Collecting prey remains vs. video recording prey deliveries: a comparison of two methods for assessing goshawk (*Accipiter gentilis*) diet during the breeding season

Byttedyrinnsamling vs. videofilming: en sammenligning av to metoder for å estimere dietten til hønsehauk (*Accipiter gentilis*) i hekkesesongen

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PREFACE

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ABSTRACT

Several techniques are available for the study of raptor diets, of which all have their inherent biases. However, some of them are assumed to be less biased than others. In this study, I compared two of the available methods to assess the diet of breeding goshawk *Accipiter gentilis* pairs (n=6). The first method applied was video recording of prey deliveries to the nests. The second method was sampling prey remains in the vicinity of the nests. Altogether, 144 individual prey were found as remains underneath the nest and at plucking posts, while 117 individual prey were registered from 288 hours of video recordings. The prey remains method had a higher ability to identify prey items to species (98.6 %) than video recordings had (67.5 %). The prey remains method also identified more species than the video recordings did, and hence yielded higher diversity indices. Moreover, there was twice as much juvenile/nestling prey in the prey remains relative to prey deliveries on video.

In the prey remains analysis, woodpigeon *Columba palumbus* was the most important species, both in terms of number of prey and biomass. In video recordings, blackbird *Turdus merula* was most important species in number, while hooded crow *Corvus corone cornix* was the most important in terms of biomass. The prey remains analyses overestimated the number of woodpigeons and large thrushes relative to video recordings. The estimated average prey size was higher with the prey remains method, compared to the video recordings.

Prey remains seem to be the most appropriate method for estimating the diversity in the diet, and obtaining information on the age structure of prey. The video recording method seems to be the most appropriate method to estimate the quantity of each species in the diet. I suggest using multiple methods to obtain an accurate estimate of the breeding season diet of goshawks. By doing this, it may be possible to reduce the biases produced by a single method.

SAMMENDRAG

Dietten til rovfugler kan studeres ved hjelp av en rekke ulike metoder. Felles for dem alle er at ingen av dem er helt nøyaktige, men enkelte metoder antas å gi et mer korrekt bilde av dietten enn hva andre metoder gjør. I dette studiet har jeg sammenlignet to metoder for å estimere dietten til seks hekkende par av hønsehauk *Accipiter gentilis*. De to metodene som er brukt er innsamling av byttedyr under reiret og på ribbeplasser, og videofilming av byttedyrleveringer på reiret.

I alt ble 144 individer av byttedyr samlet inn som rester fra ribbing, mens 117 individer ble registrert ut fra 288 timer med videofilming. Byttedyrinnsamlingene identifiserte flere bytter til artsnivå (98.6 %) enn det videofilmingene gjorde (67.5 %). Det ble også registrert flere arter ut fra byttedyrrestene enn fra videofilmene, hvilket førte til høyere diversitetsindekser i datamaterialet fra byttedyrrestene. Videre så var det dobbelt så mange juvenile og reirunger blant byttedyrrestene enn det var på videofilmene.

Ut i fra byttedyrrestene, var ringdue *Columba palumbus* den viktigste arten, både i form av antall og biomasse. I videofilmene var svartrost *Turdus merula* den viktigste arten i antall, mens kråke *Corvus corone cornix* var den viktigste i form av biomasse. Ringduer og store troster ble overrepresentert ut ifra byttedyrrestene. Videre var den estimerte gjennomsnittlige byttedyrstørrelsen lavere i videofilmene enn hva som var tilfellet i byttedyrrestene.

Innsamling av byttedyrrester synes å være den best egnede metoden for å estimere diversiteten i dietten til hønsehauken, samt aldersstrukturene på byttedyrene. Videofilming er derimot den best egnede metoden for å kvantifisere artene i dietten. Jeg foreslår at en bruker flere av de metodene som er tilgjengelige for å estimere dietten til hønsehauken til samme tid. På den måten kan man trolig redusere feilkildene fra den enkelte metode, og dermed øke muligheten for å få et mest nøyaktig bilde av hønsehaukens diett i hekkesesongen.

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CHAPTER I
INTRODUCTION

An unbiased estimation of diet composition is crucial for management of raptor populations. Firstly, it is important to know which prey species that are necessary to sustain a viable raptor population. By knowing this, it is possible for forest managers to develop conditions that foster the presence of important prey species and foraging habitats (Boal et al. 2001). It is also important to assess the raptors impact on prey species that are conservation-sensitive, such as the red squirrel *Scirus vulgaris* in England (Petty et al. 2002). Moreover, it is important to assess their impact on species that are harvested by humans (e.g. game species).

The majority of raptor diet studies focus on the breeding season, since it makes the dietary data relatively easier to collect (Lewis et al. 2004a). Several techniques are available to study their food habits, and each technique has its inherent advantages and disadvantages. None of the methods are however unbiased (Collopy 1983, Mersmann et al. 1992). The most common method to study the goshawk's *Accipiter gentilis* diet has been collecting prey remains at the nest or plucking posts (Opdam et al. 1977, Tornberg 1997). In this anlysis, as with the others, researchers reconstruct the diet by counting the minimum number of individuals present and assume that it provides a representative picture of the true diet (Booms & Fuller 2003). However, this method may result in incomplete or biased data (Widen 1987, Redpath et al. 2001). One of the reasons is that large and pale remains are often easier to detect than small and dark ones (Opdam et al. 1977, Selås 1989a, Bielefeldt et al. 1992, Redpath et al. 2001). Small prey may also be swallowed whole, leaving no remains (Tornberg 1997, Toyne 1998). Moreover, collection of prey remains to assess the diet of raptors can result in bias favouring birds. Such bias toward avian items has been revealed when comparing prey remains with direct methods (observations, video) in cooper's hawks *Accipiter cooperii* (Bielefeldt et al. 1992) and goshawks (Lewis et al. 2004a). The reason is probably that feathers in general, are easier to detect than other remains (Errington 1932, Selås 1989a, Bielefeldt et al. 1992). During the breeding season, goshawk diet contains many fledglings from which few remains will be left. Hence, prey remain analysis will result in an underestimation of such prey (Widen 1987, Selås 1989a). Results from collecting prey remains may also be biased due to loss of remains to scavengers, especially for the larger prey types (Selås 1989a, Toyne 1998, Rogers et al. 2005). On the other hand, large prey remains will persist longer in the environment. Since goshawks often move around while plucking their prey (Opdam et al. 1977), there is also a potential risk of double counting prey from remains. The probability for changing between plucking posts depends on the prey handling time, hence the risk of double counting increases with increasing size of prey (Selås 1989a). The potential risk of double counting will be most evident in common bird species, and also for birds with unichromated plumage (Selås 1989a).

Sampling of pellets is another common method used to assess raptor diet. This method is often biased due to the presence of different parts of the same prey in more than one pellet. Conversely, a pellet can also contain several individuals of the same small prey species. Furthermore, bias can occur when applying this method to Falconiiformes, since their gastric juices can digest most bones (Errington 1932). Additionally, secondary consumption of prey (e.g. arthropods) eaten by the prey species can lead to bias (Trejo et al. 2005). Examination of the nestlings gullets is regarded as a reliable method to obtain quantitative prey data, but is very invasive and labour intensive (Errington 1932). Another technique, examination of stomachs, is not reliable for quantitative data. This is because of different digestibility of prey items. This method also requires a sufficient sample of dead birds (Errington 1932).

Direct observations are assumed to be less biased than the previously mentioned methods (Manosa 1994, Redpath et al. 2001). However, even with high coverage, direct methods may still lack some prey species purely of stochastic reasons (Huang et al. 2006). Direct observations also have their disadvantages. For example, the method is very labour-demanding, so usually only a few nests are sampled during a season (Errington 1932, Collopy 1983, Redpath et al. 2001, Huang et al. 2006). Furthermore, identifying prey through spotting scopes has its difficulties, and often only identification to the upper taxonomic levels is provided. This can lead to bias towards easily identifiable prey (Mersmann et al. 1992, Trejo et al. 2006). Additionally, radio-tracking of adult goshawks has been used as a method to assess diet, both in the breeding season (Rutz 2003) and in winter (Widen 1987). The method is however labour-intensive, and as with the other techniques, small prey swallowed whole may be missed (Rutz 2003).

Remote video recording of raptor nests has become increasingly popular, especially as equipment costs decrease (Rogers et al. 2005). This method is believed to be well suited for collecting data on prey delivery rates and activity at nests (Grønnesby & Nygård 2000). Time-lapse video recording has been used in raptor studies since the early 1970's (Booms & Fuller 2003), and is regarded as less labour-intensive compared to large-scale sampling of prey remains (Lewis et al 2004a). However, several studies have relied solely on indirect methods even after the introduction of remote video recording (e.g. Widen 1987, Selås 1989b, Squires 2000, Petronilho 2002, Promessi 2004).

Goshawks are predominantly ornitophagous, but they also prey on mammals, reptiles and insects (Petronilho & Vingada 2002). Several North American studies report mammals as the dominant prey type (e.g. Promessi et al. 2004, Rogers et al. 2005, Smithers et al. 2005). The diet of goshawks does not appear to be a random sample of prey species present, but reflects the availability and vulnerability of the specific prey types (Opdam 1977, Manosa 1994, Tornberg 1997). The number of species preyed upon, and each species contribution to the total amount, varies among seasons and regions. Number of species preyed upon by goshawks in the breeding season range up to 40 or more (e.g. Selås 1989b, Toyne 1998). However, the bulk of the diet usually consists of a few species (e.g. Opdam (1977); five species accounted for 75 % of the total number, Selås (1989b); eight species accounted for 60 % of the total number, and Smithers et al. (2005); five species accounted for 82 % of the total number). Gallaniceous birds, lagomorphs, sciurids, corvids and woodpeckers are prey groups particular important in most goshawk populations (Roberson et al. 2003). Small prey, such as small passerines and voles, are little used as prey even though they are highly available (Tornberg 1997, Selås 1989b).

