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Assessing the diet of birds of prey: a comparison of prey items found in nests and images

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Prey remains and regurgitated pellets collected from nests are the most common material for investigating the diet of birds of prey. Generally such data is thought to be biased with large prey overrepresented. However, there is no analysis investigating how systematic the error is in relation to prey size, abundance, species or method used. In this study we compared the diet composition of the Goshawk (*Accipiter gentilis*) and the Buzzards (the Common Buzzard *Buteo buteo* and the Rough-legged Buzzard *B. lagopus*) in northern Finland obtained indirectly (by collection of prey remains and pellets) and by direct methods (using a movie camera and a video recording system). In order to investigate the relationship between these two types of diet data more generally, we combined our own material and some published original data. Video and film images allowed us to identify according to class or family level most of the prey items delivered to the nests during the surveillance sessions, but identification according to genus or species level often was difficult. We found that small prey items were underestimated in remains as compared to large prey items. However, when none of the prey delivered to the nest is in large numbers, prey remains give fairly reliable idea of the real diet.

1. Introduction

Collection of uneaten food remains and regurgitated pellets from nests is the most common method to study diet of birds of prey during the nesting season. Often this material is the only reliable data on the diet of certain raptor species because studying their food habits in other seasons may be extremely difficult. Numerous studies have been done based on large long-term collections of prey remains and pellets (reviews in Marti *et al.* 1993, Korpimäki & Marti 1995). However, such data may be biased in various ways. In addition to the fact that not all kills are delivered to the nest (i.e. small prey items may be eaten at the capture site; Sonerud 1992, Rutz 2003, but see Korpimäki *et al.* 1994), remains of different prey items may be preserved in the nest unequally as a result of activity of adults or young, and remains of large and pale prey are easier to discover than remains of small and dark prey (see review by Rutz 2003). Some prey species may not even be discovered in remains or pellets at all (Mersmann *et al.* 1992, Redpath *et al.* 2001, Lewis *et al.* 2004).

Generally it is thought that large prey tends to be overrepresented and small prey under-represented in food remains (Sulkava 1964, Redpath *et al.* 2001, Lewis *et al.* 2004). These flaws were often found in studies that employed direct observations at nests, feeding experiments and other methods to study diet composition of raptors (Errington 1930, Suomus 1952, Czarnecki & Foksowicz 1954, Craighead and Craighead 1956, Pinowski & Ryszkowski 1962, Sulkava 1964, Pasanen & Sulkava 1971, Jarvis *et al.* 1980, Mañosa & Cordero 1992, Mersmann *et al.* 1992, Vorišek *et al.* 1997, Lewis *et al.* 2004; see also Tjernberg 1981 and Rutz 2003 for review). In turn, this bias may affect implications based on such data because the importance of some prey may be estimated incorrectly. In some cases, remains and pellets have given results fairly similar to 'direct' methods (see Collopy 1983, Simmons *et al.* 1991). However, there is no analysis in regards to how systematic the error is in relation to prey size, species or method used.

In this study we compared the diet compositions of two raptor species – the Goshawk (*Accipiter gentiles*) and the Common Buzzard (*Buteo buteo*) – obtained indirectly (by collection of prey remains and pellets) and by direct methods (movie and video surveys). Some additional data were collected at a nest of the Rough-legged Buzzard (*Buteo lagopus*). In order to investigate the relationship between these two types of diet data, we used our own material as well as some published original data. We were interested in establishing whether over- or underrepresentation of a given type of prey in remains occurs mainly because of the prey's size only, or whether are some other factors involved as well.

2. Methods and collected data

2.1. Timing and study area

During four summers in 2002–2005 we monitored nests of the Goshawk, the Common Buzzard and the Rough-legged Buzzard with a set of video surveillance equipment. In 2002 some nests were filmed with a movie camera. Furthermore, R. Tornberg used the movie camera in his study of goshawk diet in 1989–1990. Simultaneously prey remains from and under the nests were collected. Nests were located in northern Finland, in the western part of the province of Oulu and in southern Lapland (Common Buzzards' nests only) in the vicinity of the towns Kemi and Tornio (65–66°N, 24–26°E).

