Ornis Fennica 88:147–153. 2011

Diet composition in the Tengmalm's Owl *Aegolius funereus*: a comparison of camera surveillance and pellet analysis

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Received 25 November 2010, accepted 19 April 2011

During a two-year study in Central Europe, we used a combination of pellet analysis and camera recordings to assess the diet composition of Tengmalm's Owls during the breeding season, with regards to availability of the main prey components in the field. The diet of the owls consisted mainly of voles (Arvicolidae), mice (Muridae) and shrews (Soricidae), and their proportion in the diet reflected their local abundances in the field. Pellet analysis allowed us to determine 40.2 (± 6.9 SD)% in 2004 and 46.4 (± 14.7 SD)% in 2006 of all delivered prey items recorded by cameras. We determined 77.1 (± 17.1 SD)% in 2004 and 80.2 (± 12.5 SD)% in 2006 of the prey items recorded by camera monitoring. Pellet analysis underestimated the proportions of all main diet components, but the differences were significant only for the proportion of voles and birds. The underestimation of voles may have been a consequence of their decapitation before delivery to the nest. We regularly recorded decapitated voles and mice in the nest boxes of Tengmalm's Owl, while whole shrews were found more often. Our study highlights that a combination of both methods allows for a more accurate assessment of diet composition in nocturnal raptor species.

1. Introduction

Tengmalm's Owl (*Aegolius funereus*) is a nocturnal avian predator that feeds mainly on voles in Northern Europe (Korpimäki 1981, 1988), and voles and mice in Central Europe (Korpimäki 1986, Pokorný 2000, Pokorný *et al.* 2003). The abundance of small rodents considerably varies from year to year. When their abundance is low, the proportion of shrews and birds in the diet increases substantially (Korpimäki 1981, 1988, Koivunen *et al.* 1996).

Numerous studies on the diet composition of raptors have been based on prey-remain collections and pellet analyses (reviewed by Marti *et al.* 1993). Most dietary studies on Tengmalm's Owl have been based on pellet analyses or stored prey in cavities (Korpimäki 1981, 1988, Sulkava & Sulkava 1971, Schwerdtfeger 1988, Pokorný *et al.* 2003). However, some authors pointed out that such data may be biased due to an underestimation of particular diet components (Redpath *et al.* 2001, Booms & Fuller 2003, Lewis *et al.* 2004, Tornberg & Reif 2007). Such bias can be caused by several

factors including unequal preservation of particular prey remains, manipulation of prey by chicks and adult birds at the nest, or prey coloration (Rutz 2003). While pellet analyses usually underestimate the proportion of birds, analyses of prey remains underestimate the proportion of small mammals (Simmons *et al.* 1991).

Cameras can be successfully used to study the breeding behaviour of raptors and their diet composition (e.g., Pierce & Pobprasert 2007, Reif & Tornberg 2006, Grivas *et al.* 2009). This method also produces more reliable data on diet composition and delivery rates (Korpimäki 1981, Rogers *et al.* 2005). For example, the proportion of small mammals in the diet of Common Buzzards (*Buteo buteo*) appeared to be underestimated in an analysis of prey remains (Tornberg & Reif 2007). Another advantage of camera surveillance is a lower disturbance of raptors during breeding, which may lower the risk of nest abandonment (Cain 1985). Finally, due to the nocturnal activity of owls, it is not possible to observe prey deliveries to the nest from a hide or screen. Therefore, camera monitoring remains the only effective method to study owl feeding ecology.

In this study, we assessed the diet composition of Tengmalm's Owl in the Ore Mountains, Czech Republic, by a pellet analysis from nest boxes and using nest recording by continuous camera surveillance (Reif & Tornberg 2006). The aim of the study was to compare the mean delivered numbers of main diet components collected by each method. Furthermore, we assessed the availability of the main components of small mammal prey and compared their abundance with their dietary proportion.

2. Material and methods

2.1. Study area and population

The study area was situated in forests damaged by industrial air pollution in the Ore Mountains (50° N, 13° E) in the Czech Republic at altitudes ranging between 735 to 956 m a.s.l. The study area is covered by fragments of Norway spruce forest, open areas and forest clearings (dominated by Wood Reed *Calamagrostis villosa*), solitary trees (mostly European Beech *Fagus sylvatica*) and plantations of Blue Spruce *Picea pungens*, Birches *Betula* spp., European Mountain Ash *Sorbus aucuparia* and European Larch *Larix decidua*. Within these habitats, 120 nest boxes for the Tengmalm's Owls were placed in an area of 70 km^2. Data on diet composition were collected between May and July 2004 and 2006. We monitored four nests in 2004 (27% of the nest-box breeding population) and six nests in 2006 (25% of the nest-box breeding population). All nests in both study years were successful, i.e., at least one young fledged at each nest.

