PREY PREPARATION AND INGESTING RATE IN BREEDING EURASIAN KESTRELS, *FALCO TINNUNCULUS*

BYTTEDYRHÅNDTERING OG INNTAKSRATE HOS HEKKENDE TÅRNFALKER, *FALCO TINNUNCULUS*

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Preface

The fieldwork of this study was conducted as a cooperative project. I would like to thank, Kristin Skar, my fellow student in field, for good cooperation and support in nearly two months in Trysil. I would especially like to thank my main supervisor professor Geir A. Sonerud for identification of small mammals, statistical help and reviewing early drafts. I would also like to thank associate professor Vidar Selås for identification of birds and statistical help. Ronny Steen was indispensable as technical support during the fieldwork. I would like to appreciate Bjørn Foyn and Ole Petter Blestad for locating and use of their nest-boxes, and especially Bjørn Foyn for helping me with climbing the trees and checking nest-boxes when Kristin Skar was away on a field-course at UMB. I would also like to thank the landowners for granting permission to conduct this study on their property.

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Line Marie Løw

Abstract

Prey-handling and ingestion rate was studied in breeding Eurasian kestrels, *Falco tinnunculus,* during June-July 2005 by video filming. A total of 157 prey items was delivered to ten nests during the film period of two subsequent days per nest. Of these, 89 were birds (Aves), 25 shrews (Soricidae), 18 voles (Arvicolidae), 15 common lizards (*Lacerta vivipara*), five beetles (Coleoptera), four dragonflies (Odonata) and one common frog (*Rana temporaria*). Season had an affect on the kestrels' choice of prey type delivered to the nest. The probability that a prey item delivered to the nest was captured by the male was affected by prey type and nest (random effects). The males captured 82 % of avian prey delivered, 80 % of the lizards delivered and 67 % of small mammals delivered to the nest. The females captured all insects delivered to the nest. Prey captured by the male may be delivered to the nestlings either by the male or handed over to the female. The probability that a prey item taken by the male was delivered by the male to the nestlings was affected by prey type and nest. For males, but not for females, the type of prey captured was affected by the type of previous prey captured. Birds were more often decapitated on delivery than small mammals, and among the small mammals, voles were more often decapitated than shrews. Common lizards were never decapitated. Adult avian prey was more often decapitated than juveniles. Brood age, decapitation, prey age (juvenile/adult), female or male delivery to the nest, female or male prey capture, and nest (random effects) all affected the probability that an avian prey was plucked on delivery. The best regression model for female feeding time, both for all prey types pooled, and avian prey included prey body mass and decapitation of prey, and explained 43% and 35% of the variation respectively. Female efficiency while provisioning the nestlings increased with prey body mass, both for all prey types pooled, and for avian prey, small mammals and lizards separately.

Sammendrag

Byttedyrhåndtering og inntaksrate hos hekkende tårnfalker, *Falco tinnunculus*, ble studert ved hjelp av videofilming juni-juli 2005. I løpet av filmperioden ble totalt 157 byttedyr levert til ti reir. Filmperioden ble gjennomført med to påfølgende filmdager på hvert reir. Av byttedyrene var 89 fugl (Aves), 25 spissmus (Soricidae), 18 stumpmus (Arvicolidae), 15 firfirsler (*Lacerta vivipara*), fem biller (Coleoptera), fire øyenstikkere (Odonata) og en frosk (*Rana temporaria*). Sesong hadde en effekt på tårnfalkenes valg av byttedyr levert på reiret. Sannsynligheten for at et byttedyr levert på reiret var fanget av hannen, var påvirket av byttedyrtype og reir (tilfeldig effekt). Hannen fanget 82 % av fuglene, 80 % av firfirslene og 67 % av små pattedyr levert på reiret. Byttedyr fanget av hannen kan enten bli levert til ungene av hannen eller overlevert til hunnen. Sannsynligheten for at et byttedyr fanget av hannen ble levert av hannen, var påvirket av byttedyrtype og reir. Den type byttedyr hannen fanget, var påvirket av forrige byttedyrtype hannen hadde fanget. Fugler var oftere dekapitert ved levering enn små pattedyr, og blant små pattedyr var stumpmus oftere dekapitert enn spissmus. Firfirsle ble aldri levert dekapitert. Voksne fugler var oftere dekapitert enn juvenile fugler. Ungenes alder, dekapitering, byttetdyrets alder (juvenil/voksen), om det var hunnen eller hannen som leverte byttet, om det var hunnen eller hannen som fanget byttet og reir påvirket sannsynligheten at en fugl var plukket ved levering. Den beste regresjonsmodellen for hunnens foringstid, både for alle byttedyr samlet og for fugler, inkluderte byttedyrvekt og dekapitering, og forklarte henholdsvis 43 % og 35 %. Hunnens effektivitet ved foring av ungene økte med byttedyrvekt for alle byttedyr samlet, og for fugler, små pattedyr og firfirsler separat.

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Introduction

A predator's choice of prey depends on the profitability of the prey, which is energy value divided with handling time (Krebs, 2001). Handling time is defined as a sum of capture time, preparation time and ingestion time (e.g. Kaspari, 1990). Optimal foraging theory assumes that predators will maximize the net energy gain while foraging (Krebs, 2001), and that predators will be able to rank prey, such as frogs, reptiles, birds and mammals, according to profitability (Krebs, 2001, Selås, 2001). For a predator foraging to feed its sedentary mate or offspring, the profitability of a prey type will be influenced by the cost of transportation from the capture sites to the nest (Sonerud, 1992). The profitability will thus differ in its value when the predator is foraging for itself and consuming prey at the capture sites or transporting the prey item to the nest to be consumed there. At a given distance from the nest, prey items with energy values below a certain level will not be worth transporting (Sonerud, 1989). Birds have two ways to maximize the number of offspring entering the breeding population, firstly, by adjusting their breeding time optimally in relation to food availability and, secondly, by harvesting food optimally, i.e. maximizing energy gain in relation to energy provision (Tornberg, 1997).

Prey preparation is an important behaviour for many animals and is characterized by the investment of time and energy modifying prey before of ingesting it (Kaspari, 1990). Prey preparation not only render the food down to ingestible portions, but may also remove inedible parts of the food that could restrict ingestion, waste valuable energy, or even pose a threat to the forager through toxicity or mechanical damage (Kaspari, 1991, Rands et al., 2000). Preparation often appears to increase the nutrient concentration of prey, through the selective removal of low-quality prey parts (Kaspari, 1990). Prey preparation may also remove non-essential mass and therefore reduce transport costs (Rands et al., 2000). Because energy expended in preparing prey reduces the profitability of each prey item, it is important to consider factors which influence the evolution of prey handling (Sherry and McDade, 1982).

Eurasian kestrels, *Falco tinnunculus*, (hereafter called kestrels) are medium-sized falcons which hunt by hovering or perching, watching for prey on the ground (Village, 1990). Their flexible diet enables them to live in many kinds of environment in the Paleartic region (Village, 1990). Kestrels are predominantly open-country birds, and are absent from dense woodland unless there are clearings where they can hunt (Village, 1990). During the first two weeks after hatching the male hunts and the female feeds the nestlings (Village, 1990). When the nestlings are older, both parents hunt and bring prey to the nest, where the nestlings consume the prey items on their own (Village, 1990; Fargallo et al., 2003). The diet of kestrels during breeding has been investigated extensively, and the importance of small mammals, especially *Microtus* voles, has been demonstrated (Korpimäki, 1985b, Itämies and Korpimäki, 1987, Village, 1990, Korpimäki and Norrdahl, 1991). Kestrels feed mainly on small mammals, but can feed on a wider variety of prey including small birds, lizards (Lacertilia), large insects and earthworms (Lumbricidae) (Korpimäki, 1985b, Village, 1990, Fargallo et al., 2003). Kestrels would predate on the most abundant prey at the time (Village, 1990). Switching to alternative prey when the main prey is scarce allows kestrels to persist in areas they would otherwise abandon, but they are rarely as abundant, or as successful in breeding, as under good vole conditions (Village, 1990).