2.2. Equipment and technique

We used a movie camera: Minolta XL-400 with a 1:1.2/8.5–34 Minolta lens and 8-mm colour film – Kodak Kodachrome KMA, Ektachrome 160 and Agfa Moviechrome 40. The camera took one shot per 80 sec in automatic mode. During the study in 1989–1990 a movement sensor (photo-cell) was installed next to the nest and included in the camera power circuit, switching the camera on when an adult Goshawk landed on the nest. Thereafter the camera was shooting at a random rate for about 15–20 minutes. In 2002 the sensor was not in use, and whenever possible the camera was switched off at dusk and turned on in the morning in order to save the film which was not sensitive enough in twilight. Film and batteries were replaced periodically on the site. The developed films were reviewed using an editor viewer dial.

The video set consisted of a compact digital video recorder REC HD-2166 and a colour CCD camera Topica TP-1002. The sensitivity of the camera was enough even for night twilight in June – July in the latitudes of the study area. The recorder and the camera were powered by 12V car batteries. The camera was fixed on a branch above or next to the nest in its immediate vicinity (1–2 m apart) and aimed so that the whole interior bowl and a part of the nest rim were in view. Following the installation of the camera, the nest was cleared of any visible food remains and pellets. At the end of a given surveillance session prey remains and pellets were again collected from the nest and on the ground around the nest tree. Since the youngest chicks were usually still in the nest at that time, the collection was done with caution to avoid flushing them: we were picking only visible remains, and the bedding of the nest was not collected either before or after the surveillance.

We viewed the video recordings on a 14" TV or on a computer screen. The prey delivery events were saved on VHS tape and/or on computer HDD (still images) for further identification. We also registered the exact time of each delivery for sampling the hunting patterns of the adult hawks. (See Reif & Tornberg (2006) for further details of

Table 1. Total time of surveillance and numbers of recorded and collected prey items in goshawk and buzzard nests in Oulu–Tornio region in northern Finland in 1989–1990 and 2002–2005.

Species	No. of nests	Total hours of video recordings (2002–2005)	No. of prey in images	No. of collected prey remain specimens
Goshawk	7	911	147	59
Common Buzzard	6	454	92	16
Rough-legged Buzzard	1	95	11	4
		Hours of filming (approx.)		
Goshawk (1989–1990, 2002)	4	1,174	74	50
Common Buzzard (2002)	1	158	12	7

the equipment and employed techniques and schedule of prey delivery).

The movie camera was operated in 1989–1990 and 2002 total at six nests, and the video set was used during four seasons in 2002–2005 at 15 nests (Table 1). Since we had only one video set and one movie camera, we performed short-term sampling at a maximum possible number of nests during the nestling (from hatching to fledging) period. In the case of the video system, we first started recordings at goshawk nests when the age of the youngest chick there was at least 15 days, later switching to buzzard nests. Thus, our sampling pattern covers about 2/3 of the goshawk nestling period and the second part of the buzzard nestling period. Each nest was usually monitored during four successive days in one or two sessions (depended on the capacity of the HDD installed in the recorder). In the case of two sessions, there was a 2–3 hrs break for recording review and data backup. Occasionally the break was longer because of weather conditions (heavy rainfall).

In the movie camera monitoring, the duration of filming varied from a few days to two weeks with occasional breaks. The prey remains were usually collected after filming sessions but sometimes also during the filming period. These data were pooled together with results of the video monitoring in 2005 when the protocol of the study was similar (i.e. the remains were collected irregularly during a longer surveillance period). We consider these data worth to be presented here because they were collected during the years when the last well-distinguished population peak of grouse (Tetraonids; in 1989) and two peaks of red squirrels (*Sciurus vulgaris*; in 1990 and 2005) occurred. These data referred as "movie camera" or "film" data. Similarly, the film data collected at one nest of the Common Buzzard were included in the buzzard video data. Except for these two cases, we dealt with the data of movie camera separately from the video data because of differences in recording time and collection of prey.

The duration of filming (approximately) varied at different nests from 72 to 432 hrs, being on average 266 hrs per nest, and the duration of video recordings varied from 43 to 246 hrs, being 103 hrs on average (failures in the equipment and logistic conditions reduced recording duration at several nests compared to the projected number). Altogether, we made about 2881 hrs (120 days) of surveys at 20 raptor nests (Table 1). The surveyed nests were different in each year, i.e. all nest samples were independent.