2.2. Food supply

The abundance of small mammals was assessed using the snap-trap capture method (Pelikán 1971). The captures were carried out in both years at the beginning of June (peak of the small mammal breeding season in the mountains; Dr. Vladimír Bejček, Czech University of Life Sciences, pers. comm.). The traps were laid out in three squares in each year. Each square covered an area of 100 m × 100 m, within which the traps were placed 10 m apart. Thus, a total of 121 traps were laid. The traps were exposed for three nights and checked once a day. The number of caught individuals per night was assessed in each square (number of individuals/hectare*trapping night). All caught mammals (79 individuals in 2004 and 3 individuals in 2006) were determined to species level.

2.3. Camera monitoring

The equipment consisted of a camera (DECAM OBSERVER, version 1.5.136.0, SINIT), a chip reader (PS02, ELVIS), a movement data logger (ZS4, COMET), an infrared motion detector (KS96, KOTLIN) and infrared lighting (IR diodes, SFH 485–2,880 nm; Bezouška *et al.* 2005). Cameras were installed inside the nest box opposite the opening. They were triggered by the infrared detector sensitive to movements in the nest-box opening. The time of detection was recorded by the movement data logger and 1–3 photos were taken for each feeding event. During the night, the opening was illuminated by infrared diodes during

Table 1. The abundance of small mammals captured using snap traps in 2004 and 2006.

		2004		2006	
Family	Species	Ind./ha*night ± SD	*N*	Ind./ha*night ± SD	*N*
Muridae	*Apodemus flavicollis*	6.2 ± 4.8	56	0.0	0
Arvicolidae	*Microtus agrestis*	1.1 ± 1.1	10	0.3 ± 0.7	3
	Clethrionomys glareolus	1.0 ± 0.7	9	0.0	0
Soricidae	*Sorex araneus*	0.4 ± 0.5	4	0.0	0

picture taking. All adult owls and nestlings were marked by chip rings (BR chip ring, BENZING). A chip reader fixed by the nest-box opening detected and archived all movements of chips in the nest opening. Using this equipment, we were able to record most prey items delivered to the nests and determine the genus or family of caught birds and mammals. The nests were continually monitored by the camera system for 24 hours per day from hatching to the fledging phase. Each nest was recorded over a mean period of 28.3 ± 8.5 SD days in 2004 (73.5 ± 24.2 SD% of the chicks' stay in the nest box), and 25.0 ± 8.6 SD days in 2006 (78.9 ± 17.6 SD% of the chicks' stay in the nest box).

2.4. Pellet analysis

Pellets and prey remains were collected twice during the period when most chicks were still present at the nest box (2004: 39.0 ± 3.7 SD days per nest, 2006: 31.2 ± 6.1 SD days per nest). All remaining material was collected after chicks' fledging. The material was moistened with added detergent. Consequently, the material was dissolved in a 5% solution of NaOH (Schueler 1972) and the bony material was blanched using 2–5% solution of hydrogen peroxide. Small mammals were determined by identifying skulls according to Anděra & Horáček (2005), and birds by beak and skulls using a reference collection.

2.5. Statistical analyses

All analyses (Wilcoxon matched-pairs tests, Mann Whitney *U* tests, a *t* test and a Chi-square test) were performed using STATISTICA (Statsoft Inc. 1996). Values below are reported as mean ± SD per nest or trapping site. For the non-parametric tests, we used data pooled for taxonomic families, because of similar body sizes (approximately similar energetic value) of prey species within these groups. One exception to this rule, the European water vole (*Arvicola terrestris*), was very scarce in the diet ($n = 3$) and we considered its impact on the analyses to be negligible compared to the large numbers of other small sized voles (Arvicolidae).

3. Results

3.1. Food supply

The food supply of small mammals changed between the years. The abundance of small mammals was significantly higher in 2004 than in 2006 (8.8 ± 6.2 vs. 0.3 ± 0.7 ind./hectare/night; $t = 4.1$, $P < 0.001$, $n_1 = 9$, $n_2 = 9$). The taxonomic composition of the food supply also differed significantly between the two study years ($\chi^2 = 154.0$, df = 3, $P < 0.0001$). In 2004, the yellow-necked mouse *Apodemus flavicollis* was the dominant prey species (70.9%), while only field voles *Microtus agrestis* were found in traps in 2006 (Table 1).

