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Diet and prey consumption of breeding Common Kestrel (*Falco tinnunculus*) in Northeast China

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Abstract

The diet of Common Kestrels *Falco tinnunculus* was studied during the breeding seasons from 2004 to 2008 in Northeast China. Diet was determined by direct observation of the prey brought to nests, and analysis of prey remains collected from nests. Fifteen vertebrate species from three classes, and two groups of insects were identified as prey items. Rodents were the main prey items, comprising 93.9% of the total prey items (TPI) and 97.0% of total prey biomass (TPB). Birds, frogs and insects were also eaten. The kestrels preferred to prey on small rodents (mean weight 20–40 g) and displayed density-dependent prey selection. Daily prey consumption of an adult and a nestling was 2.6 individual rodents or 87.6 g, and 1.7 individual vertebrates or 48.2 g, respectively. The estimated prey consumption of a breeding pair (adults and nestlings) during the breeding season was 520.1 individual vertebrates or 19.7 kg.

Keywords: Common Kestrel; Diet; Prey consumption; Rodent

1. Introduction

Wildlife managers first became interested in raptor diet in their attempts to assess the impact of raptors on game animals [1,2], but ecologists soon found other reasons to understand raptor diets. What a raptor eats, and how, when, and where it obtains its food are significant not only in understanding the ecology of the raptor itself, such as species' fecundity, density and habitat selection, but also in understanding community ecology [3,4]. Besides helping researchers understand raptor niches and how they relate to community structure, studying raptor diets can provide valuable information on prey distribution, abundance, behavior, and vulnerability [5–8]. Knowledge of a species' diet should therefore be an integral component of any management and conservation plans for that species [9].

Individuals adjust their behavior to local conditions in order to maximize their fitness. For example, generalist predators catch the most common or easily acquired prey items in their hunting area [10]. The Common Kestrel (*Falco tinnunculus*) is a small raptor that is widespread in open country throughout the Palearctic, Afrotropical, and Oriental regions [11]. A total of 12 subspecies have been named [12]. This raptor is considered to be an opportunistic forager that catches what is locally available [13]. The diet of Common Kestrels has been well studied in Europe [13–18] and in Africa [19–21], and several studies have reported quantitative data on the diet composition of Common Kestrels [22–24]. Provisional studies have also provided insight into their diet [25,26]. Habitat composition and prey availability for different kestrel subspecies change greatly along with geographical distribution, but few

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studies have examined the diets of the kestrel species distributed in China [27,28].

The aim of this study was to document diet composition and prey selection by Common Kestrels and to estimate prey consumption (in terms of prey numbers and grams) of a breeding kestrel pair during the breeding period (from egg-laying to nestling period) in Northeast China.