I investigated prey preparation and ingestion rate in breeding kestrels in south-eastern Norway. The male kestrel may decapitate prey, and pluck most of the feathers from avian prey before delivering it to the nest (Village, 1990). Rands et al. (2000) proposed several explanations for why a bird processes (decapitate and pluck) a prey item. 1) The bird may consume some of the parts removed from the prey, thus reducing the time it needs to forage for itself. 2) If provisioning a mate or offspring, processing may be a costly process for the non-hunting partner of the forager back at the central place. 3) Flight expenses carrying a prey item in the talons may cause a drag which could increase the cost of transport to the forager. Processing may be a form of manipulation which reduces flight costs through removal of parts that could cause drag or simply a rearrangement of the prey so that it is an aerodynamically better shape. 4) Many birds of prey process their prey at a specific plucking site a short distance form the nest. If the female processes the prey item at a place near the nest it may increase the chance of nest predation, either by leaving the nestlings vulnerable, or somehow making the location of the nest more obvious. Then, ideally the male should pluck the prey before transport rather than at a set plucking site within the territory. 5) Ectoparasites can seriously affect the nestlings’ growth rates and fitness. Processing may remove the ectoparasites.

In my study, prey body mass will be used as a substitute for prey energy value, and handling time will be restricted to female feeding time at the nest. Foraging involves time and energy expenditure in searching for, pursuing and handling prey (Sherry and McDade, 1982). Total time and energy budgets will not be estimated in my study because I have data only for prey handling at the kestrels' nest. I will therefore use female efficiency while she provision the nestlings, i.e. prey mass consumed per unit feeding time, as a measurement of profitability of the different prey types.

What variables would affect female efficiency while provisioning the nestlings? 1) Lizards (*Lacerta vivipara*), small mammals; shrews (Soricidae) and voles (Arvicolidae), may be more profitable than birds because of their size and a possible faster feeding time, and be easier to swallow whole because of their body form. They may also be more digestible than birds of similar size. Birds have feathers, beaks and long legs that are more difficult to digest. Small mammals may therefore be more profitable than similar sized birds. 2) Small mammals may be more profitable than lizards and insects; dragonflies (Odonata) and beetles (Coleoptera), because they are larger than lizards and insects in Norway.

Methods

Study area

The study was conducted in the boreal and hemi-boreal zones in Trysil municipality, Hedmark county, south-eastern Norway (61° 07´- 61° 28´ N; 12° 06´- 12° 43´ E), in May-July 2005. Ten nests of kestrels, in nest boxes provided by local ornithologists, were selected for the study. These ten nests were located mostly on bogs and 5-10 year old clear-cuts at altitudes of 300-700 m above sea level. The nest boxes were checked at least twice before filming to determine clutch size, hatching date and number of hatched young. There were no voles in the snap-traps put out by the local Hunting and Fishing Association in June 2005 (D. A. Berget. pers. comm.). This suggests that very few voles were available for the kestrels in my study.

Equipment for video recording

Ten nest boxes of plywood special-made for filming (36 cm wide, 28 cm long and 31 cm high) were used to replace the original nest boxes. The nest boxes were replaced two to four days before filming so that the kestrels could adjust to the new nest box. The boxes were placed from 5-15 m above ground level, either at exactly the same position as the original nest box, or 1-3 m lower.

A special made camera-top made of plywood contained a camera lens, which was a wired 18LED night vision CCTV camera, size 50 x 45 x 45 mm, and waterproof for outdoor use. The camera lens was positioned in such an angle that the adult kestrel with its prey could be seen on the camera display when it entered the nest box. Also the nestlings could be watched when fed by the mother or when self-feeding. The same camera-top was used at every site and had to be replaced the day before the filming. Power supply to the camera lens was provided by a 12 V lead battery placed on the ground at the base of the tree. The connection between the camera lens and recorder was made of 50 m of modified RCA video cables with male to male connectors on each end. This allowed monitoring prey deliveries, prey handling and feeding behaviour on a small digital camera display inside a camouflage tent placed 25-35 m from the nest tree.

A small box made of plywood containing a rebuilt digital scale was used at each site and had to be relocated between each filming. The scale box was put in the lower part of the nest box and replaced a small container inside the nest box during each film period. The female kestrel and the brood were staying upon the scale. A display was placed in the camouflage tent so that the mass of each prey delivered to the nest could be monitored. The digital scale was used for 12 of the 20 film days. The scale failed on day 3, and filming had to be done without the scale for five days until it was repaired. On day 17 it failed again so filming had to be done without the scale the three remaining days.

Video recording

Each brood was filmed for an average of 10 h (from 06.00 AM to 04.00 PM) on two subsequent days. The brood at location Dulpkjølen (appendix 1), however, was filmed twice at three days interval. None of the broods were abandoned (during the film period of 20 days). Total duration of the video recording obtained was c 200 h. A digital camcorder, Canon MV850i, and mini DV Panasonic Linear plus AY-DVM80FE video cassettes were used. Each cassette recorded for 2 h in long play mode. Power supply to the recorder was provided by a 12 V lead battery (10 Ah) with a voltage converter (from 12 to 8.4 V). I stayed inside a camouflage tent during filming to switch video cassettes every second hour and to observe the kestrels' behaviour outside the nest. I also recorded time of the kestrels' arrival and departure when delivering prey, whether it was the female or the male who made the delivery, the type of prey (insect, lizard, bird, shrew or vole), and whether the prey was plucked or decapitated on delivery. Temperature was recorded at each prey delivery at the nest, except for eight deliveries. Prey type, plucking and decapitation were later verified when watching the video (see below).

Video analysis

I measured feeding time by watching the video tapes on a colour TV and recording the duration of the feeding procedure with a stopwatch. If the female or nestlings stopped feeding for a longer period than 4 s, the pause was excluded from the feeding time. If a prey was consumed in two bouts, the time of the first and the second were measured and pooled. I considered female feeding time to be the time used to feed the nestlings, from when the female lowered her head to take the first piece, until the prey was completely consumed or abandoned. In some cases the female self-fed on the prey item for a short time. This behaviour was included in female feeding time. I considered nestling feeding time to be 1) the time used by one nestling on self-feeding, from when the nestling lowered its head to take the first piece until the prey was completely consumed or abandoned, 2) the time two or more nestlings used on self-feeding including some degree of fights among them, as long as they fed at the same time, from the nestlings grabbed the prey and until the prey were totally consumed or abandoned. Sibling fights over food which could be separated from feeding were excluded from feeding time. In three cases the female fed the nestlings and the nestlings self-fed on the same prey item. In those cases, I have separated female feeding time and nestling feeding time but added the two bouts in total feeding time.

All prey items were identified to species, family or order from the video. Almost all mammalian and avian prey was identified to species. Dragonflies and beetles were determined to order.

Estimating body mass of prey

Because the scale failed twice, the body mass of small mammals and lizards had to be estimated following the method used by Steen (2004). My estimation procedure could be simplified compared to that of Steen (2004) because I had ten nest boxes of the same size whereas Steen (2004) had to adjust the estimations to each nest box. I estimated body mass of all small mammals and lizards delivered, although the scale failed only for ten small mammals and seven lizards. In the lab, after the field work was finished, the nest box was provided with a grid placed in the same plane as the front of the nest box where the expected bill positions of the kestrel would appear. This was then recorded with the same video equipment as in field. The grid would appear through the longitudinal axis of the prey hanging from the kestrel's bill. The camera lens was placed in the same position and angle at each nest box by use of the special made camera-top. The angle would therefore be the same at each of the ten nest boxes in the field and when the grid was filmed in the lab. The field recordings and the grid system recordings were viewed with a video projector, Epson LCD projector (model EMP 500, 1996, on a white board. The grid was first drawn on the white board and then the prey item was drawn upon the grid.

The body mass of each small mammal delivered by the kestrel was estimated by the linear regression equation $f(x) = a + b*x^{1.5}$, based on the relationship between covered grid squares (5 x 5mm) (x) and recorded body mass (f(x)) of 20 voles and shrews of known body mass. The number of grid squares covered by natural prey items was used to calculate their body mass. For each recorded mammal prey, I counted the number of grid squares (5 x 5 mm) covered by the prey. The regression line $f(x) = a + b*x^{1.5}$ was then used to estimate recorded mammal prey. I was unable to estimate the body mass for 12 of the 43 small mammals delivered because the kestrel's held the prey in an angle that differed from the angle of the grid, or the kestrel held the prey item in its claws, or some of the prey item was obscured from sight.

To calculate the body mass of each lizard delivered, I used the regression model $\log_{10}(m) = -1.767 + 3.2010* \log_{10}(SVL)$, where SVL is snout-vent length (van Damme and van Vanhooydonck, 2001). I obtained the snout-vent length from the grid system. The body mass of two of the 15 lizards delivered could not be estimated because the kestrel held the prey in an angle that differed from the angle of the grid.