The main aim of this study was to compare two methods of estimating breeding season diet in goshawks, and evaluate their suitability for future work. The first method was sampling prey remains in the vicinity of nest trees, and the other was using digital video to record prey deliveries to the nests. The main questions were: i) Are there any differences in the taxonomic composition as represented by the two methods? ii) Are there differences in the proportions of weight classes with regard to the method used? iii) What are the advantages and disadvantages of each method to identify prey? iv) How can researchers apply the appropriate technique when sampling different kinds of dietary information on raptors?

I hypothesised that there would be: i) biases towards items showing conspicuous characters (size and colour) when using the prey remains method, and ii) a larger amount of immature prey (juveniles/nestlings) observed on video, because of their smaller size and less developed plumage.

CHAPTER II
METHODS

Study area

Data were sampled from goshawk nests in two different areas of Southeast Norway, separated by 60 km and located on opposite sides of the Oslofjord. The first area includes Ås and Frogn municipalities (59°39' N, 10°47' E), which is located in Akershus County. The second area includes Øvre-Eiker municipality (59°46' N 9°50' E), which is located in Buskerud County. Known and potential goshawk nesting areas in old forest stands were searched in the period of April-May 2005. Of the nest sites found, six were chosen for this research, and approvals from the landowner's were obtained before the initial start-up. Nests hereafter named 1, 3 and 4 where located in Ås municipality, nest 2 in Frogn municipality, and nest 5 and 6 in Øvre-Eiker municipality.

Nests in Ås and Frogn are in the boreonemoral zone, with a climate characterised by warm and dry summers, and relatively mild winters. Mean annual precipitation is 785 mm and mean annual temperature is 5.3 °C (Hansen & Grimenes 2006). Elevations range from ocean level to 172 m a.s.l. The landscape is dominated by agricultural land and fragmented forest. The amount of agricultural land mainly consists of cereal crops. Forest stands are affected by forestry, and characterised by clear-cuttings and even-aged stands (Bratli 2000). The dominating tree species are Norway spruce *Picea abies* and Scots pine *Pinus sylvestris*, with an admixture of deciduous trees such as birch *Betula pubescens*, goat willow *Salix caprea*, grey alder *Alnus incana*, and aspen *Populus tremula.*

Nests in Øvre-Eiker are situated in the middle boreal zone. The area has a more roughed topography compared to Ås and Frogn, with elevations ranging from 150 to 546 m a.s.l. The landscape is dominated by coniferous forest, mainly Scots pine. It is also characterised by a larger proportion of lakes, ponds and bogs compared to Ås and Frogn. Agricultural land also exists in this area, but it is located farther away from the goshawk nests compared to what is the case in Ås and Frogn.

Collection of prey remains

Prey remains were collected between 28 May and 12 July 2005, at the six nests where video monitoring also was conducted. Prey remains of older date were removed before the initial start-up, and not counted in the data material. The remains were collected from beneath the nest and at plucking posts within 150 m from the nest tree, typically from fallen trees, stones and other outcrops in the terrain. Prey remains were feathers, bills, legs, fur, tails, and skeletal remains with fresh meat. Collections were conducted on the evening before video recording, after video recording, and on days without video recording. Each nesting area were on average sampled 8 ±1.14 times, ranging from 4 to 12, during the breeding season. Differences in sampling were due to accessibility and available manpower in the different nesting areas.

To avoid duplicate sampling of prey: all prey remains were removed up on each visit, and remains found were compared to remains of the same species found elsewhere at the same period of time, pairing bilateral elements such as legs or primaries. The number of individuals presented from prey remains, is the minimum number of individuals. If there was doubt of prey remains belonging to one or two individuals, it was counted as only one individual. Some remains of rock dove *Columba livia* are inseparable of those of a woodpigeon *Columba palumbus*. In those cases, I assumed the prey to be a woodpigeon, since this species is more common in the hunting areas of the goshawks.

All prey remains collected were put in envelopes or plastic bags and labelled with the location and date for later examination. Identification of the prey items was facilitated by comparison with a reference collection of feathers and skeletal remains. When possible, remains were identified to species, sex and age. I did not attempt to track any specific individual prey found as remains on video tapes recorded.

Video recording

The six nests were video monitored between 1-28 June 2005. Each nest was monitored for four days; two days early in the breeding season and two days in the later part (Table 1). Twelve hours were recorded per day, from 06.00 hours to 18.00 hours. Each video recording system consisted of a lens, a recorder, two batteries, and 100 metres of cables. The lens was a wired 18LED night vision colour CCTV camera; waterproof for outdoor use, sensitization area: 3.3 mm x 4.4 mm, minimum illumination: 0 lux, dimensions: 50 x 45 x 45 mm. For recording, a digital camcorder Canon MV700i was used. The power supply for the recorder and the lens was a 12 voltages lead battery each (10 Ah). The battery for the recorder had a self-constructed voltage converter (from 12 to 8.4 voltages). Approximately 25 m of cables connected the lens to the battery placed underneath the nest tree. Modified RCA video cables, 75 m long, transmitted video images from the lens to the recorder. The power supplies provided for > 24 h of use for the recorder and > 36 h of use for the lens, before recharging was necessary.

Before installing lenses and cables, hatching of nestlings was confirmed from evidence beneath the nest (nestling excreta, prey remains). Usually a minimum of three persons was necessary for installing the video recording system. Nest trees were accessed by one person using free climbing, or by the aid of a ladder or tree spikes. In trees that were especially tall or had weak branches, climbing gear was necessary (ropes, harness, descender, carabiners, and helmet). When a nest was accessed, the lens was mounted on a branch above the nest bowl. Then while aiming the lens down at the nest, an assistant on the ground directed placement by watching the image on the video camera used to record. The third person secured (anchored) the person in the tree when climbing/abseiling. The lens was placed in the nest tree approximately 0.5-1.5 m from the nest, positioned to cover as much of the nest as possible (Fig. 1). For two of the nest trees, the lens was installed on an adjacent tree. A hide was established 50-75 m away from the nests, and the recorder was placed there. The battery for the recorder was placed with the camera in the hide.

An observer stayed in the hide during filming and changed videotapes every 2 hours. Videotapes used were Panasonic DVC (120 min LP mode). Time to the nearest second and date was encoded automatically on the video recordings. Video recording was usually conducted by two persons with one shift each per day (4 hours in the nest and 2 hours of tape rolling without anyone present in the hide). Occasionally 12 hours shifts by one person were necessary. The hide was placed out of view from the nest and the adults landing perches, so the observer could step outside of the hide for short breaks. Efforts were made to minimise time spent on installing video systems, and thereby avoiding unnecessary stress to nestlings and adult birds. The camera systems were on average installed 2 ± 0.33 days before video recording.

After the field season had ended, the videotapes were viewed on a 32-inch colour television using the same camera used to record. Slow motion and frame-by-frame functions were used to facilitate identification of prey delivered on the nests. Prey deliveries were compared to a reference collection at the Norwegian University of Life Sciences, consisting of stuffed specimens of goshawks and their potential prey. We also used fresh bodies of hooded crow *Corvus corone cornix*, jay *Garrulus glandarius*, fieldfare *Turdus pilaris*, song thrush *Turdus philomelos* and great tit *Parus major,* which we plucked*,* and then compared to the size of stuffed specimens and a goshawk tarsus. When possible, deliveries were identified to species, sex and age.

The estimated hatching date and age of the nestlings on camera installation were determined when viewing the videotapes. Characteristics used to identify their age was size and feather patterns

Fig 1. Image of a female goshawk feeding her nestlings. The picture was taken from video footage at one of the six nest recorded. The camera angle used at this nest was preferred.

Most prey were plucked before delivery to the nest, and some were delivered in parts. This made identification sometimes a difficult task. When present, the size, shape and colour of the legs, still often seemed to allow identification at family level. Unidentified deliveries were due to poor light and colours, or adults/nestlings blocking the view of some parts of the prey. The image quality did often not reveal enough detail to distinguish between thrushes, especially between song thrush and redwing

Calculating biomass

Body masses of avian prey (Appendix 3) were obtained from Cramp & Simmons (1977, 1980), Cramp (1985, 1988), Cramp & Perrins (1993, 1994), and after Selås (2001). If available, body mass data from the species in Norway and from the period of May-June was used. Biomass of prey items was calculated by using an estimate of the average live mass of a prey found as remains or delivered to nest. The actual eaten mass would be lower, especially for the larger species.

The mass of juvenile birds were set to 2/3 of adult body mass (Toyne 1998), and nestlings were assigned as juveniles. Unidentified thrushes were set as the average mass of all the five thrush species present. Prey items that were identified to be either one out of two species, were set as the average mass of those two species. Red squirrels were given a weight of 300 g (after Selås 2001). One juvenile Mountain Hare *Lepus timidus* was given a weight of 1.5 kg, which is about 1/2 of adult body mass. Capercaillie *tetrao urogallus* and black grouse *Tetrao tetrix* were assigned to a weight for each sex, due to their large sexual dimorphism. For prey items where determining sex was not possible, I used mean mass of both sexes. Tetranoids are nidifigous species, and their juveniles were assigned a weight of 150 g (Cramp & Simmons 1980).

Table 1. The estimated date of hatching for the six nests studied, their number of nestlings, and their age (days) at first video recording in each of the two periods recorded on video.

Nest ID	Estimated date of hatching	Number of nestlings at period 1	Estimated age at period 1	Number of nestlings at period 2	Estimated age at period 2
1	18 - May	4	18	4	34
2	25 - May	4	8	3	32
3	2 - June	3	6	3	26
4	27 - May	3	14	3	25
5	26 - May	2	19	2	31
6	27 - May	3	15	3	32
Mean	26 May	3.2	13	3	30
SE	2.41	0.31	2.16	0.26	1.48

Statistical analysis

Normality test of the data was done by Shapiro-Wilk test. Since the data failed to apply to a normal distribution even with transformation, non-parametric tests were used. For data pooled across nests, chi-square tests were performed. For data by nest, compositional analysis, Shannon's index, and cluster analysis were used.