2.3. Identification of prey

In most cases – when prey was not found among the food remains – we were unable to control the accuracy of our identification on the video and film images. Thus, the evaluation was subjective and based on our own experience of dealing with raptor prey remains. Consequently, we accepted the following approximation in identifying prey species and categories on the images. Among the

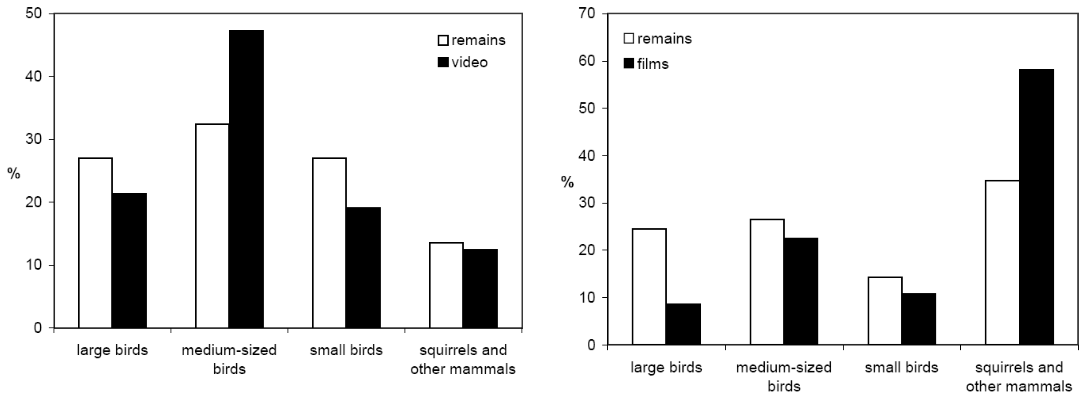

Fig. 1a, b. Proportions of different prey/prey types in the diet of the Goshawk obtained by collecting food remains and by video (a, left pane) and movie camera (b, right pane) surveillance.

mammals that we were able to identify, we noted the red squirrel, hares *Lepus sp.*, the Norway rat (*Rattus norwegicus*), the bank vole (*Clethrionomys glareolus*), *Microtus* voles and the water vole (*Arvicola terrestris*). Among the birds we ascertained the presence of the following: the Wood Pigeon (*Columba palumbus*), the Jay (*Garrulus glandarius*), small passerine-size birds, thrush-size birds, waders, ducks, juvenile and adult grouse. There are four grouse species present in our study area: the Capercaillie *Tetrao urogallus*, the Black Grouse *Tetrao tetrix*, the Hazel Grouse *Bonasa bonasia* and the Willow Grouse *Lagopus lagopus*. In the remains these were identified according to species or family and analysed as one group. The amphibians were the common frog (*Rana temporaria*) and the common toad (*Bufo bufo*). Depending on the visible details (often small prey brought to the nest was partly or completely plucked), other prey was referred to as "other birds", "other mammals" or "unidentified" prey groups. Even though sometimes we were able to recognize other species too, it was least likely that within a given selected group we could make a false identification. While analyzing the correspondence of prey in the collected remains and images, we consolidated the groups further taking into account their weight (Figs. 1, 2).

For the analysis of buzzard prey we pooled the data collected at one rough-legged buzzard nest together with those from the common buzzard nests on the basis of their ecological proximity. In the year 2003 the nest of the Rough-legged Buzzard was located much more to the south as compared to the usual range of this species in Finland, thus overlapping with the Common Buzzard's nesting range (Väisänen *et al*. 1998). Similarly to the Common Buzzard, the Rough-legged Buzzard is specialized on hunting small and medium-sized ground-dwelling prey, mostly small mammals, and kills small game as alternative prey (Pasanen & Sulkava 1971).

Prey remains and pellets were identified in the Zoological museum of Oulu University by using reference material. The prey parts found in pellets were usually identified according to species level when they contained identifiable bones. When they contained only feather and fur, the identification was done according to family or genus level.