The scale failed for 39 birds delivered. I therefore used body mass from literature for all 89 birds delivered, except for two which were impossible to identify to species because they were nestlings. Avian body mass was obtained from Cramp and Simmons (1983), Cramp (1985, 1988, 1992), Cramp and Perrins (1993, 1994), Matthysen (1998) and Selås (2001). For birds that were delivered decapitated I subtracted 12.9% of the body mass (T. Slagsvold & G. A. Sonerud, unpublished). Insect body mass was obtained from Itämies and Korpimäki (1987) and set to 0.2 gram. The body mass of the only frog (*Rana temporaria*) that was delivered could not be estimated.

Captured and delivered prey

If the male delivered the prey on the nest he was defined to have captured the prey. If the female delivered the prey on the nest, she was defined to have captured the prey if no calling from the male had been heard prior to the delivery. If calling from the male had been heard, the male was defined to have captured the prey.

Prey preparation

For avian prey the term adult denotes both adults and fledglings that I could not separate from adults, while the term juvenile denotes nestlings and newly fledged juveniles. When analysing the video I used four categories to describe the kestrels' processing of avian prey; 1) not plucked, 2) only wing- and tail-feathers plucked, 3) wing-, tail- and some body-feathers plucked, and 4) completely plucked. In the statistical tests some of these categories were pooled for simplicity and two separate analyses were run. One test was run with category (1) termed not plucked, and categories (2), (3) and (4) pooled and termed plucked. The other test was run with category (1) and (2) pooled and termed not plucked, and category (3) and (4) pooled and termed plucked.

Statistical tests

The statistical software JMP 4.0 was used for statistical analysis (SAS, 2000). Means are given with ± 1 SE. Significance was established at $p = 0.05$. Logistic regression models with Likelihood Ratio Test and backward elimination of variables were used to analyse male/female capture and delivery, and processing of prey (decapitation and plucking). I analysed feeding time and efficiency for female kestrels only. I used Stepwise regression models to analyse what affected female feeding time for all prey types pooled and for avian prey alone. Female feeding time and female efficiency while provisioning the nestlings were $\log_{10}$ transformed. The body mass of prey was $\log_{10}$ transformed in the analysis of variables affecting female feeding time and female efficiency. Likelihood Ratio Test was used to analyse the association between the type of prey captured and the type of prey previously captured.

Results

A total of 157 prey items were recorded delivered to ten nests during the filming period of 20 days (Table 1). Birds made up 56.7% of the number of prey delivered and 88.5% of total delivered mass, whereas voles made up only 11.5% of number of prey delivered and 4.0% of delivered mass.

Table 1. Number of prey items delivered by the kestrels to the nest, share of total prey by number, mean (± SE) estimated body mass of each prey group, and share of each prey group of total estimated mass.

Prey type	Number	% by number	Estimated body mass (g)	Total estimated mass (g)	Total estimated mass (%)
Birds	89	56.7	36.3 ± 2.8 (n=87)	3145.3	88.5
Shrews	25	15.9	9.8 ± 0.8 (n = 21)	193.1	5.4
Voles	18	11.5	14.1 ± 1.9 (n = 10)	140.7	4.0
Lizards	15	9.5	5.8 ± 0.8 (n = 13)	74.9	2.1
Beetles	5	3.2	0.2 (n = 5)	1.0	<0.1
Dragonflies	4	2.5	0.2 (n = 4)	0.8	<0.1
Frog	1	0.6	-	-	-
Total	157	99.9	24.1 ± 1.9 (n = 141)	3555.8	100

Captured and delivered prey

The variables significantly affecting which prey type that was delivered at the nest were female or male prey capture and delivery, season, temperature and nest (Table 2). In the variable nest, each nest was treated as an individual with random effect.

Table 2. Ordinal logistic regression model of significant effects on the type of prey delivered to the nest by the kestrels. Season denotes days after 1 June. Whole model N = 149, $\chi^2 = 60.8$, df = 14, $P < 0.0001$.

Variable	df	χ^2	P
Female or male delivery	1	11.6	0.0007
Female or male capture	1	6.1	0.0137
Season	1	5.9	0.0153
Temperature	1	5.7	0.0167
Nest (random effects)	9	25.8	0.0022

Relatively less avian prey was delivered to the nest late in the season than early. The proportion of small mammals, lizards and insects delivered to the nest increased throughout the season. This increase was smaller for small mammals than for lizards and insect (Fig. 1).

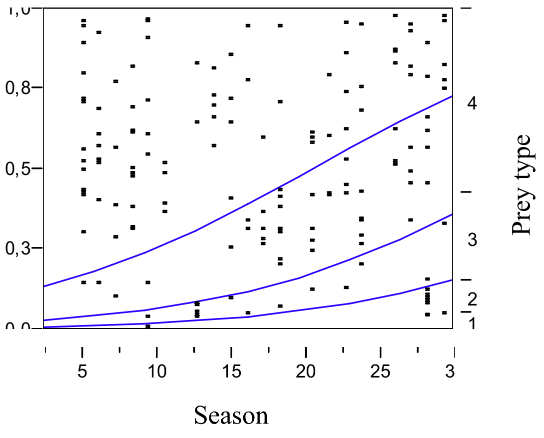

Fig 1. Ordinal logistic regression plot showing affect of season on prey type delivered to the nest. Prey types were 1) insects, 2) lizards, 3) small mammals and 4) birds. Season denotes days after 1 June. Whole model; N = 156, df = 1, $\chi^2 = 24.5$, $P < 0.0001$.

The probability that a prey item delivered to the nest was captured by the male (or female) was significantly affected by prey type and nest (Table 3). The male kestrels captured 82.0% of avian prey delivered, 80.0% of the lizards and 67.0% of small mammals to the nest. Female kestrels captured all insects delivered to the nest (Fig. 2). However, in the test 20 % of cells had expected counts less than 5, so the results should be interpreted with caution.

Thus among prey captured by males, 64.0% were birds, 25.4% small mammals and 10.5% lizards. Among prey captured by females, 38.1% were birds, 33.3% were small mammals, insects 21.4% and 7.1% lizards.

Table 3. Logistic regression model of significant effects on the probability that the male (or the female) kestrel captured a prey item which was delivered to the nest. Whole model N = 156, $\chi^2 = 63.97$, df = 12, $P < 0.0001$.

Variable	df	χ^2	P
Prey type	3	10.7	0.0135
Nest (random effects)	9	35.4	0.0001

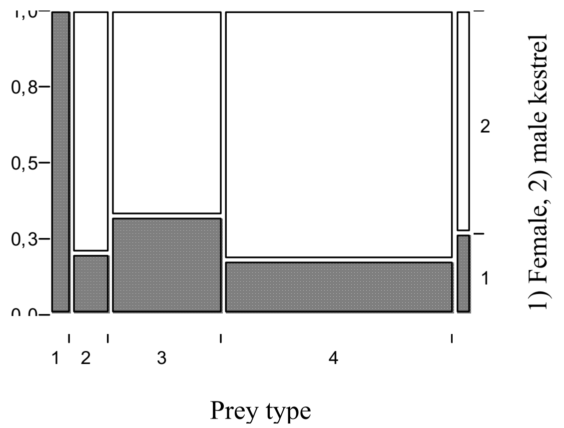

Fig 2. Proportion of the four prey types captured by female (1) and male (2) kestrels. Prey types were 1) insects, 2) lizards, 3) small mammals and 4) birds.

Regardless of who captured the prey, the probability that a prey item was delivered by the male (or female) was significantly affected by prey type and nest (Table 4). The interaction between nestling age and ambient temperature was eliminated from the final model, but was almost significant (P = 0.053). The variables nestling age and ambient temperature were far from significant by themselves. Female kestrels delivered 93.0% of all avian prey, 86.0% of all small mammals, and 53.0% of all lizards (Fig. 3)

Table 4. Logistic regression model of significant effects on the probability that the female (or the male) kestrel delivered a prey item to the nest for all prey captured pooled. Whole model N = 156, $\chi^2 = 35.6$, df = 12, P = 0.0004.