Chi-square test was used to test for difference between the two methods in the proportions of large thrushes (mistle thrush *Turdus viscivorus*, fieldfare, blackbird *T. merula*) and small thrushes (song thrush, redwing *T. iliacus).*

Compositional analysis was performed with weight classes as groups. The weight groups used were: < 85 g, 85-130 g, 130-300 g, 300-600 g, and > 600g. The test was only performed for adult avian prey, excluding eight unidentified thrushes. Compositional analysis was also conducted for five groups of prey types: pigeons, tetranoids, corvids, large thrushes and small thrushes. Compositional analysis is originally an analysis for habitat use, but is also suited for the analysis of diets (Aebischer et al. 1993). This analysis uses nests as individuals instead of pooling all nests. By doing this, it is possible to avoid interaction from dietary differences between areas. Zero values are invalid as numerator or denominator in log-ratio transformations, and were replaced with a value of 0.001 (Aebischer et al. 1993).

Shannon's index is a commonly used index to explain biological diversity (Spellerberg & Fedor 2003). I used this index to examine for differences in measure of prey diversity with regard to the two methods used to identify prey.

Shannons' index is denoted by: $H' = - \sum pi \ln pi$, where pi represents the proportion of each species in the sample. High values of Shannon's index indicate high diversity. Shannon's Evenness index was used as a measure of evenness in the relative abundance of the species. Shannon's Evenness index is denoted by: $E_H = H/H_{max} = H/\ln S$, where S represents the number of species present in the sample. The values of the evenness index, varies between 0 and 1. When the index equals 1, each species is represented in equal numbers. Lower values indicate high dominance by one species. Differences in Shannon's indices were tested with Wilcoxon signed ranks test.

To examine for similarity in prey use as represented by the two methods, I used cluster analysis dendograms. Clusters were made with the un-weighted pair-group method (UPGMA). Average distance was used for quantitative data and jaccard's coefficient for qualitative data (presence/absence).

Minitab 14.0 was used for calculating the chi-square test, while compositional analysis was conducted in Microsoft Office Excel 2003. Wilcoxon signed ranks tests were performed with SPSS version 14.0. Cluster analyses and diversity indices were performed with Multivariate statistical package 3.12 (MVSP). The null hypothesis of no difference among results represented by the two methods, were rejected at $\alpha < 0.05$. When appropriate, mean ± standard error and range are indicated.

CHAPTER III
RESULTS

Diet estimation from prey remains

From collections of prey remains, a total of 144 individuals were identified, of which 98.6 % were identified to species level. Of the prey remains sampled, there were 24 avian species and 2 mammalian species. Birds and mammals respectively, compromised 97.2 % and 2.8 % of the diet. The mean number of individual prey found at each nest site was 24 ± 1.65, ranging from 17 to 28. Juvenile and nestling prey made up 27 % of the total prey number (Table 4).

In descending order, the five most frequent prey species were woodpigeon, fieldfare, blackbird, magpie *Pica pica,* and jay. These five species made up 70 % of the total prey number (Table 2). Woodpigeon, capercaillie, and black grouse accounted together for more than half of the total biomass (Table 3.).

Estimated total biomass for avian prey was 39099 g (94.2 %) and 2400 g (5.8 %) for mammalian prey. Estimated average prey size was 288 ± 27.9 g. For avian prey it was 279 ± 27.4 g and for mammalian prey it was 600 ± 300 g.

Diet estimation from video recordings

A total of 117 prey individuals were identified from the 288 hours of videotape collected from the six nests. The mean number of individual prey delivered at each nest was 20 ± 2.60, ranging from 13 to 31. From prey deliveries, 67.5 % of the individuals were identified to species level. Of the identified prey, there were 15 bird species and one mammal species. Birds and mammals compromised 94.9 % and 5.1 % of the diet, by number respectively. Juvenile and nestling prey made up 13.7 % of the total prey number (Table 4).

The most frequent prey was the category redwing/song thrush, followed by blackbird, hooded crow and jay (Table 2). In terms of biomass, hooded crow was the most important prey, followed by woodpigeon, capercaillie, jay, and red squirrel. These five species accounted for more than half of the biomass (Table 3).

Table 2. Number and percent occurrence of mammalian and avian prey found as prey remains or recorded by video on delivery to six goshawk nest in Southeastern Norway, during the breeding season of 2005.

Prey Category	Common name	Prey remains (n = 144)		Video recordings (n = 117)	
		N	%	N	%
Birds					
Columba palumbus	Woodpigeon	31	21.5	5	4.3
Columba livia	Rock dove	2	1.4	0	0.0
Tetrao urogallus	Capercaillie	3	2.1	3	2.6
Tetrao tetrix	Black grouse	3	2.1	1	0.9
Bonasa bonasia	Hazel grouse	1	0.7	1	0.9
Ardea cinera	Grey Heron	1	0.7	0	0.0
Anas platyrhynchos	Mallard	1	0.7	0	0.0
Anas spp.	Domestic duck	1	0.7	0	0.0
Corvus corone cornix	Hooded crow	5	3.5	13	11.1
Pica pica	Magpie	15	10.4	4	3.4
Garrulus glandarius	Jay	10	6.9	13	11.1
Corvus monedula	Jackdaw	1	0.7	0	0.0
Drycopus martius	Black woodpecker	1	0.7	0	0.0
Dendrocopos major	Great spotted woodpecker	4	2.8	1	0.9
Turdus viscivorus	Mistle thrush	1	0.7	1	0.9
Turdus pilaris	Fieldfare	23	16.0	4	3.4
Turdus merula	Blackbird	21	14.6	16	13.7
Turdus iliacus	Redwing	3	2.1	2	1.7
Turdus philomelos	Song thrush	5	3.5	5	4.3
Sturnus vulgaris	Starling	2	1.4	0	0.0
Alauda arvensis	Sky lark	1	0.7	0	0.0
Anthus trivialis	Tree pipit	1	0.7	1	0.9
Fringilla Coelebs	Chaffinch	2	1.4	0	0.0
Sitta europaea	Wood nuthatch	1	0.7	0	0.0
Birds not identified to species level					
Turdus spp.	Redwing/Song thrush	1	0.7	24	20.5
Turdus spp.	Fieldfare/Blackbird			2	1.7
Turdus spp.	Unidentified thrush			9	7.7
Tetranoidae spp.	Tetraonid			3	2.6
	Tetranoid/Mallard			1	0.9
Corvidae spp.	Magpie/jackdaw			1	0.9
	Approx. size of hooded crow			1	0.9
Mammals					
Lepus timidus	Mountain Hare	1	0.7	0	0.0
Sciurus vulgaris	Red Squirrel	3	2.1	6	5.1

Table 3. Estimated biomass of prey found as prey remains or recorded by video on delivery to six goshawk nest in South-eastern Norway, during the 2005 breeding season. g = biomass in grams.

Prey Category	Common name	Prey remains (n = 144)		Video recordings (n = 117)	
		g	%	g	%
Birds					
Columba palumbus	Woodpigeon	15015	36.2	2475	10.0
Columba livia	Rock dove	740	1.8	0	0.0
Tetrao urogallus	Capercaillie	4120	9.9	2285	9.2
Tetrao tetrix	Black grouse	3321	8.0	945	3.8
Bonasa bonasia	Hazel grouse	372	0.9	372	1.5
Ardea cinera	Grey Heron	1200	2.9	0	0.0
Anas platyrhynchos	Mallard	1029	2.5	0	0.0
Anas spp.	Domestic duck	1029	2.5	0	0.0
Corvus corone cornix	Hooded crow	2500	6.0	6333	25.6
Pica pica	Magpie	2840	6.8	710	2.9
Garrulus glandarius	Jay	1286	3.1	2093	8.4
Corvus monedula	Jackdaw	235	0.6	0	0.0
Drycopus martius	Black woodpecker	318	0.8	0	0.0
Dendrocopos major	Great spotted woodpecker	360	0.9	90	0.4
Turdus viscivorus	Mistle thrush	119	0.3	119	0.5
Turdus pilaris	Fieldfare	2170	5.2	420	1.7
Turdus merula	Blackbird	1643	4.0	1392	5.6
Turdus iliacus	Redwing	168	0.4	126	0.5
Turdus philomelos	Song thrush	293	0.7	293	1.2
Sturnus vulgaris	Starling	160	0.4	0	0.0
Alauda arvensis	Sky lark	40	0.1	0	0.0
Anthus trivialis	Tree pipit	23	0.1	23	0.1
Fringilla Coelebs	Chaffinch	46	0.1	0	0.0
Sitta europaea	Wood nuthatch	24	0.1	0	0.0
Birds not identified to species level					
Turdus spp.	Redwing/Song thrush	46	0.1	1633	6.6
Turdus spp.	Fieldfare/Blackbird			200	0.8
Turdus spp.	Unidentified thrush			788	3.2
Tetranoidae spp.	Tetraonid			450	1.8
	Tetranoid/Mallard			1507	6.1
Corvidae spp.	Magpie/jackdaw			224	0.9
	Approx. size of hooded crow			500	2.0
Mammals					
Lepus timidus	Mountain Hare	1500	3.6	0	0.0
Sciurus vulgaris	Red Squirrel	900	2.2	1800	7.3

Table 4. Juvenile/nestling prey identified from prey remains and video recordings at six goshawk nests in Southeast-Norway during breeding season 2005.

