0	0
Hooded Crow *Corvus corone*	0	0	1	1
Common Starling *Sturnus vulgaris*	10	0	10	0
House Sparrow *Passer domesticus*	0	0	0	0
Eurasian Tree Sparrow *Passer montanus*	0	0	5	1
Chaffinch *Fringilla coelebs*	8	0	55	0
Brambling *Fringilla montifringilla*	5	0	1	0

Common Redpoll *Carduelis flammea*	1	0	0	0
European Greenfinch *Carduelis chloris*	0	0	5	2
Eurasian Siskin *Carduelis spinus*	0	0	0	2
Common Bullfinch *Pyrrhula pyrrhula*	0	0	0	0
Hawfinch *Coccothraustes coccothraustes*	0	0	0	0
Crossbill sp. *Loxia sp.*	0	0	0	0
Reed Bunting *Emberiza schoeniclus*	0	0	0	0
Yellowhammer *Emberiza citrinella*	12	0	21	1

Appendix 2. Number of prey items recorded at the nests

	Himsjø	Lurdalen	Løken	Slørstad	Solberg	Tierud	Torsnes
Species							
Red Squirrel *Sciurus vulgaris*	2		1		1		3
Capercaillie *Tetrao urogallus*	1 ad. f	2 juv.					
Black Grouse *Tetrao tetrix*	1 ad. f						
Hazel Grouse *Bonasa bonasia*					1		
Unid. Tetraonide *Tetraonidae*	1 + 2 juv.						
Common Wood Pigeon *Columba palumbus*		1	1		1		
Unid. Pigeon *Columbidae*	1				1		
Great Spotted Woodpecker *Dendrocopos major*		1					
Tree Pipit *Anthus trivialis*						1	
Song Thrush *Turdus philomelos*	3		3		2		
Redwing *Turdus iliacus*	1			1			
Mistle Thrush *Turdus viscivorus*		1					
Fieldfare *Turdus pilaris*		1				3	
Common Blackbird *Turdus merula*	6	2		4	1	2	1
Redwing/Song Thrush	4	3	13	3	3	6	5
Common Blackbird/Fieldfare						2	
Unid. Thrush *Turdus*	5	1	1	1		2	
Black-billed Magpie *Pica pica*		1		1	2		
Eurasian Jay *Garrulus glandarius*	2		5	4		2	5
Hooded Crow *Corvus corone*		1	2	3		2	7
Common Raven *Corvus corax*			1				
Black-billed Magpie/Jackdaw *Corvus monedula*						1	
Mallard *Anas platyrhnchos*/ Tetraonide	1						
Small passerines *Passeriformes*			2				
Unid. Bird		1			1		