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The Diet of Besra Sparrowhawk (*Accipiter virgatus*) in Yangmingshan Area, Northern Taiwan

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ABSTRACT: We monitored 25 Besra Sparrowhawk (*Accipiter virgatus*) nests from 1993 to 2002 in Yangmingshan, northern Taiwan, to document the prey composition of this species during the breeding season. Results showed that birds were the major prey both in frequency and in biomass. Besra Sparrowhawk preyed more on species active in canopy, mid-layer, and shrubs than on the ground. There were seasonal shifts in prey composition and diet diversity indices. We suggest that Besra Sparrowhawk captured prey opportunistically, capitalizing on seasonally emerging prey species that are abundant and energetically rewarding to catch.

KEY WORDS: Prey composition, Food habits, Besra Sparrowhawk, *Accipiter virgatus*, Yangmingshan, Taiwan.

INTRODUCTION

Raptors occupy high trophic levels and play important roles in terrestrial ecosystems through their regulation of prey species. Lack (1946) proposed that raptor population density is limited by the food supply. Food has been suggested to be one of three most important variables in studying resource partitioning of guilds (Schoener, 1974), and detailed diet studies have provided important information on niche differentiation of sympatric species (MacArthur, 1958; Root, 1967; Cody, 1974). Studying the food habits of raptors is therefore essential for the understanding of raptor biology and community dynamics. However, the diet of raptors can be difficult and time consuming to study since raptors usually have large home ranges and low population densities, and many species have low prey capture rates.

Directly observing prey capture or consumption, monitoring prey delivered to the nests (Collopy, 1983; Simmons *et al.*, 1991), and collecting prey remains (Joy *et al.*, 1994; Mañosa, 1994; Toyne, 1998; Thrailkill *et al.*, 2000; Rutz, 2003) and pellets (Mañosa, 1994; Toyne, 1998; Sharp *et al.*, 2002) are the most common methods to study food used by raptors. Other methods include stomach content analysis and photographic recording of prey delivery to nests (Marti, 1987).

The biology of raptors in Taiwan, especially food habits, is understudied. In a total of 189 references concerning Taiwan raptors compiled by Chen (2003), only 12 (6.4%) discussed the diet of raptors, including six on Strigiformes and six on Falconiformes. Most other reports were on migration observations, habitat descriptions, conservation, and some general sighting records. The goal of this study was to determine the diet of the Besra Sparrowhawk (*Accipiter*

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virgatus) through monitoring the prey brought back to nests, and to understand the role of this species in the local food web in the Yangmingshan area. This study is the first one to focus entirely on the diet of the Besra Sparrowhawk, and the findings should benefit future studies on the food habits of Taiwan raptors and diet differentiation among them.

MATERIALS AND METHODS

Species description and study area

The Besra Sparrowhawk is distributed throughout South and East Asia and has been differentiated into 11 subspecies (del Hoyo *et al.*, 1994). The subspecies in Taiwan, *A. v. fuscipectus*, is one of 32 diurnal raptors species recorded in Taiwan. It is widely distributed throughout Taiwan at elevations of 100 to 2800 m. Like most other raptors, sexual dimorphism in the Besra Sparrowhawk is distinct, with the female much larger than the male. Both sexes have a particularly long middle digit, and each digit has attached pads used in grasping prey. The egg-laying period of Besra Sparrowhawks on Yangmingshan is late April to early May. Incubation lasts 28 days (Huang, 1995). The nestlings fledge 22-23 days after hatching; then the fledglings disperse from the nest area 4 weeks after fledging (Huang, 1999). Thus post fledging period lasts from mid-July to early August.

We conducted this study in an area of 18 km^2 that encompassed 200-750 m in elevation in Yangmingshan area, northern Taiwan (25º09´N, 121º32´E) (Fig. 1). The average annual rainfall and the mean annual temperature of the study site are 3500 mm and 19ºC, respectively (Chen and Chai, 1986). Although Yangmingshan is located in the subtropics, its vegetation composition is relatively temperate because of the cold prevailing northeasterly monsoon from October through March. The habitat is primarily broadleaf evergreen forests, with scattered conifer plantations, farmland, and grassland. This diverse landscape provided nesting and feeding habitats for many bird species.