Variable	df	χ^2	P
Prey type	3	11.5	0.0095
Nest (random effects)	9	19.5	0.0215

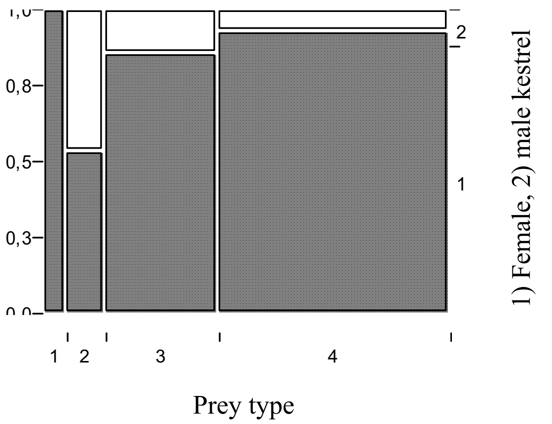

Fig 3. Proportion of the four prey types delivered by the female (1) and male (2) kestrels. Prey types were 1) insects, 2) lizards, 3) small mammals and 4) birds.

Because the female captured all the insects, the statistical test was repeated without the insects as a prey type group. Then the variable prey type was not significant, and the only significant variable was nest (whole model; N = 156, $\chi^2 = 55.1$, df = 9, $P < 0.0001$).

Prey captured by the male kestrel may be delivered to the nest either by the male or the female. Likelihood Ratio Test was therefore performed on male and female delivery for prey captured by the male only. This test yielded the same results as the one for male and female delivery for all prey captured; prey type and nest significantly affected which sex delivered the prey item (Table 5). Of the male prey captures, 58.3% of the lizards, 20.7% of the small mammals, and 5.3% of the birds were delivered to the nest by the male (Fig. 4).

Table 5. Logistic regression model of significant effects on the probability that the male (or the female) kestrel delivered a prey item to the nest, for prey captured by the male. Whole model N = 114, $\chi^2 = 34.8$, df = 11, P = 0.0003.

Variable	df	χ^2	P
Prey type	2	11.3	0.0036
Nest (random effects)	9	19.4	0.0217

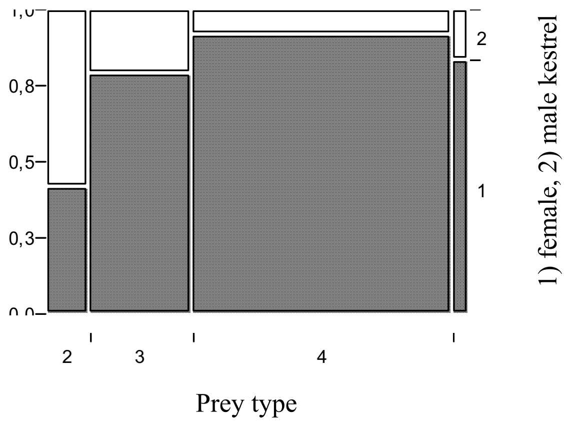

Fig 4. Proportion of the four prey types delivered by the female (1) and male (2) kestrels. Male prey captures only. Prey types were 1) insects, 2) lizards, 3) small mammals and 4) birds.

Type of prey captured and type of prey previously captured

I tested whether the prey type captured was affected by the previous prey type captured, for each sex separately. For male kestrels the association between prey type captured and previous prey type captured was significant (Fig. 5a). For female kestrels the association between prey type captured and previous prey type captured was not significant (Fig. 5b). Both tests, however, showed a warning because 20 % of cells had expected counts less than 5, so the results should be interpreted with caution. The probability that a male kestrel captured a bird after a bird was 80.0%. The probability that a male kestrel captured a lizard after a lizard delivered was 50.0%, and the probability that a male kestrel captured a small mammal after a small mammal was 38.1%.

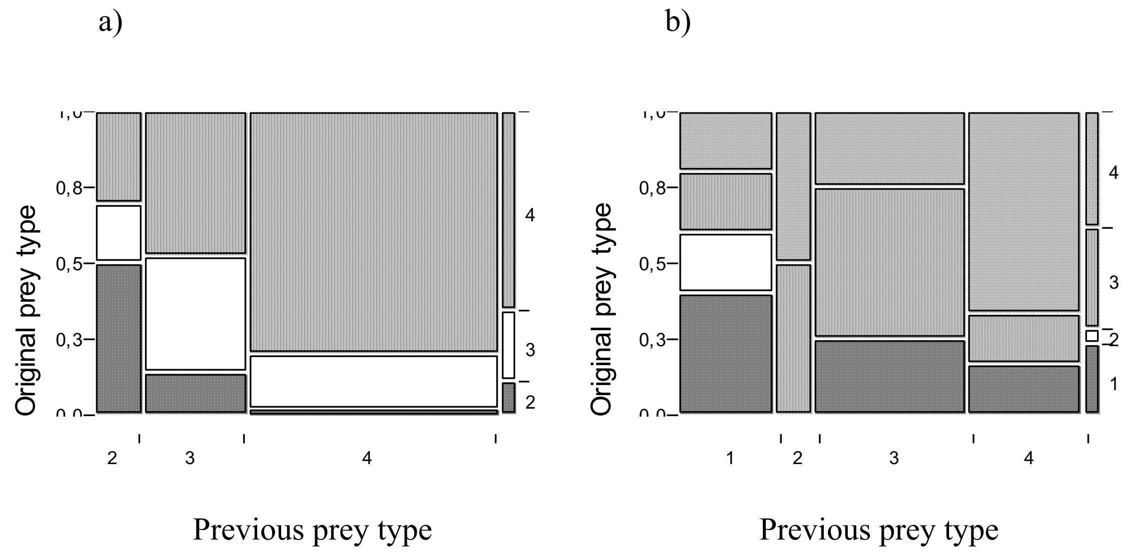

Fig 5. Proportion of the prey types captured in relation to the prey type previously captured for a) male kestrels and b) female kestrels. Prey types were 1) insects, 2) lizards, 3) small mammals and 4) birds. The association between type of prey captured and type of previous prey captured for male kestrels was significant. Likelihood ratio test; N = 81, $\chi^2 = 20.521$, df = 4, P = 0.0004. The association between type of prey captured and type of previous prey captured was not significant for female kestrels. Likelihood ratio test; N = 21, $\chi^2 = 8.12$, df = 9, P = 0.52.

Decapitated and plucked prey

Birds were delivered decapitated more often than were voles and shrews (56.2%, 27.8% and 8.0%, respectively). Lizards were never decapitated on delivery. Because it was impossible to see whether insects were delivered decapitated, insects were excluded from the analysis of factors affecting decapitation. Whether the prey item was decapitated or not was affected by prey type (Table 6 and Fig. 6). Nest was almost significant (P = 0.055).

Table 6. Logistic regression model of significant effects on the probability that avian prey delivered to the nest was decapitated. Whole model N = 147, $\chi^2 = 55.7$, df = 12, P = <0.0001.

Variable	df	χ^2	P
Prey type	3	35.0	<0.0001

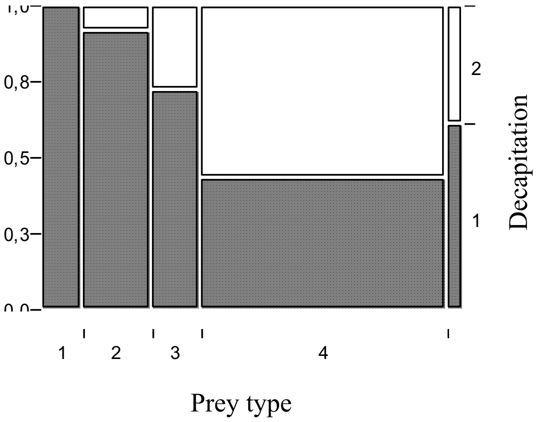

Fig 6. Proportion of prey delivered to the nest decapitated. Prey with head (1), decapitated (2). Prey types were 1) lizards, 2) shrews, 3) voles and 4) birds.

I had too little data to test what affected decapitation of small mammals alone (N = 43). I therefore only tested what affected decapitation of avian prey. The probability that a bird was decapitated on delivery depended on whether the bird was a juvenile or an adult (Table 7). Adult birds were more often decapitated than juveniles (69% vs. 33%; respectively) (Fig. 7). Nest had also a significant effect on decapitation (Table 7).

Table 7. Logistic regression model of significant effects on the probability that an avian prey delivered to the nest was decapitated. Whole model N = 88, $\chi^2 = 30.3$, df = 10, P = 0.0008.