The numbers of prey remains discovered at the end of short video surveillance periods were generally low in all nests (on average 5.3 and 3.3 prey

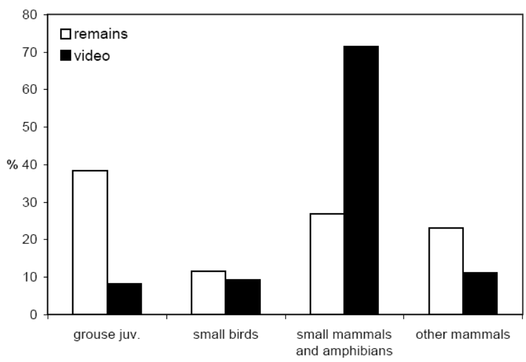

Fig. 2. Proportions of different prey/prey types in the diet of buzzards obtained by collecting food remains and by video/movie camera surveillance.

Table 2. Total and average numbers of the most common Goshawk preys from accumulated remains and video records at six nests during surveys in 2002–2004.

	Prey remains			Video records		
Prey groups	n	aver.	s.e.	n	aver.	s.e.
Grouse juv.	7	1.2	0.7	20	3.3	1.1
Grouse ad.	6	1.0	0.3	9	1.5	0.8
Jay	3	0.5	0.2	8	1.3	0.5
Other birds	12	2.0	0.8	34	5.7	1.3
Red squirrel	2	0.3	0.0	5	0.8	0.3
Hare juv. *Lepus sp.*	–	–	–	1	0.2	–
Other mammals	2	0.3	0.2	5	0.8	0.3
Unidentifiable	–	–	–	26	4.3	1.2
Total	32	5.3	1.7	108	18.0	1.6

Table 3. Total and average numbers of typical preys from remains and films/video records at seven nests of Common Buzzards in 2002–2004.

	Prey remains			Video records		
Prey groups	n	aver.	s.e.	n	aver.	s.e.
Grouse juv.	8	1.1	0.5	10	1.4	0.8
Other birds	3	0.4	0.2	7	1.0	0.4
Small voles (*Microtus* and *Clethrionomys spp.*)	5	0.7	0.2	42	6.0	3.1
Water vole	2	0.3	0.2	7	1.0	0.7
Other mammals	3	0.4	0.2	6	0.9	0.6
Amphibians	2	0.3	0.2	6	0.9	0.6
Unidentifiable	–			26	3.7	1.6
Total	23	3.3	0.8	104	14.9	4.9

specimens per goshawk and buzzard nest, respectively; Tables 2 and 3) and, thus, we were unable to evaluate proportions of prey groups in each nest on the basis of these small samples. Therefore, we pooled the data for all nests.

2.4. Comparison of data

We tested the compatibility of prey distributions between remains and image data using χ^2 tests. We also compared proportions of prey species or groups in direct observations and in food remains in our own data and in five other studies of Buzzards and Goshawks where either observations from a hide or video recordings were used along with the collection of prey remains from nests (Suomus 1952, Sulkava 1964, Pasanen & Sulkava 1971, Grønnesby & Nygård 2000, Lewis *et al.* 2004). In order to find out the ratio between data collected by direct and indirect methods in diet studies, we applied univariate ANOVA models using the statistical package SPSS. We used the proportion of prey obtained by a direct method (observations, movie/video survey) as a predictor and the proportion of prey obtained by an indirect method (collection of food remains) as a dependent variable in the model. We further used the relative weight classes and species as classifying factors. Prey was divided by weight into two classes: small prey (<400 g for goshawk prey and <100 g for buzzard prey) and large prey (>400 g and >100 g, respectively). The weight of identified prey was taken from guide books and the weight of unidentified prey was estimated approximately. Square root transformation was done for percent values to normalize distributions and to reach homogeneity in residuals for ANOVA models. Levene's test revealed that the variances were homogenous between the groups ($P > 0.05$).

2.5. Vole fur and bones

For the independent examination of our results in regards to the numbers of small mammals in the nests of Common Buzzards, we weighed the fur masses accumulated in ten buzzard nests during the nesting season and collected during a study on buzzard diet in western Finland, Southern Ostrobothnia (ca. 63–64°N, 23–24° E; Reif *et al.* 2001). For reference we estimated the weight of one grey-sided vole's fur (*Clethrionomys rufocanus*, a species similar by size to the field vole *Microtus agrestis* – the most numerous among small voles in buzzard diet) and of one water vole using museum specimens. The fur of one grey-sided vole weighs 0.7 g and that of one water vole 3 g. The mean mass of fur collected from 10 buzzard nests averaged 51 g while the number of small mammals (shrews and voles) counted on the basis of bones was 6.9 and that of water voles was 2.6. Based on the mean ratio between small voles and water voles in bone samples from these nests (3.6 in favour of small voles), the weight of one "nominal" vole's fur would be 1.2 g.