	Prey remains		Video recording	
	N	%	N	%
Woodpigeon	2	5.1	0	0.0
Capercaillie	1	2.6	2	12.5
Unknown Tetranoid	0	0.0	2	12.5
Grey Heron	1	2.6	0	0.0
Hooded crow	0	0.0	1	6.3
Magpie	5	12.8	2	12.5
Jay	6	15.4	0	0.0
Fieldfare	7	17.9	0	0.0
Blackbird	11	28.2	4	25.0
Song thrush	3	7.7	3	18.8
Redwing	1	2.6	0	0.0
Redwing/song thrush	1	2.6	1	6.3
Mountain Hare	1	2.6	0	0.0
Unknown Thrush	0	0.0	1	6.3

Estimated biomass for avian prey was 22980 g (92.7 %) and 1800 g (7.3 %) for mammalian prey. Average size of all prey was 212 ± 24.5 g. For avian prey it was 207 ± 25.8 g and for mammalian prey it was 300 ± 0 g.

Of the 117 deliveries of individual prey to nests, the delivering adult was identified 107 times. The male delivered on nests 34 times (31.8 %), whereas the female delivered prey to the nestlings 73 times (61.8 %). Note that this does not reflect which of them that had killed the prey.

Comparison of techniques

The contribution of each of six major prey groups to the total biomass differed among the two methods to identify prey (Fig. 3). Similarly, the frequency of each of the same prey groups differed among the two methods to identify prey (Fig 4). Moreover, the proportion of large and small thrushes differed significantly between the two methods ($\chi^2 = 19.22$, DF = 1, $P < 0.001$). The proportions of large thrushes were higher than the proportion of small thrushes in prey remains. In video recordings, the situation was the opposite, with a larger proportion of small thrushes.

The proportions of taxonomic groups of birds differed significantly between the two methods (Wilk's $\Lambda = 0.1349$, $\chi^2 = 12.01$, $P = 0.0172$). Pigeons were significantly overestimated by the prey remains method compared to video recordings. There was no significant result in the other prey groups (Table 5, Fig. 4). The proportions of weight groups also differed significantly between the methods used to identify prey (Wilk's $\Lambda = 0.0029$, $\chi^2 = 34.96$, $P < 0.001$). The ratio of prey remains to prey on video was significantly lower among small prey (< 85 g) than in weight groups 85-130 g, 300-600 g, and > 600 g. Furthermore, the ratio of prey remains to prey on video was almost significantly lower in prey group 85-130 g compared to prey group > 600 g, and significantly lower in weight group 130-300 g than in weight group > 600g (Table 6, Fig. 5).

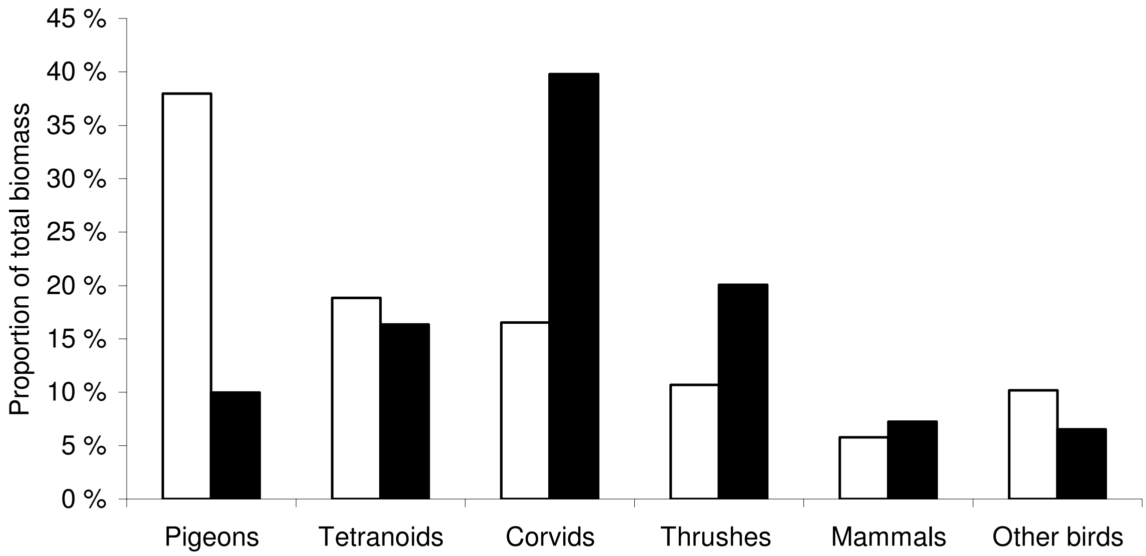

Fig 3. The contribution of different prey groups to the total biomass as represented by two methods for assessing goshawk diet. Open bars = prey remains, filled bars = video recording.

Table 5. A comparison of results from two methods of estimating the proportion of different taxonomic groups among goshawk prey. The matrices give the mean log-ratio differences (mean ± SE), which are based on comparing proportions given by prey remains with proportions given by video recording at each nest. The log-ratio differences of the lower left part of the matrices, corresponding to those of the upper right with opposite signs, are substituted with corresponding p-values. Rows are ranked according to the number of positive log-ratio differences. A low rank indicates that the taxonomic group is underestimated from prey remains, whereas a high rank indicates overestimation.

Prey groups	Pigeons	Corvids	Thrushes	Tetranoids	Other birds	Rank
Pigeons		5.68 ±1.46	6.09 ±1.07	4.59 ±1.15	4.72 ±0.92	4
Corvids	0.008		0.41 ±0.55	1.08 ±1.81	-0.95 ±2.12	1
Thrushes	0.001	0.481		1.50 ±1.59	-1.36 ±1.67	0
Tetranoids	0.007	0.571	0.382		0.01 ±1.79	3
Other birds	0.002	0.679	0.445	0.942		2

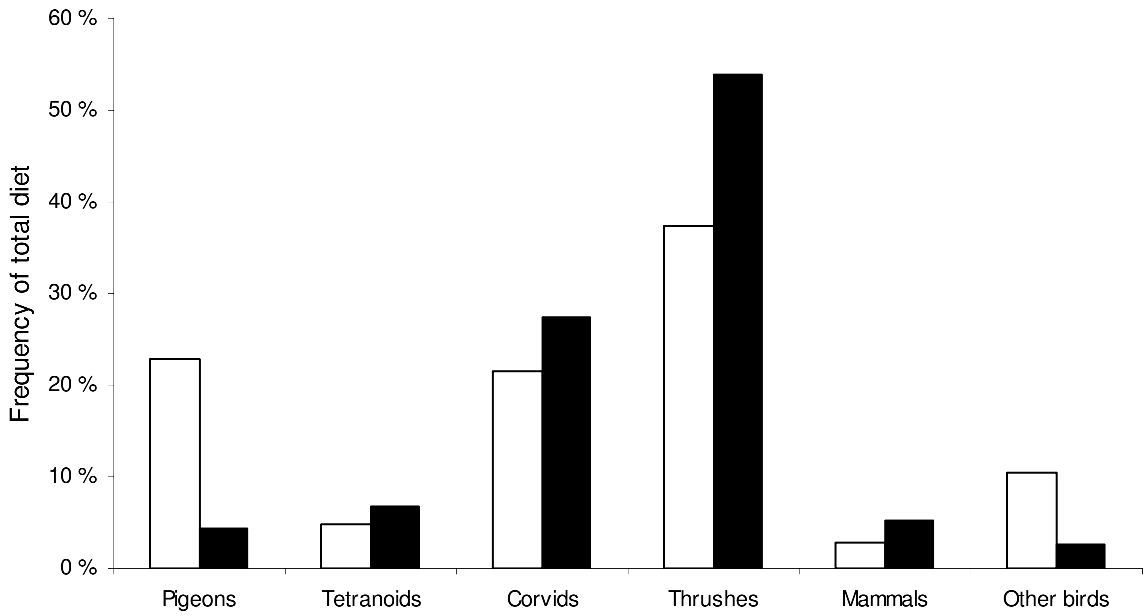

Fig 4. The frequency of different prey groups as represented by two methods for assessing goshawk diet. Open bars = prey remains, filled bars = video recording.

Table 6. A comparison of results from two methods of estimating the proportion of different weight groups among goshawk prey. The matrices give the mean log-ratio differences (mean ± SE), which are based on comparing proportions given by prey remains with proportions given by video recording at each nest. The log-ratio differences of the lower left part of the matrices, corresponding to those of the upper right with opposite signs, are substituted with corresponding p-values. Rows are ranked according to the number of positive log-ratio differences. A low rank indicates that the weight group is underestimated from prey remains, whereas a high rank indicates overestimation.