Variable	df	χ^2	P
Prey age (juvenile/adult)	1	13.3	0.0003
Nest (random effects)	9	19.5	0.0214

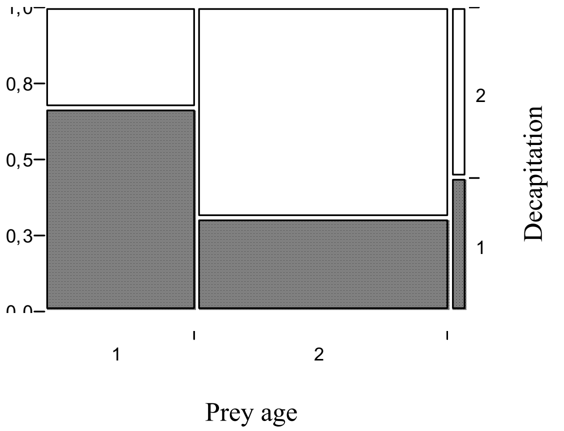

Figure 7. Proportion of juvenile (1) and adult (2) birds delivered decapitated to the nest by the kestrels. Prey with head (1), decapitated (2).

Further preparation of avian prey beyond decapitation was analysed by using four categories for the degree of plucking; not plucked (1), only wing- and tail-feathers plucked (2), wing-, tail- and some body-feathers plucked (3), and completely plucked (4). Among the 89 avian prey items, 22.5% was not plucked (category 1), 32.6% had their wing- and tail-feathers removed (category 2), 32.6% had their body-feathers removed in addition to wing- and tail-feathers (category 3), and 12.4% were completely plucked (category 4). In the statistical tests some of these categories were pooled for simplicity and two separate tests were analysed. One test was run with category (1) termed not plucked, and categories (2), (3) and (4) pooled and termed plucked. The other test was run with category (1) and (2) pooled and termed not plucked, and category (3) and (4) pooled and termed plucked. These two tests yielded different results. In Regression model (1) the probability that an avian prey delivered to the nest was plucked was significantly affected by brood age, decapitation, prey age (juvenile/adult), and nest (Table 8a). Because decapitation and plucking may be parts of the same prey preparation procedure, the Regression model (1) was repeated without the variable describing decapitated prey. Then the variable brood age became non-significant (Table 8b).

Table 8a. Logistic regression model (1) of significant effects on the probability that avian prey delivered to the nest was plucked. Whole model N = 88, χ^2 = 62.9, df = 12, P = <.0001.

Variable	df	χ^2	P
Prey age (juvenile/adult)	1	25.3	<0.0001
Decapitation	1	6.8	0.0093
Brood age	1	4.9	0.0268
Nest (random effects)	9	27.5	0.0011

Table 8b. Logistic regression model (1) of significant effects on the probability that avian prey delivered to the nest was plucked, when the variable decapitation was excluded from the analysis. Whole model N = 88, χ^2 =53.9, df = 10, P < 0.0001.

Variable	df	χ^2	P
Prey age (juvenile/adult)	1	30.7	<0.0001
Nest (random effects)	9	28.6	0.0008

In Regression model (2), there were more significant effects on the probability that an avian prey delivered to the nest was plucked than in Regression model (1). In addition to brood age, prey age (juvenile/adult) and nest from Regression model (1); female or male delivery to the nest and female or male prey capture had significant effects on whether the prey was plucked in Regression model (2). The variable decapitated prey was not significant in Regression model (2), so Regression model (2) remained the same whether the test was run with or without the variable decapitated prey (Table 8c).

Table 8c. Logistic regression model (2) of significant effects on the probability that avian prey delivered to the nest was plucked. Whole model N = 88, χ^2 = 65.0, df = 13, P < 0.0001.

Variable	df	χ^2	P
Prey age (juvenile/adult)	1	41.8	<0.0001
Brood age	1	11.9	0.0005
Female or male delivery	1	6.3	0.0119
Female or male capture	1	4.1	0.0419
Nest (random effects)	9	33.1	0.0001

Female provisioning

The best multiple regression models for female feeding time for all prey types pooled included prey body mass and decapitation of prey, and explained 43% of the variation (Table 9i). The variable season was almost significant, while brood age and size were not significant (Table 9i).

Table 9i. Stepwise regression model of variables affecting female feeding time, with $\log_{10}$female feeding time as response for all prey pooled (N= 104). Regression coefficients with standard errors refer to the chosen model. The variables are listed in the order they were obtained in a forward selection procedure, and cumulative values are given for R^2 and AIC. For each of the other variables, the values refer to the model where also this variable was selected. Season denotes days after 1 June.

Variable	Regression coefficient	df	SE	R^2	P	AIC
Intercept	2.28	1				-213.358
Log_{10}BM3*	0.64	1	0.091	0.33	<0.0001	-252.246
Decapitation	-0.13	1	0.028	0.43	<0.0001	-268.486
Season				0.45	0.0627	-270.127
Brood age				0.42	0.2505	-267.867
Brood size				0.44	0.4950	-266.973

* Log_{10} transformed prey body mass

Also for avian prey alone the best multiple linear regression models for female feeding time included prey body mass and decapitation (Table 9ii and Table 9iii). Two regression models for avian prey were analysed because two different ways of pooling categories were used (Table 9ii and Table 9iii). In Plucking variable (1) category 1 denotes not plucked, and category (2), (3) and (4) pooled denotes plucked. In Plucking variable (2) category (1) and (2) pooled denotes not plucked and category (3) and (4) pooled denotes plucked. The two models included the same significant effects on female feeding time. The selected models explained 35% of the variation. The explained variations for the non-significant variables, however, differed between the two models.

Table 9ii. Stepwise regression model of variables affecting female feeding time, with $\log_{10}$female feeding time as response for avian prey with plucking variable (1) (N = 79). Regression coefficients with standard errors refer to the chosen model. The variables are listed in the order they were obtained in a forward selection procedure, and cumulative values are given for R^2 and AIC. For each of the other variables, the values refer to the model where also this variable was selected. Season denotes days after 1 June.

Variable	Regression coefficient	df	SE	R^2	P	AIC
Intercept	2.38	1				-179.536
Decapitation	-0.14	1	0.032	0.18	0.0001	-193.356
Log_{10}BM3*	0.53	1	0.127	0.35	0.0001	-208.541
Season				0.36	0.2151	-208.172
Brood size				0.36	0.2737	-207.813
Brood age				0.35	0.4779	-207.076
Prey age (juvenile/adult)				0.35	0.5750	-206.875
Plucking (1)				0.35	0.8213	-206.595

*Log_{10} transformed prey body mass.

Table 9iii. Stepwise regression model of variables affecting female feeding, time with $\log_{10}$female feeding time as response for avian prey with plucking variable (2) (N = 79). Regression coefficients with standard errors refer to the chosen model. The variables are listed in the order they were obtained in a forward selection procedure, and cumulative values are given for R^2 and AIC. For each of the other variables, the values refer to the model where also this variable was selected. Season denotes days after 1 June.

Variable	Regression coefficient	df	SE	R^2	P	AIC
Intercept	2.38	1				-176.536
Decapitation	-0.14	1	0.032	0.18	0.0001	-193.356
Log_{10}BM3*	0.53	1	0.127	0.35	0.0001	-208.541
Season				0.33	0.2151	-208.172
Brood size				0.33	0.2737	-207.813
Brood age				0.32	0.4779	-207.076
Prey age (juvenile/adult)				0.32	0.5750	-206.875
Plucking (2)				0.32	0.6716	-206.732

*Log_{10} transformed prey body mass

Female efficiency, i.e. mass (g) of prey fed to the nestlings per unit time (min), while provisioning the nestlings increased significantly with prey body mass for all prey type pooled, and for birds, small mammals and lizards separately (Fig. 8a, b, c, d). Female efficiency and prey body mass were $\log_{10}$ transformed.