2. Study area and methods

2.1. Study area

The study was conducted in the Zuojia Natural Reserve in Jilin Province, Northeast China, during the breeding seasons (from late March to late July) from 2004 to 2008. The Zuojia Natural Reserve runs from the eastern Chang Bai Mountains to the western plain (126°1′–127°2′N, 44°6′–45°5′E) and its elevation ranges from 200 to 530 m. The study area was approximately 748 ha, covered by about 35% open habitat and 65% forest habitats. The climate is eastern monsoon, characterized by hot, dry summers and cold, snowy winters. The vegetation within the study area was diverse, although the existing forest was secondary. The most common trees in the study area were Mongolian oak (*Quercus mongolica*), Dahurian birch (*Betula davurica*), Manchurian linden (*Tilia mandschurica*), Japanese elm (*Ulmus davidiana var. japonica*), Scots pine (*Pinus sylvestris*), Korean larch (*Larix olgensis*) and Masson's pine (*Pinus massoniana*). The average age of the trees ranged from 40 to 50 years; the average height of the trees ranged from 12.7 to 16.2 m. Korean raspberry (*Rubus crataegifolius*), Dahurian rose (*Rosa dahurica*), Korean rose (*Rosa doreana*), Willowleaf spiraea (*Spiraea salicifolia*), Amur barberry (*Berberis amurensis*), Prickly rose (*Rosa acicularis*), Ural false spiraea (*Sorbaria sorbifolia*), Amur honeysuckle (*Lonicera maackii*), Manchur honeysuckle (*Lonicera ruprechtiana*) and Sakhalin honeysuckle (*Lonicera maximowiczii*) dominated the shrub layer. One hundred and ninety bird species have been recorded in Zuojia, dominated by passerines (101 species) and raptors (28 species) [29]. The raptors consisted of falconiformes and strigiformes. The Common Kestrel, Eastern Red-footed Falcon (*Falco amurensis*), Hobby (*Falco subbuteo*), Grey-faced Buzzard (*Butastur indicus*), Long-eared Owl (*Asio otus*), Ural Owl (*Strix uralensis*), Oriental Scops Owl (*Otus sunia*) and Collared Scops Owl (*Otus lettia*) were common species in the study area. There were 15 rodent species, 7 amphibian species and 11 reptile species recorded in the Zuojia area (data from the Zuojia Natural Reserve). The Striped Field Mouse (*Apodemus agrarius*), Reed Vole (*Microtus fortis*), Large Field Mouse (*Apodemus peninsulae*), Siberian Chipmunk (*Eutamias sibiricus*), Eurasian Red Squirrel (*Sciurus vulgaris*), Grey Red-backed Vole (*Clethrionomys rufocanus*), House Mouse (*Mus musculus*), Brown Rat (*Rattus norvegicus*) and Greater Long-tailed Hamster (*Cricetulus triton*) were common rodent species, whereas the Daurian Ground Squirrel (*Spermophilus dauricus*), Manchurian Zokor (*Myospalax psilurus*), Harvest Mouse (*Micromys minutus*), Chinese Hamster (*Cricetulus barabensis*), Chinese Birch Mouse (*Sicista concolor*) and Northern Red-backed Vole (*Clethrionomys rutilus*) were rare. Frogs were dominated by the Black-spotted Frog (*Rana nigromaculata*) and the Chinese Forest Frog (*Rana chensinensis*).

2.2. Methods

2.2.1. Field data collection

Common Kestrels do not build their own nests, but rely mainly on the stick nests of the Magpie (*Pica pica*), in the study area [30,31]. Most magpie nests used by the kestrels in the study area were inaccessible. From 2004 onward, we therefore installed nest boxes to develop the study, and most kestrels then shifted to breed in nest boxes.

Various methods can be used to study the diet of raptors, including the analysis of pellets, stomach contents, the remains of prey in nests, and direct observation and/or photographs of prey delivered to nests [32]. In this study, we monitored diet composition of the kestrels mainly by collecting the remains of prey from nests, and we also identified some food items through direct observation of prey delivered to the nest. Prey remains were collected from most occupied nest boxes at intervals of 3–5 days during the study period. Rodent and bird remains in nests were identified with reference to museum specimens from the Northeast Normal University or from Fauna Sinica Mammalia [33]. Frogs were identified from remaining skin and various bones. Prey items that could not be identified to species level were not included in the analysis. Nest observations were conducted between 6:00 am to 7:00 pm and lasted for 5–12 h. Observations were from blinds situated 50–100 m from the nests, using a 20–50× telescope to avoid influencing the normal behavior of the kestrels. Two to three randomly selected nests were observed by 4–6 observers simultaneously. They recorded the frequency of food delivery and the identity of the food items (if possible). In all, we recorded data from 553 observation hours during the incubation period and 848 observation hours during the nestling period. The data from the incubation period were used to estimate the daily prey consumption of the adults, because the males provided food for the incubating females. Data from the nestling period were used to determine the daily prey consumption of the nestlings.

Only vertebrate prey items were considered in counting procedures, because invertebrate species were not likely to be found in the nest boxes. Moreover, the insect food was too small to quantify, even when we saw parent birds delivering insects to their young. To avoid the underestimation of invertebrates, we decided to consider only their presence in the diet. Therefore, insect preys were considered only for taxonomic identification at the order level.