Prey weight (g)	<85	85-130	130-300	300-600	>600	Rank
<85		-3.04 ±1.04	-2.71 ±1.79	-3.31 ±0.77	-5.79 ±1.94	0
85-130	0.027		0.33 ±1.60	-0.27 ±0.99	-2.75 ±1.18	2
130-300	0.181	0.842		-0.60 ±1.77	-3.08 ±1.21	1
300-600	0.005	0.795	0.745		-2.48 ±1.75	3
>600	0.025	0.059	0.043	0.206		4

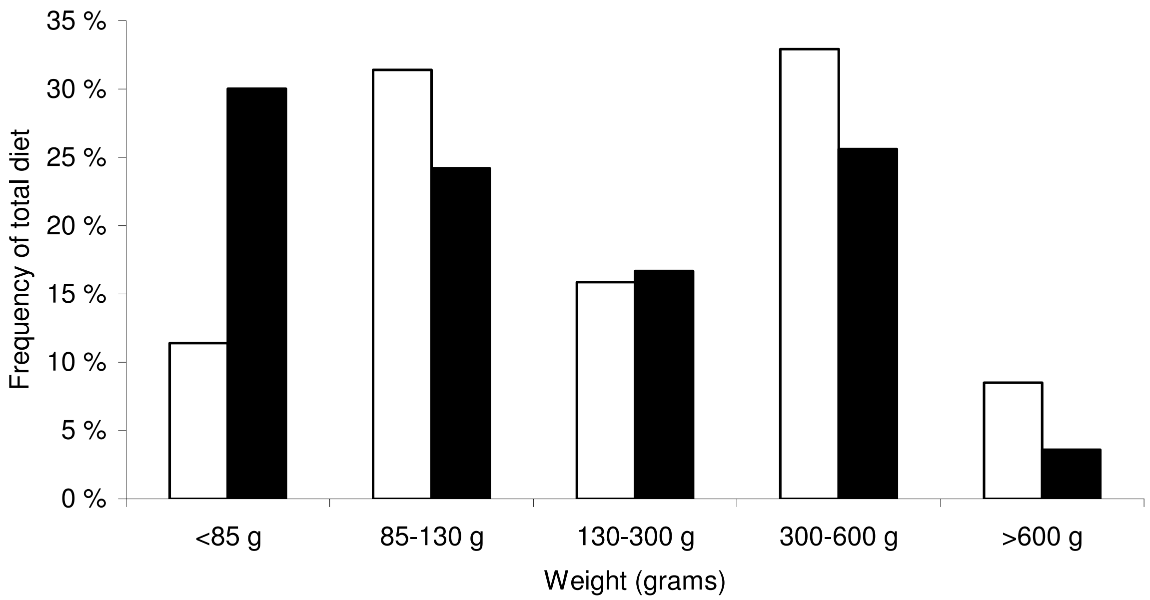

Fig 5. The frequency of prey in different weight classes as represented by two methods for assessing goshawk diet. Open bars = prey remains, filled bars = video recording.

The prey remains method gave a higher measure of prey diversity compared to video recording (H = 2.549 vs. H = 2.269, all nest pooled). The difference in Shannon's indices between the two methods was significant (Wilcoxon signed ranks test, W = 21, P = 0.028). The prey remains method gave a lower evenness index compared to video recording E = 0.782 vs. E = 0.860), but the result was not significant (W = 4, P = 0.173).

The cluster analyses revealed a low degree of similarity between both nests and methods used to identify prey. In quantitative data, video recording from nest 4 and prey remains from nest 6 had the highest degree of similarity. Prey remains from nest 1 and nest 3 had the highest degree of dissimilarity (Fig. 6). In qualitative data, video recordings from nest 1 and nest 3 exhibited the highest degree of similarity. The least degree of similarity was shared by prey remains found at nest 5 and 6, and prey remains at nest 3 and 4 (Fig. 7).

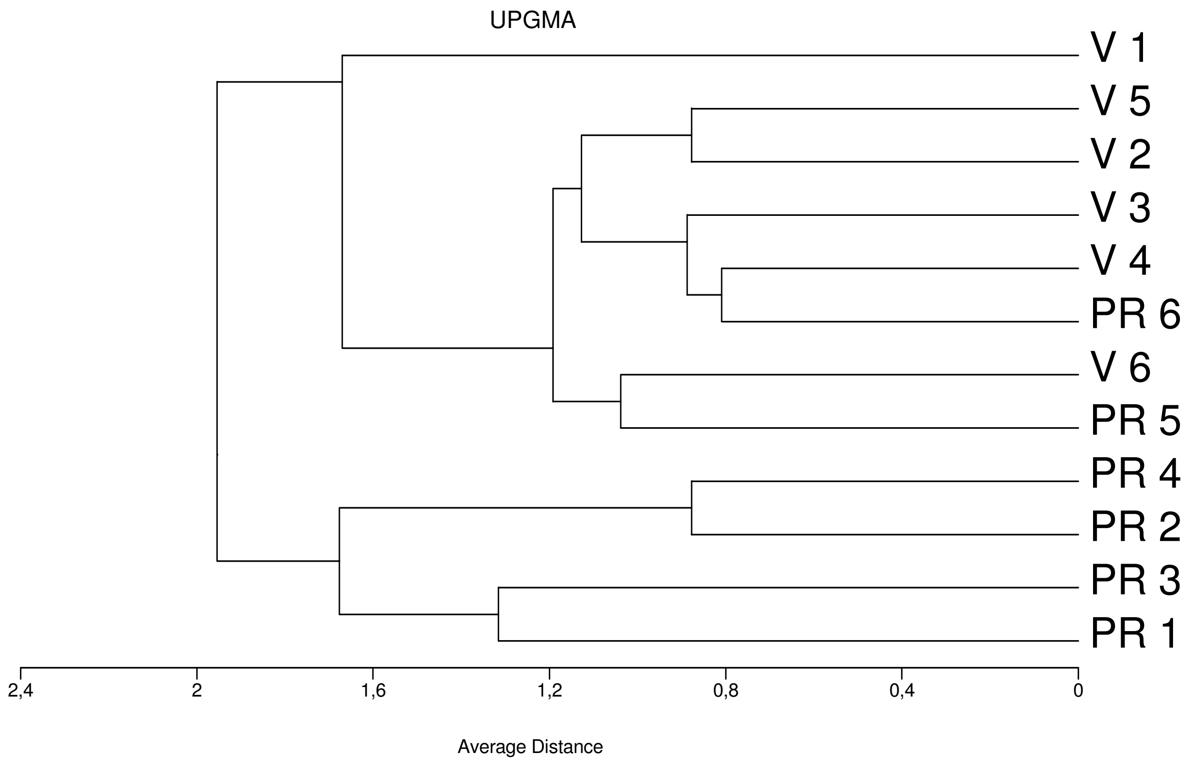

Fig 6. Cluster analysis dendogram for quantitative information on goshawk diet in South-eastern Norway, during the breeding season of 2005. Letters represent method used (PR = prey remains method, V = video recording method), whereas numbers (1-6) indicate at which nest the respective method was used.

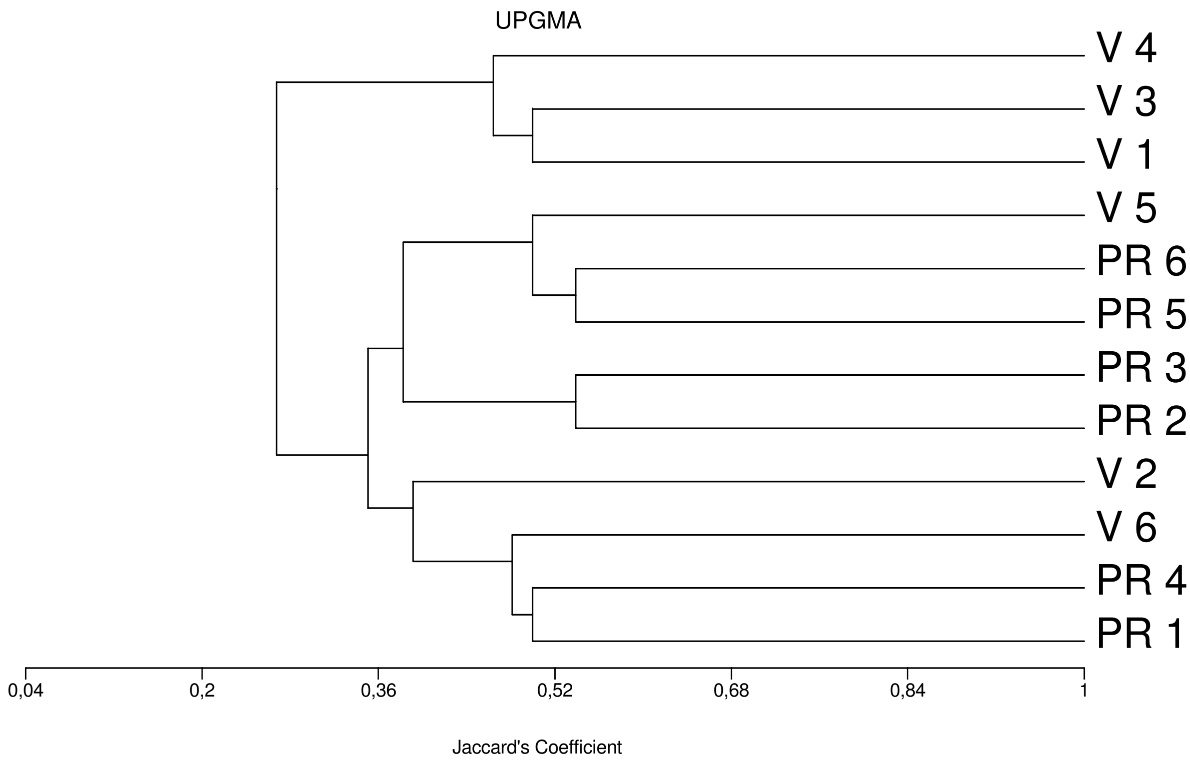

Fig 7. Cluster analysis dendogram for qualitative information on goshawk diet in South-eastern Norway, during the breeding season of 2005. Letters represent method used (PR = prey remains method, V = video recording method), whereas numbers (1-6) indicate at which nest the respective method was used.

CHAPTER IV

DISCUSSION

Comparison of techniques

The level of taxonomic determination differed between the two methods. The prey remains method identified more species than the video recordings did, similar to findings by Grønnesby & Nygård (2000). The ability to identify 67.5 % of the prey deliveries on video tapes to species level, is similar or exceeds the level of identification in other goshawk studies (Grønnesby & Nygård 2000; 25.6 % and 2.3 % identified to species, Smithers et al. 2005; 69 % identified to species, Rogers et al. 2005; 62 % identified to genus). Booms & Fuller (2003) identified 54 % of prey deliveries at Gyrfalcon *Falco rusticolus* nests in West Greenland using time-lapse video. The ability to identify prey to species level in my study was high using the prey remains method (98.6 %). Other studies using prey remains analysis have also had a high identification rate to species level (Grønnesby & Nygård 2000; 85 %, Rutz 2003; 95 %).