Field data collection

We monitored 25 nests of Besra Sparrowhawks in 10 sites from late April to early August from 1993 to 2002. In another study of ours (Huang *et al*., *Zoological Studies*, under review), we showed that the study method employed significantly affected the type and amount of food recorded. Therefore, for this study we combined three possible methods to determine the food habits of Besra Sparrowhawks, including direct observations, and collection of food remains and pellets. Each of these methods is described below.

Direct observations: We built a blind on an uphill location from each nest to allow a clear view of the nest and prey delivery activities, aided with binoculars and a spotting scope. For each transfer of prey from male to female, prey delivery to the nest, or hunting attempt by a fledgling around the nest, we recorded the type, size, and shape of the prey.

Collection of food remains: We strung up a 10 x 10 m net with a 0.3 x 0.3 cm mesh size below each nest to capture food remains which fell from the nest, including feathers, bones, a lower jaw, teeth, fur, skin, unconsumed portions, and insect exoskeletons. All food remains from the nets and on the ground around the nests were collected at 1-3 day intervals. Every 1-7 days we climbed the nest trees to collect food remains left in the nests. Since Besra Sparrowhawks add fresh green nesting material to the nest until the nestlings fledge, we also searched among the twigs and leaves in the nests for food remains. All food remains were cleaned up on each visit to avoid double counting.

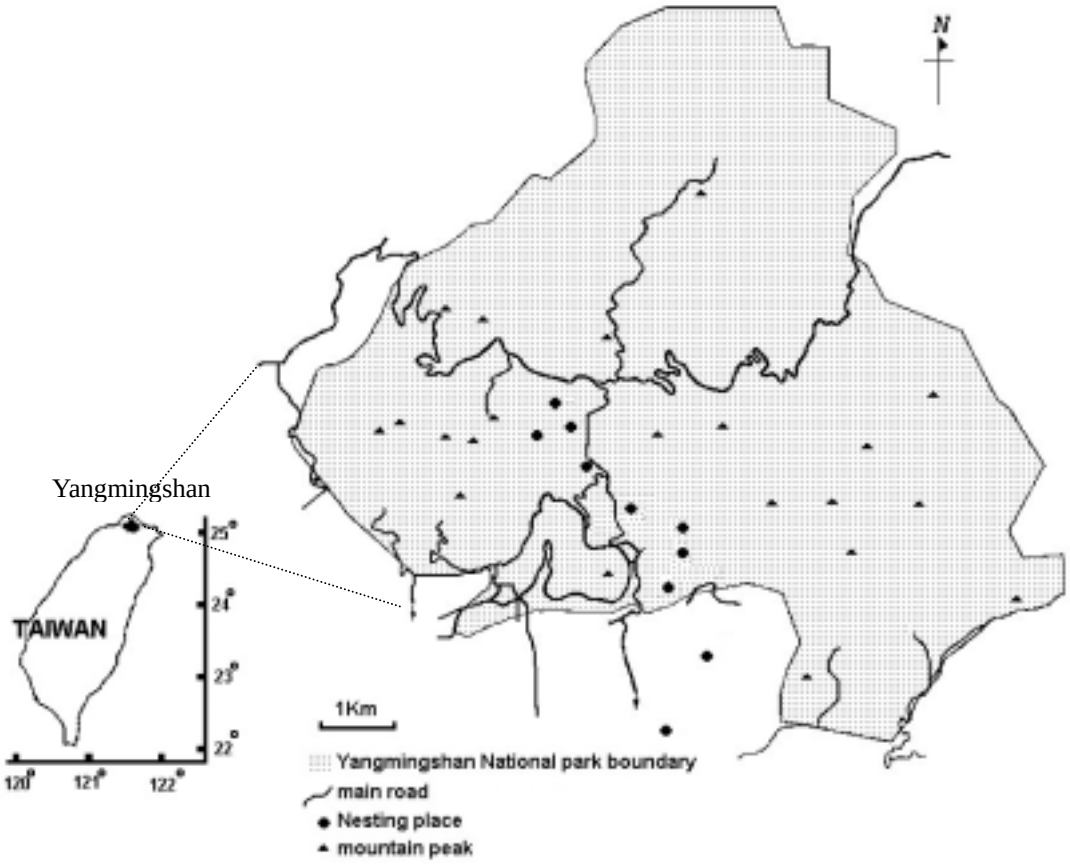

Fig. 1. The distribution of Besra Sparrow Hawk nesting places in Yangmingshan (1993-2002).