3. Results

3.1. Prey identification in the images

The video and film images revealed 336 prey items delivered to the nests while remains of 136 prey items were collected from the nests (Table 1). When the Goshawk and the Common Buzzard are examined separately, there was 3.4- and 4.5-fold difference between the numbers of prey in remains and images (Tables 2 and 3). Altogether, 28% of prey items were identified according to species or genus, 29% according to family and 16% according to class. The majority of the prey identified according to species consisted of red squirrels, followed by Jays, water voles and adult grouse. We did not find differences in identification rate between the video and the movie camera data. The films gave even higher rate of identification according to species level (52% vs. 29%), but this was mainly due to a high number of easily recognizable red squirrels in this data.

3.2. Comparison of prey remains and images

The distribution of prey types between remains and images of goshawk nests did not differ significantly in the video study (χ^2 = 3.3, d.f. = 3, P = 0.35, Fig. 1a), but differed in the film data (χ^2 = 21.2, d.f. = 3, P < 0.001, Fig. 1b). In order to avoid excessively low cell frequencies (< 5) in the buzzard data we pooled the prey further into two classes: small prey (voles, small birds and amphibians) and large prey (grouse chicks, water voles and juvenile hares). Within these classes the difference of the distributions of prey types in the remains and on the video images was highly significant (χ^2 = 29.6, d.f. = 1, P < 0.001). Regardless of the nest's host large birds were generally found in higher proportions among the remains than in the images. Medium-sized birds were over-represented in remains in goshawk nests in the video study, but no difference between remains and images was observed in movie camera data (Figs. 1a, b). In regards to small birds we did not find marked difference in the study of Buzzards (Fig. 2). Red squirrels were found strikingly more often in the images than in the remains of goshawk prey in the study with the movie camera (Fig 1b).

In the goshawk nests adult grouse composed the majority (3/4) of the large birds in the remains but only 1/2 in the video images. The situation was opposite in the data collected with the movie camera. However, in both cases adult grouse were overrated in the remains (Fig. 3). Juvenile grouse

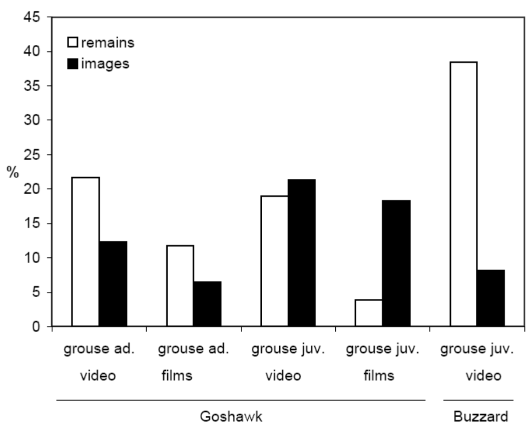

Fig. 3. Proportions of adult and juvenile grouse in diets of Goshawks and Buzzards obtained by two methods.

Table 4. Results of analysis of variance for the Common Buzzard, the Rough legged Buzzard and the Goshawk: proportion of prey in remains (square-root transformed) predicted by proportion of prey obtained by direct method, weight class of prey and method used in direct observation. Sources of the data are Suomus 1952, Sulkava 1964, Pasanen & Sulkava 1971, Grønnesby & Nygård 2000, Lewis *et al*. 2004 and this study. Pooled datasets over years for each study were used.