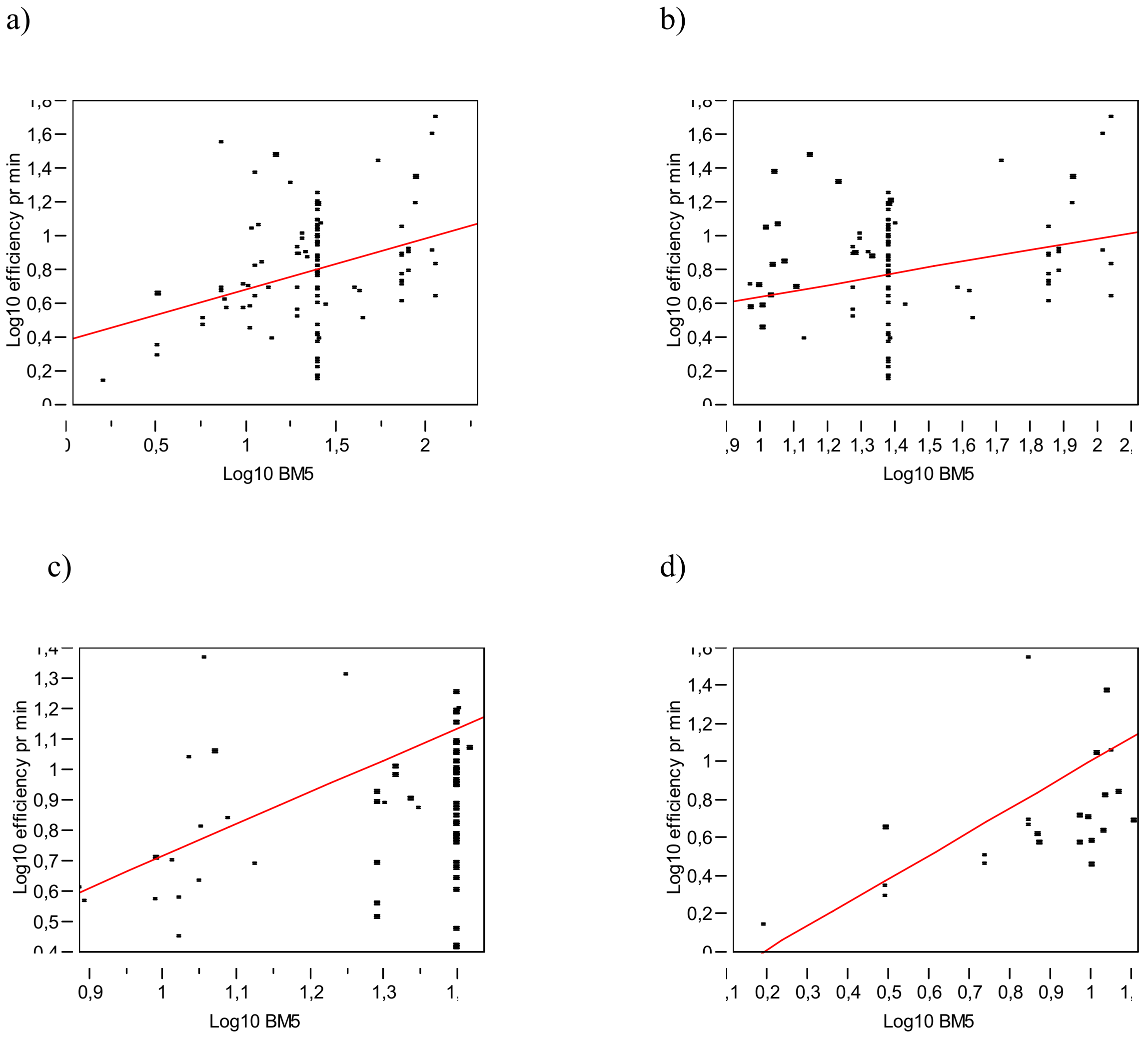

Fig. 8. The relationship between the female kestrels' efficiency while provisioning the nestlings and prey body mass. a) All prey types pooled. Log_{10} efficiency = 0.391 + 0.303 $\log_{10}$BM5. Whole model; N = 104, $R^2 = 0.11$, P = 0.0008. b) Avian prey. Log_{10} efficiency = 0.310 + 0.341 $\log_{10}$BM5. Whole model; N = 79, $R^2 = 0.07$, P = 0.0176. c) Small mammals. Log_{10} efficiency = -0.302 + 1.056 $\log_{10}$BM5. Whole model; N = 16, $R^2 = 0.33$, P = 0.0202. d) Lizards. Log_{10} efficiency = -0.021 + 1.244 $\log_{10}$BM5. Whole model; N = 9, $R^2 = 0.6$, P = 0.0221.

Female efficiency while provisioning the nestlings with avian prey increased significantly with both body mass for items with head and for decapitated items, but the increase was steeper for the former than the latter (Fig. 9a, b).

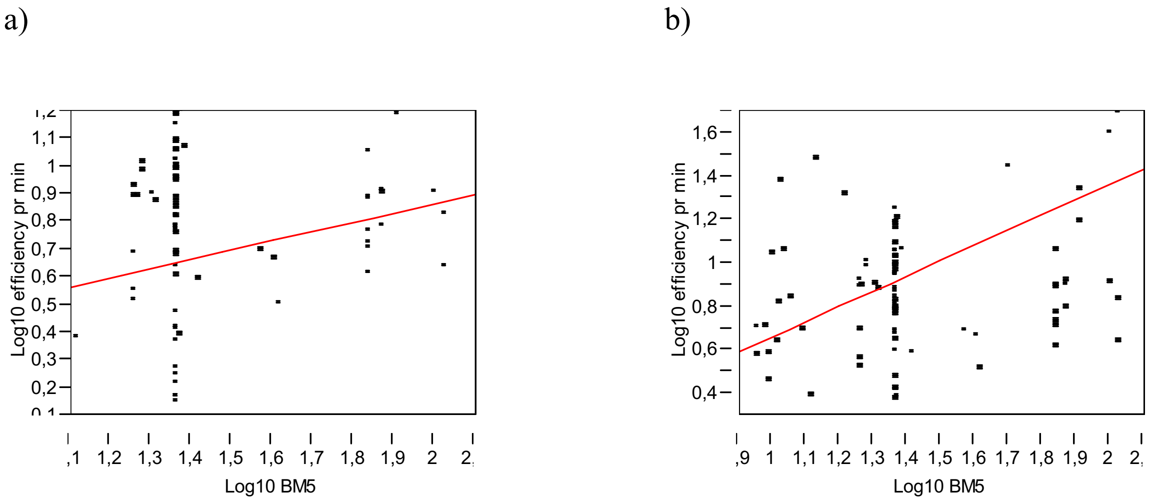

Fig 9. The relationship between the female kestrels' efficiency while provisioning the nestlings and prey body mass. a) Decapitated avian prey. Log_{10} efficiency = 0.184 + 0.341 $\log_{10}$BM5. Whole model; N = 44, $R^2 = 0.09$, P = 0.04657, and (b) avian prey with head. Log_{10} efficiency = -0.045 + 0.704 $\log_{10}$BM5. Whole model; N = 35, $R^2 = 0.28$, P = 0.0011.

Discussion

I found that kestrels delivered mainly birds (57% of all prey), while shrews (16%), voles (12%), lizards (10%) and insects (6%) each made up a small part. Voles, regarded as the kestrel's main prey (Korpimäki, 1985a, Village 1990, Korpimäki and Norrdahl, 1991), were scarce in my study, according to snap-traps set up by the local Hunting and Fishing Association, *Trysil Fellesforening for Jakt og Fiske* (D. A. Berget, pers. comm.). Trysil municipality expands over a wide area and the vole densities may have varied a lot within my study area.

The kestrels in my study may have taken the high number of birds to compensate for the low vole densities. Small birds, shrews, lizards, and insects are regarded as alternative prey types for kestrels (Korpimäki, 1985b, Itämies and Korpimäki, 1987, Village 1990, Korpimäki and Norrdahl, 1991). Birds serve as an important alternative prey when the availability of voles is poor (Valkama et al., 1995). Small birds are important prey for kestrels in urban areas (Yalden, 1980). In Manchester, birds comprised 76% of prey taken (Yalden, 1980), and birds predominated in the kestrels' diet during the nestling and post fledging periods in Rome (Piattella et al., 1999). In Finland, small birds, water voles (*Arvicola terrestris*) and bank voles (*Clethrionomys glareolus*) were the next most important prey groups after *Microtus* voles in the kestrels' diet in farmland and pine forest (Korpimäki and Norrdahl, 1991). In good vole years agricultural fields are a source of *Microtus* voles, but in poor years they are probably a source of small birds and bank voles that dispersed from nearby forests (Valkama et al., 1995).