We constructed an identification key for potential prey, using the fur and skeleton collection of Yangmingshan National Park as reference material. The identification key was based on the color and shape of the bill, tarsus, remiges, and rectrices, the color and other characteristics of body feathers of birds, special features of insect exoskeletons, the tails of mammals and lizards, and the color of the hair, skin, and fur of mammals. Following methods described in Rutz (2003), we adopted a conservative method for counting prey frequencies in food remains. When body parts from a prey collection could be pieced into a single individual, they were considered to belong to only one individual.

Pellet collection: During each collection of prey remains we also searched for pellets and carried them back for further analysis. Regurgitated pellets were softened and washed with water, teased apart with fingers and forceps, and then dried in an oven (Sabo and Laybourne, 1994). Feathers, bones, bristles, exoskeletons of insects, and scales of reptiles were the main content of pellets. Aided by the key we developed, we visually identified prey items within a pellet and, when necessary, under a magnifying glass. We recorded the content of each pellet and counted the number of pellets. We followed Redpath *et al.* (2001) in counting prey frequencies in pellets. All parts of the same species in a single pellet were considered to be from the same individual prey while parts in different pellets belonged to different individuals.

The three methods described above all have advantages and limitations when applied in the field (Collopy, 1983; Real, 1996; Redpath *et al.*, 2001). Hence, to overcome the bias created by a single method, data collected from all three sources were pooled for analysis.

We tried to identify prey items to species level whenever possible. For those we could not, we identified them to genus level (rodents), family level (insects), or class level. The average biomass of each prey species was obtained from museum specimens, reference books, or by capturing a few individuals in the field. The biomass of unidentified prey was estimated according to its body size. For data analyses, we divided the breeding season into three periods: late April to May, June, July to early August.

Data analysis

We used the modified Simpson index (1 - *D*, $D = \sum p_i^2$) (Simpson, 1949; Odum, 1975) to estimate dietary diversity where p_i is the proportion of prey taxon *i* in the diet. The modified Hill index, $(N_2 - 1)(N_1 - 1)$ (Hill, 1973; Alatalo, 1981), was used to estimate the evenness of prey in the diet where $N_2 = 1/D$, $D = \sum p_i^2$, $N_1 = anti\log H'$, with H′ as Shannon's index = $-p_i \log p_i$. These indices range from 0 to 1, with larger values indicating greater evenness. If all prey were taken in equal numbers, dietary evenness would be 1. Food-niche breadth (FNB) was estimated using Levins' (1968) index, FNB = $1/(\sum p_i^2)$, where p_i is the proportion of prey taxon *i* in the diet. We used SPSS 10.0 (SPSS Inc.) and Microsoft Office Excel 2002 (Microsoft Corporation) to perform these analyses.

RESULTS

Frequency and biomass of prey in the diet

In total, 988 prey items were recorded from 25 Besra Sparrowhawk nests over 10 years using direct observations, food remains, and pellet analysis methods. Among these prey items, 871 could be identified to class, of which 34.1% were through direct observation, 42.0% from food remains, and 23.9% from pellet samples (Table 1).

Preys delivered to the nests by the Besra Sparrowhawk belonged to at least five classes comprising 30 types of prey: 14 types of birds, 8 types of insects, 4 types of mammals, 3 types of lizard, and 1 type of frog. Their diet was dominated by birds which comprised 58.1% of the prey numbers and 82.5% of the prey biomass. Insects, the second most important source of the diet, accounted for 31.6% of the total prey numbers but only 4.4% of the prey biomass (Table 1). Besra Sparrowhawks captured prey in a broad range of size categories: 1.5 g (insects in the families Buprestidae, Cerambycidae, and Scarabaeidae) to 250 g (Bamboo Partridge, *Bambusicola thoracica*). The most important prey in the diet in terms biomass included Black-browed Barbet (*Megalaima oorti*) (18.9%), Bamboo Partridge (7.4%), and Light-vented Bulbul (*Pycnonotus sinensis*) (7.3%). However, in terms of total number of prey, cicadas (*Cryptotympana holsti*) occupied a prominent role (Table 1). Special findings included 2 species of bats (*Pipistrellus abramus* and *Hipposideros terasensis*) and Collared Scops Owl (*Otus lettia*). We also recorded a number of nestling and fledging Passerines in the diet but could not identify them to species because they were already plucked when brought in. The role of mammals in the diet was 11.8% by biomass but 3.0% by frequency. Reptiles contributed 7.1% of the diet by frequency and 1.2% in biomass, while amphibians accounted for only a minimal portion (< 0.3%) by both frequency and biomass.