Source	df	Mean Square	F	Sig.
Corrected Model	4	12.256	9.737	0.000
Intercept	1	43.468	34.535	0.000
Weight class	1	6.803	5.405	0.025
Species	1	1.838	1.460	0.234
Method	1	3.347	2.659	0.110
Video	1	44.175	35.097	0.000
Error	42	1.259		

R Squared = 0.481

accounted for 1/2 of the medium-sized birds among the goshawk prey remains in the video study, but only 1/6 in the movie camera study. In the images they accounted for about 1/2 in both studies. Figure 3 indicates that prey remains collected in the goshawk nests slightly underrepresented grouse chicks in the video study and considerably underrepresented them in the movie camera study. On the other hand, in the buzzard nests the proportion of grouse chicks in the remains was 4–5 times higher than in the video images.

3.3. Comparison of direct and indirect methods

The variation in the proportion of prey found in the remains was mainly explained by the proportion of prey obtained by direct methods (observations or video surveys). Other main effects – weight class and method – explained the rest of the variation while species turned out to be not an important predictor (Table 4). (We entered all two-way interactions in the model, but none of them was statistically significant; therefore they were removed.) We observed a significant main effect for weight class, indicating that small and large prey were preserved differently in the remains. Predictably smaller prey seems to be more underestimated in remains than large prey (Fig. 4). The regression line for small prey crosses the 1:1 line at 10% and for large prey around 35%, respectively. Both lines did not, however, deviate from a 1:1 ratio (95% CL < 1.0). Hence, when prey is delivered to the nest in a proportion around 10–30%, remains likely give fairly reliable estimate of the diet. It also seems that video/movie camera surveys are somewhat more efficient in capturing prey brought to the nest as compared to observations from a hide, i.e. the ratio "observed by direct method/found in the remains" was higher in video and film data (Fig. 5). Regression lines for these parameters did not deviate from 1:1 ratio either (95% CL < 1.0).

3.4. Numbers of voles obtained from fur and bones

Based on weights of fur masses found in ten buzzard nests in the study area in western Finland, and the weight of one vole's fur, we estimated that Buzzards brought on average 42.4 voles to the nests. The number of individual voles based on counted bones was 9.5, i.e. 4.5-fold lower.

4. Discussion

The video and film images allowed us to identify (to a certain extent) most of the prey items delivered during the surveillance sessions. Seventy-three percent of prey delivered to the nests by Goshawks and Buzzards was identified according to (at least) class, which is in accordance with other studies where video technique was used for this purpose (Grønnesby & Nygård 2000, Lewis *et al.*

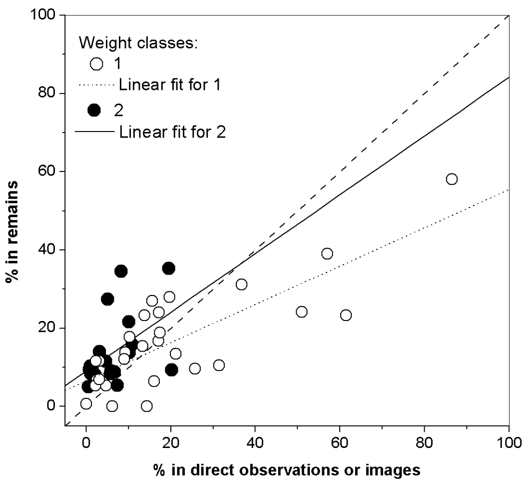

Fig. 4. Relationship between proportions of different prey/prey types in the diet of three raptors (the Goshawk, the Common Buzzard and the Rough-legged Buzzard) obtained by direct observations or movie/video surveillance and by collection of prey remains. Weight class 1 denotes small prey (< 400 g for the Goshawk and 100 g for the Buzzard) and weight class 2 denotes large prey. Line for 1:1 ratio is given by dashed line. The data originate from six studies: Suomus 1952, Sulkava 1964, Pasanen & Sulkava 1971, Grønnesby & Nygård 2000, Lewis *et al.* 2004 (values averaged in percentages by pellets and remains) and this study (film and video data separated).