Immature prey made up 13.7 % of all prey deliveries on video, in contrast to the prey remains, where 27 % of all prey were juveniles or nestlings. The latter is in accordance with another prey remains study in Southern Norway (i.e. Selås 1989b). Lewis et al. (2004a) reported that video recordings gave more complete information on the age structure of prey than prey remains did. This was because the video method made it possible to identify prey from other characteristics than just feather development, for instance the size of the prey. They also concluded that birds identified from prey remains were predominantly adults, probably because nestlings were rarely plucked. As opposed to Lewis et al. (2004a), the highest percentage of juveniles and nestlings in my study were obtained from prey remains data, not from video recordings as I predicted. However, data obtained from video recordings in my study, may have underestimated the proportion of young birds to some extent. This because several heavily plucked prey items may have been assigned as adults, even if they were not. Grønnesby & Nygård (2000) stated that the video method was superior in detecting unfeathered young prey. In my study, the video method seemed to have a similar ability when it came to unfeathered prey robbed from nests.

The two methods were fairly similar in estimating the proportion of avian prey and mammalian prey in the diet, both in terms of frequency and biomass. However, they differed in the contribution of each species to the total number or biomass. Furthermore, different results were obtained in the estimation of the most important prey species. In the prey remains analysis, the most important prey species was woodpigeon, both in terms of number of prey and biomass. Petty et al. (2002) also found pigeons as the most abundant prey group in analyses of goshawk prey remains in England. Moreover, Widen (1987) studied goshawk breeding season diet by means of sampling prey remains. His results from South Central Sweden indicated that woodpigeon was the most frequent single species in goshawk diet, but capercaillie as the most important in terms of biomass. In video recordings from my study, hooded crow was the most important prey species in terms of biomass. From prey identified to species level, blackbirds were the most important prey in numbers. In both prey remains and video recordings, approximately five species made up the bulk of biomass, but the composition of species was different.

The estimated average prey size was higher with prey remains method, compared to video recordings (76 g of difference). The average prey size of mammals were higher in prey remains relative to video recordings. However, the sample size was low and affected by the presence of a mountain hare in the prey remains. With birds, there is clearly a difference in the estimates of the average size of prey delivered or found as remains, an average of 76 g heavier in the latter. I do not know about other studies that have compared the average prey size of data obtained from video recordings with data from prey remains. A solely comparison of the average prey weight (birds) obtained from video recording in my study to video recording results from studies in other areas, would not be reasonable either, since the average prey weight will differ dependent on the available prey fauna.

Shannon's indices differed significantly between the two methods. A higher index of prey diversity in the diet was obtained from prey remains data, when compared to data from video recordings. All prey species present in the video recording samples were also present in the prey remains samples (data pooled across all nests). Contradictory, eleven species were only recorded with the prey remains method. In contrast to my study, Lewis et al. (2004a) reported that the video recording method identified more prey categories than the prey remains method did. However, it is noteworthy that their data materials from video recordings were about seven times bigger than the data material obtained from prey remains. Six prey categories in their study were found on video recordings only, whereas two categories were found solely as prey remains. Huang et al. (2006) compared results from prey remains, pellets and direct observations when assessing the diet of besra sparrowhawk *Accipiter virgatus,* and crested goshawk *A. trivirgatus.* They found that for the besra Sparrowhawk, prey remains identified more taxa than the two other methods, but for the crested goshawk direct observations identified more taxa. The observation conditions (distance, foliage, brood size) were although more difficult in the case of the besra sparrowhawk.

Potential biases and their sources

Goshawks present challenges to researcher of food habits because of their diversity in prey. Actual diet usually remains unknown, but some diet assessment methods are believed to be less biased than others. Logically, video recording would be a more reliable method compared to sampling prey remains on the ground. This is because of video recordings providing data of prey before ingestion, while prey remains providing data from prey after ingestion.

Prey remains may result in bias favouring avian prey due to easier detection of feathers. Bias toward birds can also be a result of more thorough plucking of birds compared to mammals (Lewis et al. 2004a). Smithers et al. (2005) suspected that previous research on goshawk diet in their study area had overestimated the proportion of birds. In my study, mammals were represented in fairly equal proportions in both prey remains and video recordings (2.8 % vs. 5.1 %). In accordance with Lewis et al. (2004a), mammals in my study seemed to be more thoroughly plucked than birds. However, the sample size of mammals was low, and the result must therefore be seen in this context.

An overrepresentation of conspicuously coloured prey in a raptors diet can be a result of increased prey vulnerability due to plumage brightness (Huhta et al. 2003). However, large and brightly coloured prey remains are known to be easier to detect when sampling prey remains. In accordance to the latter theory, Lewis et al. (2004a) reported that prey remains from birds with brightly coloured feathers were identified most frequent in goshawk diet. As mentioned, large prey should also be overrepresented by the prey remains method, not only due to easier detection, but also longer persistence in the environment. On the other hand, large prey remains may also be more prone to scavenging from species like the red fox *Vulpes vulpes*. The density of red fox in my study area was intermediate, but no such incidents were evident.

In my study, woodpigeons were overestimated by the prey remains method relative to video recordings. Woodpigeons are conspicuous with regard to size and colour, which is in consistency with the idea of bias towards conspicuous prey. There was also a discrepancy among the two methods in estimating the amount of large thrushes (>85 g) and small thrushes (< 85 g). Small thrushes were more frequent than large thrushes in video recordings compared to prey remains, whereas large thrushes were more frequent than small thrushes in prey remains. The small thrushes, redwing and song thrush, both have nearly the same coloration as a fieldfare, and hence should also be overrepresented in prey remains rather than in video recordings. However, they were rather underrepresented. The reason may be attributed to weight rather than colouration. Redwings and song thrushes are smaller than fieldfares, respectively weighing approximately 78 % and 66 % the weight of fieldfares. Blackbirds are closer to the fieldfare in weight, but have an inconspicuous plumage (black/brownish). Blackbirds were given at fairly equal proportions with both methods in my study. Contradictory, Rutz (2003) reported that blackbirds were overestimated by the prey remains method when comparing to data from radio tracking of adult male goshawks.

When assigning prey types to five different groups with regard to their weight, there was a significant difference between the two methods I used to identify prey. Small prey were underestimated compared to larger prey. The only exception was the weight group 130-300 g. Rutz (2003) found that small birds and rock doves were underestimated by prey remains analyses in the nest territory. The first finding is in agreement with the idea of remains from smaller prey being more difficult to detect, but the latter finding is not. An explanation is presumably selective processing of prey. Ruts (2003) found that large prey often were more thoroughly plucked than small prey at the capture site, and therefore are not found as remains close to the nest stands were prey remains analyses are performed. In consistency, large prey were more plucked than small prey in my study (see Fagerland 2006). Interestingly, some of the largest prey types, the capercaillie (females) and black grouse, were represented in almost equal proportions with both methods. The sample size however was low, and the result must be seen in this context.

One possible explanation for an underestimation of a prey species by use of video recording could be that the specific prey is being hunted in the hours before and after the video recording interval. If the prey species have an activity pattern that makes it especially vulnerable at late evening/early morning, the remains may be found, but the delivery to the nest would not be recorded. Using time-lapse video would eliminate this problem, but probably would have lead to a lower rate of prey identification due to lower frame-rates. A 24 hour recording can be obtained by using a rate of 5 frames/sec, compared to real-time which involves 60 frames/sec (McQuillen and Brewer 2000).

Goshawks may also cache and retrieve cached prey items (Schnell 1958), a behaviour which may lead to bias in data obtained from video recordings. Lewis et al. (2004a) and Smithers et al. (2005) respectively, identified 7.3 % and 8.3 % of prey deliveries on video recordings as retrievals. I did not attempt to quantify the number of retrievals, but I believe that most of the retrievals were identified as retrievals, not as new prey items. Hence, probably no such bias did occur in this study.

In agreement with Grønnesby & Nygård (2000), the video method seemed to provide better quantitative information than prey remains did. Excluding skeletal remains in the data material, may give results more in accordance with data from video recording. As far as I know, only a few studies have excluded skeletal material from prey remain analysis (i.e. Opdam 1977, Rutz 2003). Especially the number of woodpigeons in this study would be much lower if sterna and humeri were not counted in the data material. The amount of remains from the large thrushes would however not be reduced at the same extent, since remains of those species were mostly found as feathers.

Direct observations from blinds are quite similar to video recordings, although identifying prey through scopes can be more difficult. In a study of Golden eagle *Aquila chrysaetos* diet, Collopy (1983) found no difference between direct observations and combined data of pellets and remains. However, the lack of bias was likely due to predominance of medium-sized mammals in the diet (Mersmann et al. 1992). Manosa (1994) studied goshawk diet in Spain, and he also did not obtain a significant difference between direct observations and prey remains. Nevertheless, there was a tendency in overestimating the proportion of rabbits in the diet, while underestimating thrushes. Furthermore, Mersmann et al. (1992) analysed captive bald eagle's *Haliaeetus leucocephalus* food remains, of which small mammals were underrepresented, while birds and medium-sized mammals were overrepresented.

Technical advantages and disadvantages of each method

The video recording method has the benefits of direct observations, and offers some additional advantages (Lewis et al. 2004a). An advantage using video recording is that videotapes provide a permanent record that can be viewed repeatedly and by multiple persons. This factor probably makes the chance of correct prey identification more certain and reduces observer bias (Cutler & Swann 1999). Video recording also have the ability to record infrequent behavioural events (Rogers et al. 2005). An additional advantage with video recordings is the exact time reference to prey deliveries or other events in the nest. Potential disadvantages by using a video recording system are cost, mechanical failure (Grønnesby & Nygård 2000, Booms & Fuller 2003, Lewis et al. 2004b), and disturbance (Margalida et al. 2006). Technical failures include battery/power failure (Grønnesby & Nygård 2000, Booms & Fuller 2003, Lewis et al. 2004b, Sabine et al. 2005), water damage (Rogers et al. 2005), and damage to cables by rodents or ungulates (Rogers et al. 2005, Margalida et al. 2006). Insufficient training of personnel may also result in technical difficulties (Grønnesby & Nygård 2000). Moreover, power supplies are often burdensome to transport to remote locations (Lewis et al. 2004b). The video recording method also offer a potential risk to the researchers, due to hazardous climbing if not proper equipment is used.