Diet variations among periods of the breeding season

There was a significant variation in the diet composition across time intervals by both

Table 1. Number (N), frequency and percentage of biomass of prey items in Besra Sparrowhawk diet based on nest provisioning.

Prey	N[a]	Frequency (%)	Biomass[b] (%)
MAMMALS	26	3.0	11.8
Pipistrellus abramus	2	0.2	tr[c]
Hipposideros terasensis	4	0.5	0.7
Niviventer coninga	1	0.1	0.6
Rattus sp.	19	2.2	10.5
BIRDS	506	58.1	82.5
Bambusicola thoracica	8	0.9	7.4
Streptopelia chinensis	3	0.3	1.8
Streptopelia tranquebarica	3	0.3	1.1
Otus lettia	3	0.3	2.0
Megalaima oorti	64	7.4	18.9
Hirundo rustica	8	0.9	0.5
Hypsipetes madagascariensis	3	0.3	0.5
Pycnonotus sinensis	58	6.7	7.3
Pomatorhinus ruficollis	11	1.3	1.9
Stachyris ruficeps	7	0.8	0.3
Zosterops japonica	14	1.6	0.6
Passer montanus	26	3.0	1.8
Melopsittacus undulates	1	0.1	0.1
Unidentified	297	34.1	38.3
REPTILES	62	7.1	1.2
Sphenomorpbus indicus	3	0.3	0.1
Japalura swinhonis	18	2.1	0.4
Unidentified	41	4.7	0.8
AMPHIBIANS	2	0.2	0.1
Unidentified (frog)	2	0.2	0.1
INSECTS	275	31.6	4.4
Cryptotympana holsti	227	26.1	4.0
Pomponia linearis	21	2.4	0.2
Anotogaster sieboldii	6	0.7	0.1
Hierodula patellifera	6	0.7	0.1
Scarabaeidae	10	1.2	0.1
Cerambycidae	2	0.2	tr[c]
Buprestidae	1	0.1	tr[c]
Unidentified	2	0.2	tr[c]
TOTAL	871	100.0	100.0

[a] Number of prey items identified at least to class.
[b] Total Biomass estimated was 27074 g.
[c] tr≦0.05%

frequency (x^2 = 69.9, df = 8, $p < 0.01$) and biomass (x^2 = 570.1, df = 8, $p < 0.01$) (Table 2). For all three time periods in the breeding season, birds consistently constituted the major diet component of the Besra Sparrowhawk. However, as the breeding season proceeded, the frequency of birds in the diet decreased even though the total biomass contributed by birds remained relatively stable. The frequency of insects delivered increased noticeably but the biomass contributed by insects only increased slightly.

Table 2. Frequency and biomass of prey in the diet of the Besra Sparrowhawk during breeding season.

	Late April~May	June	July~Early August
By frequency (%)			
Mammals	2.9	3.5	2.7
Birds	85.3	69.4	50.6
Reptiles	8.8	8.5	6.3
Amphibians	2.9	0.4	0.0
Insects	0.0	18.3	40.3
By biomass (%)			
Mammals	12.1	13.8	10.4
Birds	85.0	82.8	82.4
Reptiles	1.3	1.2	1.2
Amphibians	1.6	0.2	0.0
Insects	0.0	2.0	6.0

Table 3. Prey items and diet diversity indices of the Besra Sparrowhawk during breeding season.

Period	N[a]	Prey type[b]	Simpson's index 1-D	Hill's index	FNB[c]
Late April~May	34	8	0.53	0.45	2.11
June	284	21	0.79	0.64	4.74
July~Early August	553	28	0.79	0.51	4.77
Total	871	30	0.80	0.52	5.01

[a] Number of prey items.
[b] Includes unidentified prey in a known class.
[c] FNB, food niche breadth.