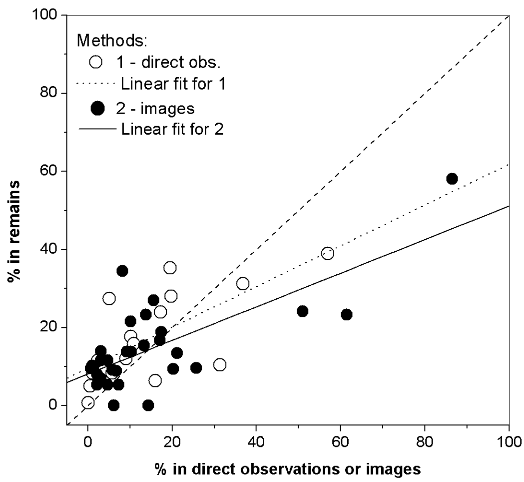

Fig. 5. Relationship between proportions of different prey/prey types in the diet of three raptors (the Goshawk, the Common Buzzard and the Rough-legged Buzzard) obtained by direct observations or movie/video surveillance and the collection of food remains. Method 1 denotes direct observation from a hide, and 2 denotes video/movie camera observation. 1:1 ratio is given by dashed line. Data are the same as in Fig 4.

2004). On the other hand, we were much less certain in identification according to genus or species (cf. Rogers *et al.* 2005, Smithers *et al.* 2005). Therefore, in our analysis we concentrated on higher taxonomic levels. Young grouse were fairly easy distinguishable in the video and film images because of their relatively long and lightly feathered tarsus, but we were usually unable to identify them according to species. However, the same level (family) is usually used for identification of grouse chicks in collected remains (e.g. Tornberg 1997).

Some small prey specimens (i.e. grouse chicks in the goshawk diet, small birds in the goshawk and buzzard diets) tend not to be underestimated in the prey remains as much as expected (cf. small birds in Grønnesby & Nygård 2000). Surprisingly, squirrels were strongly underestimated in remains although they constitute relatively large prey and their remains should be readily recognizable. Lewis *et al.* (2004) also found underestimation (3.5-fold) of squirrels in the diet of the Goshawk in the data from remains and pellets. Squirrels, having relatively thin bones, might be usually eaten completely by chicks or the female because claws and fur are often found in pellets.

Our results for grouse chicks in the Goshawk's diet partly coincide with the findings of Sulkava (1964) who observed juvenile grouse brought to the nest, on average, in a 3.5-fold higher proportion than discovered from remains. With respect to the buzzard nests, the ratio of juvenile grouse in remains vs. images was opposite. Similarly, Suomus (1952) found a higher juvenile grouse proportion in nests of the Common Buzzard in food remains than was detected from a blind, as observed also by Pasanen & Sulkava (1971) in nests of Rough-legged Buzzards. On the contrary, Redpath *et al.* (2001), observing nests of Hen Harriers (*Circus cyaneus*), found nidifugous young to be underestimated in prey remains. Although juvenile grouse are caught by Buzzards and Goshawks in similar proportions (in western Finland it was 4.2% and 4.7%, respectively – Reif *et al.* 2001 and in prep.), for Buzzards grouse chicks are relatively large prey, while for the Goshawk they are small or medium-sized prey. Therefore, their representation in goshawk and buzzard nests may be different (Fig. 4). Furthermore, the overestimation of the proportion of juvenile grouse in remains in buzzard nests may be due to the underestimation of the most numerous prey – small mammals (Fig. 2).

Our ability to identify exact numbers of small mammals in the nests of buzzards was limited because in most cases there was a compressed layer of fur from pellets which was not collected (in order to avoid flushing the fledglings that were often ready to jump out of the nest). As we could observe at our recordings, voles were often swallowed by one of the young in one piece, leaving no remains. This explains the relatively large (2-fold) difference in numbers of this prey group in the remains as compared to the recorded images. The ratio between the numbers of small mammals counted based on accumulated fur and bones was 4.5, which is even higher. This might be due to relatively weak vole populations during the study (as we could judge based on the low frequency of delivery of voles in buzzard nests, except for one area in Kemi in 2003 where 24 voles were recorded in prey deliveries at one buzzard nest during four days).

Suomus (1952) also found small mammals to be underrepresented in food remains of Common Buzzards and Pasanen & Sulkava (1971) obtained similar results analysing pellets of Rough-legged Buzzards. In the studies on the Hen Harrier and the African Marsh Harrier (*Circus ranivorus*) small mammals were equally represented in combined data of remains and pellets when compared to direct observations (Simmons *et al.* 1991, Redpath *et al.* 2001).