3.2. Diet composition

In 2004, 300 prey items were determined by pellet analysis (75.0 ± 8.5 individuals per nest). We recorded 754 prey items using camera monitoring, of which we were able to determine 570 items (142.5 ± 15.9 prey items per nest; Fig. 1). Thus, we were able to determine to genus/species 40.2 ± 6.9% of items in the pellet analysis and 77.1 ± 17.1% of items in the camera monitoring. In 2006, 809 prey items were recorded using the camera

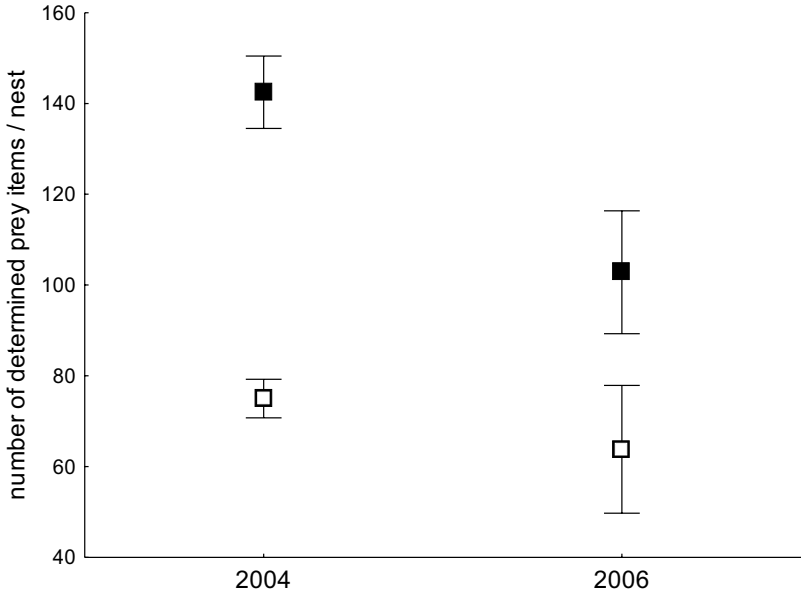

Fig 1. The number of prey items per nest determined by pellet analysis and camera monitoring in 2004 and 2006 (mean ± SD). Open squares – pellet analysis, filled squares – camera monitoring.

system. Of these, we were able to determine 383 prey items to genus/species by pellet analysis (63.8 ± 34.4 prey items per nest) and 617 items (102.8 ± 33.2 prey items per nest; Fig. 1) by camera monitoring. In total, pellet analysis allowed a determination to genus/species in 46.4 ± 14.7% of cases, and camera monitoring for 80.2 ± 12.5% of all delivered prey items.

The main diet component consisted of voles, which made up 56.0% of prey in camera data and 46.6% in pellet data. The identified species were field vole *Microtus agrestis*, common vole *Microtus arvalis*, bank vole *Clethrionomys glareolus* and European water vole. Other important components were mice (28.5% in camera and 36.3% in pellet data; species: yellow-necked mouse and wood mouse *Apodemus sylvaticus*) and shrews (9.6% in camera and 13.3% in pellet data; species: common shrew *Sorex araneus* and Eurasian pygmy shrew *Sorex minutus*). Minor dietary components were song birds (5.2% in camera and 3.4% in pellet data; species: Chaffinch *Fringilla coelebs*, tits *Parus* spp., *Sylvia* and *Phylloscopus* warblers, European Robin *Erithacus rubecula*, pipits *Anthus* spp., Dunnock *Prunella modularis*, and others) and dormice (0.8% in camera and 0.4% in pellet data; species: hazel dormouse *Muscardinus avellanarius*).

Table 2. Mean numbers of prey items ± SD delivered to Tengmalms' Owl nests recorded by cameras during early and late phases of chick rearing (ages <16 days and ≥ 16 days, respectively).

Taxa	Early	*N*	Late	*N*
Muridae	11.5 ± 16.4	115	21.4 ± 26.6	214
Arvicolidae	25.3 ± 15.1	253	42.7 ± 17.3	427
Soricidae	4.6 ± 3.4	46	7.9 ± 6.5	79
Birds	1.5 ± 1.0	15	3.5 ± 2.2	35
Gliridae	0.2 ± 0.4	2	0.1 ± 0.3	1

Camera monitoring and pellet analysis may be incomparable to some degree because most pellets accumulated at the end of the rearing period, while cameras were used throughout rearing. Therefore, we performed an analysis to compare the similarity in the numbers of delivered prey items recorded by cameras between early and late breeding phases (chicks' age < 16 and ≥ 16 days, respectively). We did not find significant differences between these two phases (Table 2; Wilcoxon matched-pairs test: $Z = 1.7$, $P = 0.079$). Based on these results, we used the whole camera dataset for further comparisons.