The effects of installing cameras near raptor nests vary among species and individuals. Video recording of nests appear to be more invasive compared to collecting prey remains at plucking posts. Although goshawks in my study were distressed when installing the camera systems, they seemed unaffected by its presence shortly after. If there would be any potential negative impacts of installing camera systems, the effects can be reduced by installing cameras during the pre-laying period (Margalida et al. 2006).

A major disadvantage of the camera systems in my study was the labour intensity, since someone had to be present when recording to change videotapes. In comparison, sampling prey remains was much less time consuming. Use of time-lapse video recording in this study would have lowered the labour intensity, but could have affected the level of prey identification due to lower frame rates. Reviewing the videotapes and identifying prey deliveries also require an extensive amount of time, even when fast-forwarding tapes during non-prey delivery times (Rogers et al. 2005, Huang et al. 2006).

As with the video recording method, prey remains offers both advantages and disadvantages. Collecting prey remains at plucking posts or beneath the nest involve little disturbance to the birds (Lewis et al. 2004a). Some authors mention that collecting prey remains will provide a lower sample size compared to video recording (e.g. Lewis et al. 2004b). This was not the case in my study. More prey deliveries were found as prey remains than were observed on videotapes. However, if time-lapse video recording had been used, or a few more days with recording, the situation would probably be the opposite. Most likely, some prey remains were overlooked even when the ground was carefully scanned, as mentioned in other studies (Opdam et al. 1977, Widen 1987, Toyne 1998). The ability to find prey remains by scanning the ground may also be affected by the skill of the collector and differ among studies.

No mechanical failures were experienced during this study, except from trouble with loose connections at one camera installation. The overall impression of the system was that it seemed simple in use and reliable. Proper camera angel and placement with regard to the adult's flight paths was critical to identify delivered prey. Mostly the adults landed on the same side of nest, but variation occurred. Because of the large size of some of the goshawk nests, it was difficult to cover the whole nest and still have the proper magnification. I did not observe the adult's movement patters at the nest before installing the camera system, but other authors recommend to do so (Booms & Fuller 2003, Rogers et al. 2005). The ideal position of the lens seemed to be at a 40-60 degree angel about 1 m away, placed beside the adults most commonly used landing spot. Positioning the camera to record beyond the edge of the nest is also beneficial, so that it is possible to record the adults before they land. Positioning the lens straight above the nest (> 60°) is not recommended, since the field of view often will be obstructed by the goshawks. The lenses seemed to have an inability to adjust colour settings when rapidly changing light conditions occurred, such as a combination of strong sunlight and partially clouded sky. Better lenses would be preferable, but with a limited budget, the choice of lenses will be a trade-off between quality and quantity.

The expense of using video recording systems will often result in few sample units, whereas with the prey remains method, large sample sizes can be obtained at a low cost. However, large sample sizes do not automatically validate the sampling technique. Low biases are just as important as large sample sizes. Lewis et al. (2004a) suggested that in large-scale projects, video recording could be used as sub-samples to calibrate data from prey remains. Computing correction factors has also been suggested by Rutz (2003). He suggested using radio-tracking data in pilot studies to correct data obtained from prey remains.

Use of multiple techniques

A more accurate estimate of the goshawks breeding season diet may be combining data from both prey remains and video recording. However, there is a potential danger of double counting prey items when combining several methods at the same period of time. Redpath et al. (2001) compared methods to assess hen harrier *Circus cyaneus* diet. They found that both pellets and prey remains overestimated lagomorphs and underestimated passerines relative to direct observations. This suggests that maybe more than two techniques are necessary, since the same prey type can be biased in the same direction by two techniques. According to Lewis et al. (2004a), a combination of pellets, prey remains and video recording is the best way to reach a proximate representation of goshawk diet. Huang et al. (2004) pooled data from direct observations, prey remains and pellets to overcome bias created by a single method in a study of besra sparrowhawk. Moreover, Huang et al. (2006) reported that a combination of prey remains and pellets could eliminate some biases in diet studies, due to finding large sized prey in remains and finding small prey in pellets. Mersmann et al. (1992) also suggests using multiple techniques. However, neither video recordings nor prey remains will truly reflect the diet of the adult male, or the adult female when she also hunts in the later part of the breeding season. This is because of selective transportation, which means that often only the larger prey items are brought to the nest, while the smaller prey items are eaten at the capture site (Sonerud 1992).

CHAPTER V
CONCLUSIONS

Compared to prey remains, the video recording method seems to be better for assessing quantitative data. The relative importance of each prey type is therefore more accurate determined using this method. Prey remains from this study seem to provide an inaccurate measure of frequency by number in some species. However, video recordings gave the highest percentage of unidentified prey and a lower measure of prey diversity. Hence, for qualitative information such as dietary breadth, I would prefer using prey remains analysis. Questions regarding age structure of prey in the diet, which is quantitative information, seems also to be addressed best with the prey remains method. Sampling prey remains is probably necessary to register rare prey species. Evenness indices are based on quantitative data, which I believe are probably better assessed when using data from video recordings.

In conclusion with others (Mersmann et al. 1992, Lewis et al. 2004a), I suggest using multiple methods to assess diet of goshawks, or raptors in general. The video method should at least be used as a calibration factor for prey species found as remains to correct their numbers (quantity). The time per day covered by video must however be high. Preferably more than 12 hours per day should be recorded. The period of video recording and prey remains sampling should also overlap as much as possible. An overlap is necessary to avoid dietary shifts among the two methods due to shifts in seasonally prey abundance's.

Several factors need to be considered when deciding on a method of diet assessment. Such factors are time spent on collecting samples, sample availability, disturbance to birds, and the reliability (level of identification, biases, and technical difficulties). As a conclusion, the choice of dietary sampling method should be evaluated from the objective of the study and time available to perform the study.

Studies to be performed in the future should involve a high coverage of video recording when comparing to indirect methods or direct observations. Mersmann et al. (1992) investigated the persistence of bald eagle prey items on shorelines. It would be interesting to do similar studies on the persistence of specific goshawk prey in different environments. Hopefully, by doing this it will be possible to make correction factors for certain climates and faunas (scavengers).

REFERENCES

Aebischer N. J., Robertson P. A., and Kenward R. E.1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74: 1313-1325

Bielefeldt J., Rosenfield R. N., and Papp J. M. 1992. Unfounded assumptions about diet of the Cooper's Hawk. Condor 94: 427-426

Boal C. W., Andersen D. E., and Kennedy P. L. 2001. Home range habitat and use of Northern Goshawks in Minnesota. Final report. Minnesota Cooperative Fish and Wildlife Research Unit, Univ. Minnesota, St. Paul, MN U.S.A.

Booms T. L. and Fuller M. R. 2003. Time-lapse video system used to study nesting Gyrfalcons. Journal of Field Ornithology 74: 416-422

Bratli H. 2000. Biologisk mangfold i Ås Kommune. NIJOS Rapport 05/2000. Norsk institutt for jord- og skogkartlegging.

Cramp S. and Simmons K. E. L. (eds.). 1977 and 1980. Handbook of the Birds in Europe, the Middle East and North Africa. The birds of the Western Palearctic. Vol. 1 and Vol. 2. Oxford University Press. Oxford.

Cramp S. (ed.). 1985 and 1988. Handbook of the Birds in Europe, the Middle East and North Africa. The birds of the Western Palearctic. Vol. 4 and Vol. 5. Oxford University Press. Oxford.

Cramp S. and Perrins C. M. (eds.). 1993 and 1994. Handbook of the Birds in Europe, the Middle East and North Africa. The birds of the Western Palearctic. Vol. 7 and Vol. 8. Oxford University Press. Oxford.

Collopy M. W. 1983. A comparison of direct observations and collections of prey remains in determining the diet of golden eagles. Journal of Wildlife Management 47: 360-368

Cutler T. L. and Swann D. E. 1999. Using remote photography in wildlife ecology: a review. Wildlife Society Bulletin 27: 571-581

Errington P. L. 1932. Technique of raptor food habits study. Condor 34: 75-86.

Fagerland K. L. 2006. Prey preparation and feeding of the nestlings in the Goshawk (*Accipiter gentilis*). Master thesis. Department of Ecology and Management. Norwegian University of Life Sciences.

Hansen V. T. and Grimenes A. A. 2006. Feltstasjon for agroklimatiske studier. Metrologiske data for Ås 2005. Institutt for matematiske realfag og teknologi. Universitet for miljø- og biovitenskap.

Grønnesby S. and Nygård T. 2000. Using time-lapse video monitoring to study prey selection by breeding Goshawks *Accipiter gentilis* in Central Norway. Ornis Fennica 77: 117-129

Huang K. Y., Lin Y. S., and Severinghaus L. L. 2006. Comparison of three common methods for studying the diet of nestlings in two *Accipiter* species. Zoological studies 45 (in press).