Amphibians are another prey group that is significantly underrepresented in remains of buzzard prey. The Common Buzzard is known to hunt frogs and toads, but they, especially frogs, are rarely found in nests (Selås 2001). While we found remains of single frogs in only two nests, video records detected frogs being delivered into three nests, and in one of them four frogs were brought (none of which was discovered among the remains). Interestingly, the highest frequency of food deliveries per day (21 prey items during 18 hours) was also detected in this nest, voles being the most common among the identified prey items. The higher number of frogs killed by this pair may support Selås' (2001) supposition that changes in hunting habits of Buzzards in peak vole years lead to increased numbers of reptiles in the diet.

It seems that under- or overestimation of prey proportions in remains, especially with respect to small prey, is strongly dependent on the numbers of prey brought to the nest. This was clearly seen in two cases: thrush-sized birds in the data of Grønnesby & Nygård (2000) and squirrels in our movie camera data (see also Redpath *et al.* 2001). The red squirrel is likely the easiest prey to identify in images, but it may simply vanish among remains (cf. Rogers *et al.* 2005). The film and video image data from two peak years of squirrels (1990, 2005) revealed that more than 50% of the delivered prey were squirrels while they comprised only about 20% in the remains.

In our study, the time period during which the remains were accumulated in the nests before collection was rather short, as was the case in some other studies (e.g. Redpath *et al.* 2001, Lewis *et al.* 2004). Unfortunately, this important circumstance was insufficiently reported in many papers. It is likely that the longer the interval between the collections of remains, the more remains will be lost. This would lead to the accumulation of bias. This is typically seen in nests of Buzzards when they specialise on small mammals (our own observations). Pellets dissolve easily, and, given effective digestion in raptors (Bocheński *et al.* 1999), very few bones are found in remains relative to deliveries when remains are collected only once.

Earlier studies provide evidence that the combined use of food remains and pellets is the best way to study raptor diets by indirect methods (Collopy 1983, Simmons *et al.* 1991, Redpath *et al.* 2001). Direct methods give the best picture of the diets, but they may be less suitable for collecting a large amount of data over many nesting sites because of high costs. Our results imply that indirect methods may give fairly reliable results when no prey species or category prevails in the deliveries. Hence, if one suspects that the studied raptor species is specialising on a certain prey, a direct method should be applied.

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Keruu- ja kuvausmenetelmien vertailu kana- ja hiirihaukan ravinnon määrityksessä

Pesistä kerätyt saalisjätteet ja oksennuspallot ovat yleisimmin käytetty menetelmä tutkittaessa petolintujen ravinnonkäyttöä. Tällä tavalla saatu aineisto voi kuitenkin olla monin tavoin vääristynyttä. Yleisesti on ajateltu, että suuret saaliseläimet tulevat yliedustetuiksi ja pienet saaliit aliedustetuiksi saalisjätemateriaaliin perustuvissa ravintoselvityksissä kuten useat tutkimukset osoittavat. Toisaalta ei ole tutkittu, miten systemaattinen tämä virhe on suhteessa saaliin kokoon, yleisyyteen, petolintulajiin tai käytettyihin menetelmiin.

Tässä tutkimuksessa vertasimme kanahaukan (*Accipiter gentilis*) ja *Buteo*-lajien (hiirihaukka *Buteo buteo* ja piekana *Buteo lagopus*) pesiltä Pohjois-Suomesta kerättyä epäsuoraan (saalisjätteiden ja oksennuspallojen keräily) että epäsuoraan menetelmään (kaitafilmaus ja videotaltiointi) perustuvaa ravinnonkoostumusta. Voidaksemme yleisemmin tutkia näiden aineistotyyppien suhteita yhdistimme oman aineistomme eräisiin julkaistuihin aineistoihin. Video- ja filmikuvausaineisto mahdollisti pesiin tuotujen saaliiden määrittämisen luokka- tai heimotasolle havainnointijaksojen aikana, mutta määrittäminen suku- tai lajitasolle oli usein vaikeaa.

Havaitsimme, että pienet saaliit tulivat aliedustetuimmiksi kuin suuret saaliit. Toisaalta, kun kun mikään saalislaji tai saalisryhmä ei ole vallitsevana saaliin joukossa, antaa saaliskeruumenetelmä kohtuullisen luotettavan kuvan todellisesta ruokavaliosta.

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