In order to determine what kinds of rodents were available to the kestrels in Zuojia, we used wooden snap traps to investigate which rodent species were present in different habitat types during the breeding season each year. For each plot, we set 50 snap traps at 10-m intervals on two consecutive nights and checked them once a day (modified from Korpimäki and Norrdahl, 1991) [34]. We recorded the quantity, species and body mass of the trapped animals.

2.2.2. Estimating prey consumption

We estimated the numbers of prey items (NPI) consumed by a breeding raptor pair as follows (modified from the formula of Lindén and Wikman Lindkn, 1983 by Korpimäki and Norrdahl, 1991) [34,35]:

$$\mathrm{NPI} = \frac{(CA + CY) \times PPI}{MMPI},$$

where CA is total prey consumption (in grams) by adults in the breeding season, which is $2 \times$ daily food requirement $\times$ length of breeding season in days; CY is total consumption (in grams) by young ones in the breeding season, calculated by mean brood size per pair $\times$ mean daily food requirement of young ones during the nestling period $\times$ length of the season in days; PPI is the proportion of prey items' biomass in the diet of breeding raptors; and $MMPI$ is the mean mass (in grams) of prey items.

The daily prey consumption was estimated by directly observing the frequency with which prey was delivered to the nest. We assumed that the daily prey consumption of the male was the same as that of the female. The daily prey consumption of an adult Common Kestrel was estimated from the frequency with which prey was delivered to the females by the males during the incubation period. Mean brood size per pair, mean daily food requirements of the young during the nestling period, length of the breeding season (from the egg-laying period to fledging) and the length of the nestling period were estimated from our unpublished data. The mean combined length of the egg-laying and incubation periods was 35.4 ± 1.1 days ($n = 56$) and of the nestling period was 33.1 ± 0.9 days ($n = 41$). Mean brood size was 4.8 ± 1.4 ($n = 52$). Mean body mass (in grams) of prey items was estimated using combined data from the museum specimen records at the Northeast Normal University, web database (http://www.mnh.scu.edu.cn), measurements from trapped rodents and birds, and some intact prey items from nests.

2.2.3. Data analysis

Analysis of diet composition and calculation of the percentages of individual prey items and biomass were based on the combined data from 2004 to 2008. Combining data from prey remains and food items delivered to the nest increased the sample size, so reducing or eliminating biases in estimated diet composition and prey consumption [36]. Birds, frogs, insects and some species of rodents were absent from the prey recorded during the incubation period, thus only the mean weight of rodents in the diet was used to estimate the adults' daily prey consumption during the incubation period. In order to analyze prey selection, we separated prey items into 10 grades, based on mean body weight. We analyzed the relationship between the occurrence of rodents in the diet and trapped rodents using Pearson's correlation coefficient. We performed statistical tests using SPSS for Windows version 13.0 (SPSS Science, Chicago, Illinois) with a two-tailed significance level of 0.05.

3. Results

3.1. Diet composition

A total of 391 prey items were identified from 41 nest boxes during the incubation and nestling periods. There were 15 species of vertebrates belonging to three classes and two groups of invertebrates belonging to a single class (Table 1). Rodents were the most important contributors to TPI (93.9%) and TPB (97.0%). Ten species of rodents occurred in the diets of Common Kestrels: the Striped Field Mouse (28.7%) was the most important contributor to TPI, followed by the Reed Vole (24.6%) and the Large Field Mouse (17.1%). The important contributors to TPB were the Reed Vole (25.8%), the Striped Field Mouse (22.7%), the Large Field Mouse (15.1%) and the Siberian Chipmunk (15.0%). Common Kestrels also fed on some small birds and frogs, but these only accounted for 6.1% TPI and 3.0% TPB. We identified some grasshoppers and dragonflies, either directly or by their remains, but dismembered items were not always identifiable.