In 2003, when Steen (2004) studied kestrels in the same area as I did, lizards made up 25% of prey delivered to the nest, while voles made up 30%, shrews 25%, and birds only 19%. The share of voles in particular, and that of lizards and shrews in general were much higher in the study of Steen (2004) than in my study. This may imply that vole density was higher when Steen (2004) conducted his study. Common buzzard, *Buteo buteo*, appeared to take avian prey more frequently in low vole years than in peak vole years, suggesting that the buzzards then switched from vole-hunting to bird-hunting (Selås, 2001). According to Selås (2001), reptiles were more common as prey for buzzards in peak vole years, probably because buzzards then concentrated on hunting ground-dwelling prey in habitats with high vole populations. Other small ground-dwelling species, than voles, may thus experience an increased risk of predation in vole years (Selås, 2001). Kestrels are open-country hunters (Village, 1990, Korpimäki and Norrdahl, 1991) like the buzzard (Selås, 2001), with voles as their main prey. The same effect, that ground-dwelling prey like lizards and shrews are more common as alternative prey in peak vole years than in low, may occur also in the kestrel. Korpimäki (1985a) found that kestrels mainly hunted *Microtus* voles living in fields, while the birds eaten consisted primarily of species breeding in the forest. The proportion of birds and insects fluctuated inversely with the proportions of mammals (Korpimäki, 1985b). Birds and insect were the most numerous prey groups in the diet in the poor vole years, while frogs and lizards varied irregularly (Korpimäki 1985b). Fargallo et al. (2003), however, found that lizards and shrews were fed to the nestlings with a higher frequency in the year of low food supply than in the year of high food supply, and considered a high presence of insects, lizards and shrews in the kestrels' diet to be indicative of environmental food restrictions. Sonerud (1992) stressed that lizards may be consumed at the capture site and therefore underestimated in the kestrels' diet and suggested that alternative prey might have been insects and lizards rather than birds in the study of Korpimäki (1985b), because large items of prey captured by single-prey loaders are more often carried to the nest and less often consumed at captures sites than small ones. At a given distance from the central place, prey items with energy values below a certain level are not worthy of transporting (Sonerud, 1989). These different findings may suggest that more research is needed to find out what kind of mechanisms influence choice of prey by single-prey loading open-country hunters like kestrels and buzzards.

Season had an affect on the kestrels' choice of prey type delivered to the nest. In my study the proportion of birds delivered to the nest decreased in the diet throughout the season, while the proportion of small mammals, lizards and insects delivered to the nest increased in the diet throughout the season. For small mammals the increase was small, while for lizards and insect the increase was high. This contradicts with the findings of Korpimäki (1985b) and Itämies and Korpimäki (1987), who found that the proportion of voles decreased towards the end of the breeding season, while the proportions of shrews and birds increased. The kestrels in my study may have started the breeding season later than usual in 2005 due to low vole density (cf. Village, 1990), and therefore the proportion of birds were larger in the start of the breeding season in my study.

Type of prey captured and type of prey previously captured

I found that for male kestrels, but not for females, the type of prey captured depended on the type of the prey previously captured. The probability that a male kestrel captured a lizard after a lizard was 50%, a small mammal after a small mammal was 38%, and a bird after a bird was 80%, compared to the random expectations of 11%, 25% and 64% respectively from all prey captured by the male. This may suggest that male kestrels have an area-concentrated search and return to the last capture site to search for a new prey. Area-concentrated search is an efficient strategy for exploiting prey with a clumped and stationery distribution; it implies either continuous stay within a clump of prey between successive captures non-central place foraging or successive returns to the clump from a central place (CP) (Sonerud, 1985a). Single-prey loaded CP foraging birds commonly use win-stay strategy when searching for prey, i.e. they return form their CP to the previous capture site more often than by change (Sonerud, 1985a). However, for lizards the relationship between prey capture and previous prey capture may be due to temperature. Steen (2004) found that lizards were delivered at higher ambient temperatures than voles and birds. Lizards may be easier for the kestrel to capture on warm sunny days when lizards are more active foraging and they spend more time basking, so that lizards may be captured in run on such days.

Movement and activity in general are dangerous for prey (Mitchell and Lima, 2002). To survive, prey must avoid predation and starvation. During the day while foraging the prey risk predation and during the night the prey risk starvation when they draw down their energy reserves to pay overnight metabolic cost (Mitchell and Lima, 2002). Animal movement is a phenomenon that may be favoured by a number of factors, such as dispersal, territory patrolling or local food depletion (Mitchell and Lima, 2002). Prey movement as a form anti-predator behaviour has not been given much consideration (Sonerud 1985a, b, Mitchell and Lima, 2002). Sonerud (1985a, b) and Mitchell and Lima (2002) have proposed that prey may move frequently to avoid predators; pointing out that such a phenomenon requires a predator with good spatial memory.

Prey preparation

Among the prey delivered by the kestrels in my study, birds were more often decapitated than small mammals. Bird heads may be too large for the nestlings to swallow. Avian prey may therefore be decapitated more often than small mammals and lizards. The kestrels in my study decapitated adult avian prey more often than juveniles. Juvenile birds have softer skulls and smaller beaks than adults and may therefore be easier for the nestlings to swallow and eat. The male kestrel may have decapitated adult avian prey to increase their profitability for the nestlings by increasing the female efficiency in provisioning the nestlings. Voles were more often decapitated than shrews, and lizards were never decapitated. Voles are usually larger than shrews and lizards. Shrews and lizards may be easier to swallow whole for the nestlings because of their smaller and more cylindrical body form, while it may be more profitable to decapitate large voles. Kaspari (1990) found that cylindrical body form made the prey item easier to swallow. The decapitation of large voles may be in accordance to the width hypothesis which predicts that those parts contributing most to prey width should be more frequently removed (Kaspari, 1991). The head of a vole is larger than that of a shrew or a lizard, and therefore more difficult to swallow. The decapitation of voles and birds may be to increase the nutrient value of the remaining carcass (c.f. Kaspari, 1991).

I used four categories of plucking degrees to describe the kestrels' preparation of prey items when analysing the video-recording. To simplify the statistical test, however, I used two plucking variables in the analysis. The two plucking analysis gave different results. Regression model (1) may be biased because the plucking categories (2) (3) and (4) were pooled and termed plucked. Not all avian prey in plucking category (2) may have been plucked; some may have been juveniles without full-grown wing- and tail-feathers and some prey items were difficult to identify as a juvenile or adult bird. Regression model (2) would not be completely true since plucking category (1) and (2) are pooled and termed not plucked (see methods).

Brood age, decapitation, prey age (juvenile/adult) and nest affected the probability that an avian prey delivered was plucked in Regression model (1). Since decapitation and plucking may be parts of the same procedure the test was also done without decapitation as a variable, and then the variable brood age was not significant. This result may be by chance, but it may suggest that decapitation and plucking when pooled are affected by brood size in this regression model. In Regression model (2) brood age, prey age (juvenile/adult), female or male delivery, female or male prey capture, and nest had all an effect on plucking. Decapitation, however, was not significant. Brood age may affect plucking because older nestlings may handle more difficult prey as they become larger and more experienced.

Part removal according to width should increase when the prey item increases in size (Kaspari, 1991). Kaspari (1991) found, however, that grasshopper sparrow (*Ammodramus savannarum*) were more likely to remove prey parts if this maximized the rate of which nutrients were concentrated in the remaining carcass. Birds have several body parts difficult to consume, like long and hard beaks, feathers and long tarsus. These body parts may contribute little to energy and nutrition value, and the feathers contribute to the prey item's width so it becomes difficult for the nestlings to handle and swallow.

Another benefit of prey preparation may occur in animals that have to transport a prey item rather than consume it at the capture site, such as kestrels carrying food back to the nest to feed its young. Removing excess mass from the prey item may mean that the cost of carrying will be reduced (Rands et al., 2000). Plucking of feathers will reduce the mass of the prey item and considerably improve the prey items aerodynamics (Rutz, 2003). The total energy savings of preparing a prey item may be proportional to the transport distance and therefore increase the net rate of energy delivered to the nest (Sodhi, 1992). The kestrels in my study may have decapitated and plucked large avian prey to reduce transport costs. The male will then have to spend less time foraging to replace energy he uses for flight. Therefore a trade off may exist between the time spent processing, and the time spent replacing the extra energy expended through carrying unprocessed prey (Rands et al., 2000).

Several of the females in my study plucked avian prey in the nest. Many birds of prey process their prey at a specific plucking site a short distance from the nest. If the females process the prey item at a place near the nest it may increase the chance of nest predation, either by leaving the nestlings vulnerable, or somehow making the location of the nest more obvious (Rands et al., 2000). The male may thus pluck the prey at a capture site away from the nest to reduce the nestlings' vulnerability. Korpimäki (1985b) found, however, that female kestrels plucked the prey and ate the prey remains near or in the nest, often at the same stone or in the same tree.