Huang K. Y., Lin Y. S, and Severinghaus L. L. 2004. The diet of Besra Sparrowhawk (*Accipiter virgatus)* in Yangmingshan area, Northern Taiwan. Taiwania 49: 149-158

Huhta E., Rytkonen S., and Solonen T. 2003. Plumage brightness of prey increases predation risk: an among-species comparison. Ecology 84: 1793-1799

Lewis S. B., Fuller M. R., and Titus K. 2004a. A comparison of 3 methods for assessing raptor diet during the breeding season. Wildlife Society Bulletin 32: 373-385

Lewis S. B., DeSimone P., Titus K. and Fuller M. R. 2004b. A video surveillance system for monitoring raptor nests in a temperate rainforest environment. Northwest Science Vol. 78 No.1

Manosa S. 1994. Goshawk diet in a Mediterranean area of northeastern Spain. Journal of Raptor Research 28: 84-92

Margalida A., Ecolan S., Boudet J., Bertran J., Martinez J-M., and Heredia R. 2006. A solar-powered transmitting video camera for monitoring cliff-nesting raptors. Journal of Field Ornithology 77: 7-12

McQuillen H. L. and Brewer L. W. 2000. Methodological considerations for monitoring wild birds using video technology. Journal of Field ornithology 71: 167-172

Mersmann T. J., Buehler D. A., Fraser J. D., and Seegar J. K. D. 1992. Assessing bias in studies of Bald Eagle food habits. Journal of Wildlife management 56: 73-78

Opdam P.1977. Feeding ecology of Goshawk *Accipiter gentiles.* Journal of Ornithology 188: 35-51

Petronilho J. M. S and Vingada J. V. 2002. First data on feeding ecology of Goshawk *Accipiter gentilis* during the breeding season in the Natura 2000 site Dunas de Mira, Gândara E Gafanhas (Beira Litoral, Portugal). Airo 12: 11-16

Promessi R. L., Matson J. O., and Flores M. 2004. Diets of nesting Northern Goshawks in the Warner Mountains, California. Western North American Naturalist 64: 359-363

Petty S. J., Lurz P. W. W., and Rushton S. P. 2002. Predation of red squirrels by northern goshawks in a conifer forest in northern England: can this limit squirrel numbers and create a conservation dilemma? Biological Conservation 111: 105-114

Redpath S. M., Clarke R., Madders M,. and Thirgood S. J. 2001. Assessing raptor diet: comparing pellets, prey remains, and observational data at Hen Harrier nests. Condor 103: 184-188

Roberson A. M., Andersen D. E., and Kennedy P.L. 2003. The Northern Goshawk (*Accipiter gentilis atricapillus*) in the western Great Lakes region: a technical conservation assessment. Minnesota Cooperative Fish and Wildlife Research Unit, Univ. Minnesota, St. Paul, MN U.S.A.

Rogers A. S., Destefano S., and Ingraldi M. F. 2005.Quantifying Northern Goshawk diets using remote cameras and observations from blinds. Journal of Raptor Research 39: 303-309

Rutz C. 2003. Assessing the breeding season diet of Goshawks *Accipiter gentilis*: biases of plucking analysis quantified by means of continuous radio-monitoring. Journal of Zoology 259: 209-217

Sabine J. B., Meyers J. M., and Schweitzer S. H. 2005. A simple, unexpencive video camera setup for the study of avian nest activity. Journal of Field Ornithology 76: 293-297

Schnell J. H. 1958. Nesting behaviour and food habits of Goshawks in the Sierra Nevada of California. Condor 60: 377-403

Selås V. 1989a. Analysis of the food habits of raptors based on prey remains and pellets collected at the nesting places. Fauna 42: 13-21

Selås V. 1989b. Prey selection in the Goshawk *Accipiter gentilis* during the breeding season. Fauna 42: 104-110

Selås V. 2001. Predation on reptiles and birds by the common buzzard, *Buteo buteo*, in relation to changes in its main prey, voles. Canadian Journal of Zoology 79: 2086-2093

Smithers B. L., Boal C. W., and Andersen D. E. 2005. Northern Goshawk diet in Minnesota: an analysis using time-lapse video recording systems. Journal of Raptor Research 39: 264-273

Sonerud G. A. 1992. Functional responses of birds of prey: biases due to load-size effect in central place foragers. Oikos 63: 223-232.

Spellerberg I. F. and Fedor P. J. 2003. A tribute to Claude Shannon (1916-2001) and a plea for more rigorous use of species richness, species diversity and the "Shannon-Wiener" index. Global Ecology & Biogeography 12: 177-179

Squires J. R. 2000. Food habits of Northern Goshawks nesting in South Central Wyoming. Wilson Bulletin 112: 536-539

Tornberg R. 1997. Prey selection of the Goshawk *Accipiter gentilis* during the breeding season: The role of prey profitability and vulnerability. Ornis Fennica 74: 15-28

Toyne E. P. 1998. Breeding season diet of the Goshawk *Accipiter gentilis* in Wales. Ibis 140: 569-579

Trejo A., Ojeda V., Kun M., and Seijas S. 2006. Prey of White-throated Hawks (*Buteo albigula*) in the southern temperate forest of Argentina. Journal of Field Ornithology 77: 13-17

Widen P. 1987. Goshawk predation during winter, spring and summer in a boreal forest area of central Sweden. Holarctic Ecology 10: 104-109

APPENDICES

Appendix 1. Prey remains collected at six goshawk nests in Southeastern Norway, during the breeding season of 2005.*

Species	Nest 1	Nest 2	Nest 3	Nest 4	Nest 5	Nest 6
Woodpigeon	3	10	7	8	2	1
Rock dove	-	1	1	-	-	-
Capercaillie	-	-	-	1	2	-
Black grouse	-	-	-	-	2	1
Hazel grouse	-	-	-	-	1	-
Grey Heron	-	-	-	1	-	-
Mallard	1	-	-	-	-	-
Domestic duck	-	1	-	-	-	-
Hooded crow	1		-	-	-	4
Magpie	4	2	4	3	1	1
Jay	1	2	3	1	2	1
Jackdaw	-	1	-	-	-	-
Black woodpecker	-	-	-	1	-	-
Great spotted woodpecker	-	1	1	-	2	-
Mistle thrush	-	-	-	-	-	1
Fieldfare	9	1	6	2	3	2
Blackbird	3	4	2	4	4	4
Redwing	2	-	-	1	-	-
Song thrush	1	-	-	1	2	1
Redwing/Song thrush	-	-	-	-	1	-
Starling	1	1	-	-	-	-
Sky lark	-	-	1	-	-	-
Tree pipit	-	-	-	1	-	-
Chaffinch	-	-	2	-	-	-
Wood nuthatch	-	-	-	1	-	-
Mountain Hare	-	-	-	-	-	1
Red Squirrel	1	-	1	1	-	-

* dash indicate zero-values

Appendix 2. Prey deliveries identified by video recording at six goshawk nests in Southeastern Norway, during the breeding season of 2005.

Species	Nest 1	Nest 2	Nest 3	Nest 4	Nest 5	Nest 6
Woodpigeon	-	3	-	-	1	1
Capercaillie	-	-	-	-	2	1
Black grouse	-	-	-	-	-	1
Hazel grouse	-	1	-	-	-	-
Tetraonid	-	-	-	-	-	3
Domestic duck	-	-	-	-	-	-
Hooded crow	7	-	3	2	1	-
Magpie	-	2	1	-	1	-
Jay	5		4	2	-	2
Great spotted woodpecker	-	-	-	-	1	-
Mistle thrush	-	-	-	-	1	-
Fieldfare	-	-	-	3	1	-
Blackbird	1	1	4	2	2	6
Redwing	-	-	1	-	-	1
Songtrush	-	2	-	-	-	3
Redwing/Song thrush	5	3	3	5	3	5
Fieldfare/Blackbird	-	-	-	2	-	-
Unidentified thrush	-	-	1	2	1	5
Tree pipit	-	-	-	1	-	-
Mountain Hare	-	-	-	-	-	-
Red Squirrel	3	1	-	-	-	2
Capercaille/Mallard	-	-	-	-	-	1
Magpie/Jackdaw	-	-	-	1	-	-
Unidentifed bird	-	-	-	-	1	-

* dash indicate zero-values

Appendix 3. The body mass data used in calculations and their sources.

Prey type	Weight (grams) [a]	Location/time of year	Source
Capercaille ♀	1985	Norway	Cramp & Simmons 1980
Capercaille 18 days	150		Cramp & Simmons 1980
Grey Heron 3 1/2 weeks			Cramp & Simmons 1977
Black grouse ♂	1269	Norway: autumn-winter	Cramp & Simmons 1980
Black grouse ♀	945	Norway: autumn-winter	Cramp & Simmons 1980
Mallard ♂	1100	May	Cramp & Simmons 1980
Mallard ♀	957	June	Cramp & Simmons 1980
Hooded crow	500 (333)		Cramp & Perrins 1994
Wood pigeon	495 (330)		after Selås 2001
Rock dove ♂	370	Turkey: June	Cramp 1985
Hazel grouse	372		after Selås 2001
Black woodpecker	318	Norway: autumn	Cramp 1985
Red squirrel	300		after Selås 2001
Jackdaw	235		Cramp & Perrins 1994
Magpie	213 (142)		Cramp & Perrins 1994
Jay	161 (107)		Cramp & Perrins 1994
Mistle thrush	119	Great Britain: April-August	Cramp 1988
Fieldfare	105 (70)		Cramp 1988
Blackbird	95 (63)		Cramp 1988
Great Spotted Woodpecker	90		after Selås 2001
Starling	80	Netherlands: April-June	Cramp & Perrins 1994
Song Thrush	74 (49)		Cramp 1988
Redwing	63 (42)		Cramp 1988
Sky lark	40	Southern England: Oktober	Cramp 1988
Tree Pipit	23		Cramp 1988
Chaffinch	23	Norway: spring/autumn	Cramp & Perrins 1994
Wood nuthatch	24		Cramp & Perrins 1993
Song thrush/redwing *	69 (46)		
Mallard **	1029		
Black grouse **	1107		
Fieldfare/blackbird *	100		
Unidentified thrush *	91 (60)		
Tetranoid (juveniles) ***	150		
Mallard/capercaillie **	1507		
Magpie/jackdaw **	224		
Domestic duck ****	1029		

[a] calculated juvenile/nestling weight in parentheses

* middle weight of the two or more species

** weight of unsexed prey

*** assigned the same weight as capercaille chicks

**** assigned the same weight as unsexed mallard