3.2. Prey selection

We recorded 11 species of rodents using the snap trapping method (Table 1). Daurian Ground Squirrels and Manchurian Zokors were not preyed upon by Common Kestrels. No Harvest Mice were trapped, but they did occur in the diets of the kestrels. Common Kestrels preferred to prey on vertebrates with mean body masses of 30.0–39.9 g, followed by those with mean body masses of 20.0–29.9 g (Fig. 1). Rodents with body masses >100.0 g and <10.0 g were only taken occasionally. There was a highly significant correlation between the occurrence of prey rodents in the diet and trapped rodents ($r = 0.761$, $p = 0.004$, $n = 12$).

3.3. Prey consumption

The daily prey consumption of an adult Common Kestrel during the breeding season was 2.6 ± 0.8 ($n = 35$) rodent individuals, or 87.6 g. The daily prey consumption of a nestling was 1.7 ± 0.9 ($n = 47$) rodent individuals, or 48.2 g. The estimated total number of prey items (NPI) consumed by a breeding kestrel pair during the breeding season was 520.1 rodent individuals (317.5 for adults and 202.6 for nestlings), or 19.7 kg (12.0 kg for adults and 7.7 kg for nestlings) (Table 2).

Table 1
Species of prey items in the diets of Common Kestrels and species of trapped rodents at Zuojia, Jilin Province, Northeast China.

Species	Mean body mass (g)	Prey remains observed			Frequency of trapped rodents
		n	%TPI[a]	%TPB	
Rodents					
Striped Field Mouse *Apodemus agrarius*	29.9 ± 8.7 ($n = 78$)	112	28.7	22.7	71
Large Field Mouse *Apodemus peninsulae*	33.2 ± 11.5 ($n = 43$)	67	17.1	15.1	55
House Mouse *Mus musculus*	14.0 ± 3.9 ($n = 18$)	10	2.6	1.0	4
Brown Rat *Rattus norvegicus*	84.1 ± 42.9 ($n = 11$)	7	1.8	4.0	4
Harvest Mouse *Micromys minutus*	7.5 ± 2.8 ($n = 7$)	5	1.3	0.3	0
Reed Vole *Microtus fortis*	39.7 ± 9.7 ($n = 7$)	96	24.6	25.8	6
Greater Long-tailed Hamster *Cricetulus triton*	37.1 ± 2.9 ($n = 5$)	24	6.1	6.0	3
Grey Red-backed Vole *Clethrionomys rufocanus*	30.6 ± 12.7 ($n = 71$)	15	3.8	3.1	11
Siberian Chipmunk *Eutamias sibiricus*	76.3 ± 23.8 ($n = 26$)	29	7.4	15.0	15
Eurasian Red Squirrel *Sciurus vulgaris*	292.2 ± 62.2 ($n = 7$)	2	0.5	4.0	3
Daurian Ground Squirrel *Spermophilus dauricus*	212.7 ± 51.5 ($n = 9$)	0	0	0	1
Manchurian Zokor *Myospalax psilurus*	262.9 ± 56.0 ($n = 8$)	0	0	0	1
Birds					
Great Tit *Parus major*	13.8 ± 1.7 ($n = 46$)	8	2.0	0.7	–
Daurian Redstart *Phoenicurus auroreus*	12.5 ± 1.1 ($n = 6$)	4	1.0	0.3	–
Marsh Tit *Parus palustris*	11.4 ± 1.5 ($n = 13$)	2	0.5	0.1	–
Rustic Bunting *Emberiza rustica*	17.0 ± 18.3 ($n = 15$)	3	0.8	0.3	–
Frogs					
Black-spotted Frog *Rana nigromaculata*	33.9 ± 4.3 ($n = 9$)	7	1.8	1.6	–
Insects					
Dragonfly, grasshopper	–	–	–	–	–
Total	–	391	100	100	174

[a] %TPI, percent of total prey individuals; %TPB, percent of total prey biomass.