Pellet analysis, compared to camera monitoring, underestimated the mean delivered numbers of individuals in all diet groups. However, significant differences were found only for voles and birds (Table 3). For mice, these differences were marginally significant ($P = 0.0506$). Between-year changes in mean numbers of delivered prey were

Table 3. Mean number of items ± SD per nest in the diet of Tengmalm's Owls in 2004 (n = 4 nests) and 2006 (n = 6 nests) recorded by pellet analysis and camera monitoring, and results of statistical analyses. Method comparison was carried out using Wilcoxon matched-pairs test, and between-year comparison was undertaken using Mann-Whitney U test. Significant ($P < 0.05$) values are marked with an asterisk.

Taxa	Camera	Pellet	Z	P	2004	2006	U	Z	P
Muridae	33.8 ± 41.6	24.8 ± 30.1	2.0	0.0506	69.9 ± 17.2	2.3 ± 2.7	38.4	3.7	0.0002*
Arvicolidae	66.4 ± 25.6	31.8 ± 26.9	2.8	0.0051*	31.4 ± 19.0	60.9 ± 32.6	22.5	–1.9	0.0537
Soricidae	11.4 ± 7.3	9.1 ± 9.9	1.6	0.1097	3.6 ± 2.9	14.7 ± 8.3	11.0	–2.8	0.0048*
Birds	6.1 ± 1.8	2.3 ± 3.3	2.0	0.0469*	2.9 ± 3.4	5.1 ± 3.0	29.5	–1.4	0.1622
Gliridae	1.0 ± 1.2	0.3 ± 0.5	1.6	0.1056	1.0 ± 1.3	0.4 ± 0.7	37.0	0.9	0.3559

significant for mice and shrews. The numbers of delivered mice changed consistently with the availability of mice in the field. In 2006, we recorded low numbers of mice in the field as well as in the diet of Tengmalm's Owls (Tables 1 and 3). A similar pattern was found for shrews and voles; however, their total numbers in the field were low (Table 1).

4. Discussion

The diet composition of vole-eating specialists strongly depends on the abundance of voles, their main prey species (Jaksic & Braker 1983, Recher 1990, Marti *et al.* 1993, Valkama *et al.* 2005). In Northern Europe, the diet composition of Tengmalm's Owl is closely related to the abundance of their main prey in the field (Korpimäki 1981, 1988). In Central Europe, changes in vole abundance do not show regular 3–4 years cycles, but show greater variability between years (Tkadlec & Stenseth 2001). Our two-year data partially supported previous findings in that we confirmed an overall, high significance of voles as the main prey for Tengmalm's Owls. However, we also recorded a high proportion of mice in the diet, and their numbers changed in concert with their availability in the field. In 2006, the availability of mice decreased, and we recorded an increased proportion of voles in the diet. North European Tengmalm's Owls use shrews and small birds as alternative prey (Korpimäki 1981, 1988). In our data, the number of shrews in the diet also increased with increased availability, but the numbers of eaten birds did not change significantly, supporting studies done at similar latitudes (Pokorný 2000, Pokorný *et al.* 2003).

Only a handful of studies can be used for methodological comparisons with our results. Korpimäki (1981) studied Tengmalm's Owl diet and obtained inconsistent results: his camera system tended to overestimate the number of delivered prey items in one year, but underestimate the number in subsequent years. Our results showed that pellet analysis underestimated the number of prey delivered to the nest relative to camera monitoring. These findings agree with earlier studies on Common Buzzard *Buteo Buteo*, Rough-legged Buzzard *Buteo lagopus* and Goshawk *Accipiter gentilis* (Tornberg & Reif 2007). Interestingly, our results support these findings despite the different digestive ability of owls and diurnal birds of prey. Diurnal birds of prey can digest more bones than owls due to lower pH in their digestive tracts (Duke *et al.* 1975). According to our experience, there are marked differences in preservation of bones among complete pellets and material taken from the nests. Bones were scarcer in the material from the nests probably, due to the activity of chicks (J. Riegert, pers. obs.).

The effectiveness of determining prey species to higher taxa (genus or family) was higher for camera monitoring than pellet analyses. In our data, we were able to determine 40.2% (in 2004) and 46.4% (in 2006) of delivered prey items by pellet analysis. Camera monitoring allowed for the determination of a higher proportion of delivered prey items than pellet analyses (77.1% and 80.2%, respectively). When accounting for the time of camera exposition (73.5% in 2004 and 78.9% in 2006 of the chicks' stay at nest), the proportion of determined prey using pellet analysis was further decreased to approximately 30–35%. Similar results were obtained by Tornberg & Reif (2007), but they noted that the exact determination to spe-

cies level was more difficult using a camera system compared to a prey-remains analysis. Our experience supports this finding. For example, determination of bird-prey items to species was nearly impossible by camera monitoring, and an exact determination was only possible using prey remains and pellet analysis.