Female provisioning and prey profitability

Larger prey was more profitable than smaller ones when female kestrels provisioned their nestlings in my study. Large prey items may be more profitable because the female can selectively provision the nestlings with more eatable parts like flesh and entrails, and eat less edible parts of the carcass like skull, skeleton, tarsus and legs herself. Female kestrels may therefore increase the efficiency of provisioning large prey items. Korpimäki (1985a) found that kestrels showed a preference for larger voles. In many cases I observed that the female kestrels provisioned their nestlings with tarsi from smaller avian prey while they either ate tarsi on large avian prey themselves, or carried them away from the nest, or dropped them in the nest without any feeding attempts. When the female offered pieces with tarsi or wings, the nestlings used longer time to feed than when they got fleshy parts (pers. obs). The female efficiency while provisioning the nestlings increased more with body mass for avian prey items with head than for decapitated avian prey items. The female kestrels may have eaten the head of large avian prey themselves while they provisioned the nestlings with the head of small avian prey. This may result in longer feeding time for decapitated for small avian prey with head.

Although larger prey was more profitable for the females to provision to the nestlings in my study, large prey items may not be the most profitable prey items to handle totally. In order to evaluate the effect of prey size on prey selection, it is important to determine whether handling times (and thus costs) rise faster or slower than prey energetic value (Sherry and McDade, 1982). Goshawks, *Accipiter gentilis*, prepared larger prey more thoroughly than small prey; they plucked large prey longer and more thoroughly (Rutz, 2002). This may induce a higher cost for larger prey than small ones. Both Sherry and McDade (1982) and Grosch (2003) found that predators should prefer smaller prey to large prey in order to improve handling efficiency. Prey handling efficiency decreased with increasing prey length (Grosch, 2003). Sherry and McDade (1982) found, however, that prey mass rather than prey length influenced the handling time of prey. Food provisioning in birds requires considerable time and usually has to be traded-off against other parental and non-parental activities (Grieco, 2002). A prey choice model by Grieco (2002) that takes the energetic needs of the parents into consideration predicted that the same amount of food could be delivered by increasing prey size through an increase in prey selectivity and reducing visit rate.

Conclusion

Prey preparation was common in my study. Birds were more often plucked and decapitated than small mammals, and lizards were never decapitated. Female efficiency while provisioning the nestlings increased with prey body mass, suggesting that larger avian prey was more profitable to feed the nestlings. If the female selectively fed the nestlings with flesh and entrails, they may have increased the profitability of large prey items. Larger prey may, however, not be the most profitable prey to provision the nestlings if the handling time is included. If the male has to prepare the prey item thoroughly then the costs of handling may rise faster than the energy value. More research is needed to evaluate the prey profitability and take the male kestrel's preparation of prey into consideration.

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Appendices

Appendix 1

Date	Locality (nest number)	GPS- coordinates	Clutch size	Brood size	Brood age	Day of filming
26.6. 2005	Dulpkjølen (1)	33V0345985 UTM6795518	5	5	9-10	1
27.6. 2005	Stortjønna (2)	33V0347892 UTM6797574	4	4	9-10	2
28.6. 2005	Stortjønna (2)	33V0347892 UTM6797574	4	4	9-10	3
29.6. 2005	Dulpkjølen (1)	33V0345985 UTM6795518	5	5	12-13	4
30.6. 2005	Grønkjølen (3)	33V0347678 UTM6797056	3	2	10-11	5
1.7. 2005	Grønkjølen (3)	33V0347678 UTM6797056	3	2	10-11	6
3.7. 2005	Vestby (4)	33V0343222 UTM6794025	3	2	12-13	7
4.7. 2005	Vestby (4)	33V0343222 UTM6794025	3	2	12-13	8
5.7. 2005	Flendalen (5)	33V0353745 UTM6816849	5	1	16-18 ?	9
6.7. 2005	Flendalen (5)	33V0353745 UTM6816849	5	1	16-18 ?	10
7.7. 2005	Munkmyra (6)	33V0338861 UTM6787838	5	5	17-18	11
8.7. 2005	Munkmyra (6)	33V0338861 UTM6787838	5	5	17-18	12
9.7. 2005	Stormyra 7)	33V0350893 UTM6797311	4	1	10-11	13
10.7. 2005	Stormyra (7)	33V0350893 UTM6797311	4	1	10-11	14
12.7. 2005	Hollsætra (8)	33V0353113 UTM6822857	3	3	12-13	15
13.7. 2005	Hollsætra (8)	33V0353113 UTM6822857	3	3	12-13	16
15.7. 2005	Litlåsen (9)	33V0351989 UTM6813375	5	5	12-14	17
16.7. 2005	Litlåsen (9)	33V03511989 UTM6813375	5	5	12-14	18
17.7. 2005	Storkjellkanken (10)	33V0350740 UTM6825066	?	3	12-14	19
18.7. 2005	Storkjellkanken (10)	33V0350740 UTM6825066	?	3	12-14	20

Appendix 2 Prey body mass of birds recorded as prey at ten Eurasian kestrel nests in Norway in 2005, after Cramp and Simmons (1983), Cramp (1985, 1988, 1992), Cramp and Perrins (1993, 1994), Matthysen (1998) and Selås (2001).

Species	Latin name	Country	Season	Body mass (g)
Broad-billed Sandpiper	*Limicola falcinellus*	Finland	-	37
Common Sandpiper	*Actitis hypoleucos*	Norway	-	50
Wryneck	*Jynx torquilla*	West-Germany	May - June	40
Tree Pipit	*Anthus trivialis*	Germany	Breeding season	19
Robin	*Erithacus rubecula*	Norway	July - October	18
Northern Wheatear	*Oenanthe oenanthe*	Norway	Breeding season?	24
Song thrush	*Turdus philomelos*	England	May - June	74
Redwing	*Turdus iliacus*	Netherlands	April - May	63
Fieldfare	*Turdus pilaris*	Norway	All year	105
Garden Warbler	*Sylvia borin*	Finland	Breeding season	19
Willow Warbler	*Phylloscopus throchilus*	Netherlands	Spring	9
Tits sp	*Parus*	Norway	Spring /August-April	13
Nuthatch	*Sitta europaea*	Finland	Summer	23
Chaffinch	*Frigilla colebs*	Norway	Spring / autumn	23
Bullfinch	*Pyrrhula pyrrhula*	Norway	April - May	31
Common crossbill	*Loxia curvirostra*	Norway	September - December	41

Appendix 3 Number and estimated body mass of prey items delivered by kestrels to the nest during video recording in June-July 2005, Norway. Body mass of lizards, shrews and voles are estimated and body mass of birds were obtained from literature (see appendix 2), body mass of some birds were estimated from the video. Decapitated birds were subtracted for body mass of head (Sonerud & Slagsvold unpublished).

Species	Latin name	No. of prey items	Estimated body mass (g)	No. of prey with estimated mass
Common frog	*Rana temporaria*	1	-	0
Common lizard	*Lacerta vivipara*	15	5.3	13
Bird unknown (nestlings)	Aves	2	-	0
Bird unknown	Aves	1	23	1
Grouse sp (nestlings)	Tetraonidae	2	100	0
Broad-billed Sandpiper	*Limicola falcinellus*	1	37	1
Common Sandpiper	*Actitis hypoleucos*	1	50	1
Woodcock	*Scolopax rusticula*	2	100	2
Wryneck	*Jynx torquilla*	1	40	1
Tree Pipit	*Anthus trivialis*	5	23	5
Robin	*Erthacus rubecula*	5	18	5
Northern Wheatear	*Oenanthe oenanthe*	2	24	2
Thrush sp	*Turdus*	2	80.7	2
Song Thrush	*T. philomelos*	3	74	3
Song Thrush / Redwing	*T. philomelos / T. iliacus*	7	68.5	7
Fieldfare	*T. pilaris*	4	105	4
Garden Warbler	*Sylvia borin*	2	19	2
Willow Warbler	*Phylloscopus throchilus*	2	9	2
Tits sp	*Parus*	1	13	1
Nuthatch	*Sitta europaea*	1	23	1
Passerine sp	Passeridae	3	23	3
Chaffinch	*Fringilla colebs*	40	23	40
Bullfinch	*Pyrrhula pyrrhula*	1	31	1
Common Crossbill	*Loxia curvirostra*	1	41	1
Shrew	Soricidae	25	8.3	21
Unknown vole	Arvicolidae	1	10.5	1
Field vole	*Microtus agrestis*	4	20.5	1
Root vole	*Microtus oeconomus*	3	17.3	2
Bank vole	*Clethrionomys glarelous*	10	12.5	6