4. Discussion

4.1. Diet composition

Some studies found that small mammals, especially voles, formed the major constituent of the kestrel's diet [14,15,37,38], while other prey species only occurred in the diet when the availability of voles decreased [39,40]. Other studies found that birds were the main component of the diet [16,21,41,42], while still others indicated that lizards, birds, and particularly insects represented the main components of kestrels' diets [17–19,43]. These apparent discrepancies probably relate to large-scale geographical (latitudinal) variation [10]. The results of our study indicated that rodents played an important role in the kestrel diet, accounting for 93.9% of TPI and 97.0% of TPB. The proportion of rodents eaten by the kestrels in this study was higher than the 80% of items and 78% of biomass reported by Warsaw [38], or the 70% of biomass reported in studies from western Finland [34]. A previous study of the diet composition of the kestrels conducted in Zuojia also found rodents to be the main type of prey, accounting for over 85.0% of total prey [28]. Our results are also in agreement with those of another study on Com-

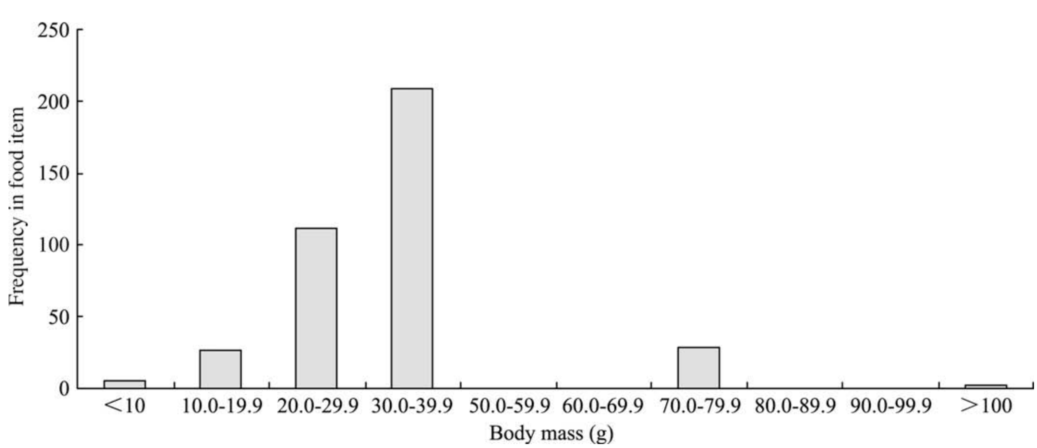

Fig. 1. Vertebrates of different body masses selected by Common Kestrels.

Table 2
Estimated numbers and biomass of prey items consumed by a breeding kestrel pair during a breeding season (from the egg-laying period to the nestling period) in Zuojia, Northeast China.

Species	Number of prey items (n)			Prey biomass (g)		
	Adults	Nestlings	Total	Adults	Nestlings	Total
Rodents						
Striped Field Mouse *Apodemus agrarius*	91.1	58.1	149.2	2724.3	1738.4	4462.7
Large Field Mouse *Apodemus peninsulae*	54.6	34.8	89.4	1812.2	1156.4	2968.6
House Mouse *Mus musculus*	8.6	5.5	14.1	120.0	76.6	196.6
Brown Rat *Rattus norvegicus*	5.7	3.6	9.3	480.0	306.3	786.3
Harvest Mouse *Micromys minutus*	4.8	3.1	7.9	36.0	23.0	59
Reed Vole *Microtus fortis*	78.0	49.8	127.8	3096.3	1975.8	5072.1
Greater Long-tailed Hamster *Cricetulus triton*	19.4	12.4	31.8	720.1	459.5	1179.6
Grey Red-backed Vole *Clethrionomys rufocanus*	12.2	7.8	20	372.0	237.4	609.4
Siberian Chipmunk *Eutamias sibiricus*	23.6	15.1	38.7	1800.2	1148.7	2948.9
Eurasian Red Squirrel *Sciurus vulgaris*	1.6	1.0	2.6	480.0	306.3	786.3
Birds						
Great Tit *Parus major*	6.1	3.9	10	84.0	53.6	137.6
Daurian Redstart *Phoenicurus auroreus*	2.9	1.8	4.7	36.0	23.0	59
Marsh Tit *Parus palustris*	1.1	0.7	1.8	12.0	7.7	19.7
Rustic Bunting *Emberiza rustica*	2.1	1.4	3.5	36.0	23.0	59
Frogs						
Black-spotted Frog *Rana nigromaculata*	5.7	3.6	9.3	192.0	122.5	314.5
Total	317.5	202.6	520.1	12001.1	7658.2	19659.3