Taxonomic diet composition estimation was also affected by the method used. Using pellet analyses, we recorded lower numbers of all main prey groups, but marked differences were found in voles, birds and mice. Similar results were already shown in a study on Common Buzzards, where the proportion of voles was underestimated by pellet analysis (Tornberg & Reif 2007). Contrary to our research, Lewis *et al.* (2004) showed that the proportion of birds in the Goshawk diet was underestimated by pellet analysis and the proportion of mammals was underestimated by camera monitoring. These differences across species may be caused by the size of delivered prey and prey handling behaviour. For example, in the diet of Gyrfalcons (*Falco rusticolus*), the proportion of small passerines was underestimated sevenfold using prey remains, but the proportion of large prey (Rock Ptarmigan *Lagopus mutus*) was underestimated threefold using camera monitoring (Booms & Fuller 2003). The bias can be explained by the prey consumption habits of Gyrfalcons, since Rock Ptarmigans were rarely eaten completely and small prey items were almost always eaten entirely. A similar pattern was found in our data, as the underestimation of voles (and mice) observed by camera monitoring was probably a result of vole decapitation before their delivery to the nest. This is supported by our regular findings of decapitated voles and mice in the nest boxes. Prey decapitation is a well-known feeding behaviour in raptors (hawks Accipitriformes, falcons Falconiformes and owls Strigiformes) and may play several functions such as decreasing the weight of the transported prey items and food preparation for chicks (Glutz von Blotzheim & Bauer 1980, Steen *et al.* 2010). In agreement with Steen *et al's.* (2010) study on Kestrels (*Falco tinnunculus*), we recorded frequent decapitation in voles and mice, but shrews were never decapitated. Furthermore, light conditions and image quality can influence the estimated diet composition assessed by camera monitoring (Booms & Fuller 2003). If the prey is decapitated then its taxonomic determination through pellet analysis based on post-cranial features becomes nearly impossible.

Based on our results, we recommend the use of both pellet analysis and camera monitoring to accurately assess diet composition of breeding raptors and owls. This is especially crucial in owls, where observations from hides or screens are impractical due to darkness.

Acknowledgments. Many thanks to Jan Zárybnický for his help in the field and technical support. The authors would also like to thank Vladislav Bezouška and Pavel Děd for technical assistance. This work has been supported by grants from the Czech University of Life Sciences Prague (CIGA 41110–1313–3156, VGA 41110–1643–6457), Ministry of Education, Youth and Sports of the Czech Republic (FRVS 41110–1161–1625) and (MSM 600766 5801). Linguistic corrections were made by Dr. Keith Edwards.

Helmipöllön ravinnon koostumus: kameraseurannan ja pellettianalyysin vertailu

Toteutimme Keski-Euroopassa kaksivuotisen seurannan, jossa määritimme pellettianalyysin ja kameraseurannan avulla helmipöllön (*Aegolius funereus*) pesimäkautista ravinnon koostumusta suhteessa maastossa saatavilla olevaan ravintoon. Pöllöjen ravinto koostui enimmäkseen myyristä (Arvicolidae), hiiristä (Muridae) ja päästäisistä (Soricidae), ja näiden osuus ravinnossa heijasteli niiden saatavuutta maastossa. Pellettianalyysissä tunnistimme 40,2 (± 6,9 SD) % vuonna 2004 ja 46,4 (± 14,7 SD) % vuonna 2006 kaikista kameraseurannassa havaituista saaliseläimistä.

Kameraseurannalla tunnistimme 77,1 (± 17.1 SD) % vuonna 2004 ja 80,2 (± 12,5 SD) % vuonna 2006 kaikista kameran tallentamista saaliseläimistä. Pellettianalyysi tuotti kaikista pääsaalisryhmistä aliarvion, mutta erot olivat tilastollisesti merkitseviä vain myyrien ja lintujen osuuksille. Myyrillä tämä voi johtua siitä, että emo usein poistaa saaliilta pään ennen sen tuomista pesälle. Havaitsimme päättömiä myyriä ja hiiriä säännöllisesti helmipöllön pöntöissä, mutta päästäiset olivat useammin kokonaisia. Tutkimuksemme osoittaa, että menetelmien käyttö yhdessä tuottaa tarkemman saaliskoosteen arvion yöaktiivisilla petolinnuilla.

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