mon Kestrel diet conducted in Southern China [27]. Although rodents dominated the overall diet, the main category of prey shifted from rodents to insects during the late nestling period, accounting for 46.7% [28]. Birds, frogs and insects also formed part of the diet in our study, but those prey items mainly occurred during the nestling period, which could reflect a reduced availability of rodents due to their being preyed upon continuously by several raptor species. Nine other species of raptors were also found to be breeding in our study plot during the study period. Some of these, such as the Eastern Red-footed Falcon, Long-eared Owl, Oriental Scops Owl and Collared Scops Owl [28,44], preyed mainly on rodents, while others, such as the Northern Goshawk, Hobby, Grey-faced Buzzard, Ural Owl and Eurasian Sparrowhawk [28,44], preyed partly on rodents. Some studies have reported that kestrels feed on reptiles, beetles, mollusks, scorpions and ants in some regions [16–18,43], but none of these food items were found in the kestrels' diets in our study. The diet composition of Common Kestrels in Northeast China was similar to that in Northern and Central Europe, but differed from that of Southern Europe and South Africa, by having a large vertebrate component for breeding birds.

4.2. Prey selection

Many foraging theories have been developed to explain prey selection by predators [45–47]. The optimal foraging theory is based on the assumption that predators choose prey so as to maximize fitness [48,49], and that there is some "currency", such as energy, time, or nutrients that influences fitness [47,50]. We found that the kestrels preferred to prey upon small vertebrates with mean body masses of 20–40 g, which is similar to the results of a report from Southern China [27] and other parts of the world [51]. In the current study, vertebrate prey items with body masses in this range included five species of rodents and one species of frog. Rodents with body masses >100 g or <10 g were only preyed on occasionally, possibly because of the energy expenditure and handling time involved [47,52]. Only one of three species of rodents heavier than 100 g occurred in the diet twice in this study; this could be because the kestrels have difficulty in catching them, or they may refuse to prey on them at all.

In general, kestrels are considered to be opportunistic foragers, catching what is locally available, resulting in a diet that varies considerably between habitats [10,13]. The kestrels in this study demonstrated density-dependent prey selection, such that the frequency of rodents in the diet was significantly correlated with their relative abundance in the habitat, indicated by trapping. Three species, the Striped Field Mouse, Large Field Mouse and Siberian Chipmunk, which had higher relative abundances, were important contributors to TPI and TPB in Zuojia. The Reed Vole formed a higher proportion of the diet than would be suggested by its abundance estimated from trapping, but this may have been due to fewer traps being set in farmlands during the cultivation period.

4.3. Prey consumption

The daily food requirements of feral Common Kestrels in the Netherlands have been estimated at 48 g for an adult and 38 g for a nestling [37]. The mean number of prey species consumed by a breeding kestrel pair was 390 individuals (ranging from 170 to 610 individuals) during a breeding season [34]. The estimated daily food consumption in our study was higher than that in the Netherlands; 87.6 g for an adult and 48.2 g for a nestling, with estimated prey consumption for a breeding kestrel pair (including adults and nestlings) of 520.1 individuals (in vertebrate numbers) or 19.7 kg (in weight). Several potential sources of error may confound estimates of prey consumption that are based on: (1) the length of the breeding season, (2) the number of young kestrels produced, (3) the food requirements, (4) diet composition, (5) the mean weight of the prey species. Variables 1 and 2 were easily measured by observations of breeding performance, but variables 3–5 were potential sources of error. Although insects are abundant in the diet in terms of prey number, especially in poor vole years, their contribution to prey biomass is low [14,41], and their exclusion from diet analysis was therefore unlikely to have a serious effect on estimates of the diet composition by prey mass.

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