The diet of the Besra Sparrowhawk was diverse (modified Simpson index of 0.80) but uneven (modified Hill index of 0.52), concentrating on only a few kinds of prey. Food niche breadth (FNB) for the Besra Sparrowhawk was 5.01 (Table 3).

DISCUSSION

Our study is the first to report on the diet of the Besra Sparrowhawk in Taiwan and our results are based on long term monitoring. Birds formed the major diet component of the Besra Sparrowhawk both in frequency and in biomass. Among the 46 bird species recorded for Yangmingshan area during the breeding season (Huang, unpublished data), we found Besra Sparrowhawk to prey on 13 of them. Other accipiter species are also primarily bird predators, for example Northern Sparrowhawk (*A. nisus*) (Newton, 1986; Solonen, 1997; Rytkönen *et al.*, 1998) and Sharp-shinned Hawk (*A. striatus*) (Joy *et al*., 1994). These three accipiters are similar in size, occupy similar niches in woodlands within their own distribution ranges, and play a role of “bird hunters”. However, the number of bird species preyed on by Northern Sparrowhawk and Sharp-shinned Hawk and their food niche breadths (Marti *et al*., 1993) were higher than those of Besra Sparrowhawk. This could be because breeding bird communities usually contained more bird species in continental forests than in forests on islands (Wiens, 1989).

Some of the bird prey for Besra Sparrowhawk was primarily aerial, eg. House Swallow (*Hirundo rustica*), some primarily on the ground, eg. Bamboo Partridge, some in the canopy, eg. Black-browed Barbet; some in the shrub layer, eg. Streak-breasted Scimitar Babbler (*Pomatorhinus ruficollis*), while others may be active from the canopy to the shrub layer, eg. Light-vented Bulbul. The presence of all these species in the diet of Besra Sparrowhawk

suggests that this raptor can capture prey from scrub, middle and canopy layers of the forest, and in the air, but tree or shrub dwelling species constituted the bulk of the prey. The hunting height of Besra Sparrowhawk appears to be quite different from that of Northern Sparrowhawk, since Sparrowhawks preyed more on ground-foraging bird species than tree- or bush-foraging species (Selås, 1993).

The presence of nestling and fledging passerines in the diet suggests that Besra Sparrowhawks do rob bird nests, just like that reported for other accipiters, eg. Northern Sparrowhawk (Newton, 1986), Northern Goshawk (*A. gentilis*) and Japanese Lesser Sparrowhawk (*A. gularis*) (Takagi *et al.*, 1995). Many bird species breed at the same time as do the Besra Sparrowhawk in Yangmingshan area. This synchrony no doubt provides some easy food resource for this raptor.

None of the Besra Sparrowhawk prey was a grassland species, suggesting this hawk did not hunt in grassland habitat. In addition to daylight hours, Besra Sparrowhawk sometimes also hunted at dawn or dusk, as is evident from the two bat species and three Collared Scops Owls found among the prey items. Many species of diurnal raptors were known to be preyed on by owls (see examples given in Newton, 1979). Ours were among the few records that owls were preyed on by diurnal raptors. Besra Sparrowhawk and Collared Scops Owl, in addition to predator-prey interactions, may also compete for nest sites. In 2002, one of the active Besra Sparrowhawk nests was taken over by a Collared Scops Owl as a roosting site, resulting in the abandonment of the breeding effort (Huang, personal observations). Owls in Europe have been known to dislike hawks nesting nearby and prey on breeding hawks and their feathered young (Newton, 1979). Nest site conflicts between European hawks and owls probably resulted in some hawk mortality (Newton, 1986).

Different species of prey may require different hunting techniques. Versatile predators are often opportunistic hunters which hunt prey that are easy to catch and provide the highest rewards. Opportunists can also easily shift from one prey type to an alternative prey types (Korpimäki and Sulkawa, 1990; Sulkawa *et al.*, 1997). The Besra Sparrowhawk mostly preyed on birds in and around woodlands, but apparently is versatile enough to utilize easy prey species which emerge seasonally. We can see this from the seasonal shift in the prey types delivered to the nests. The high proportion of birds from late April to May decreased from June through July along with an increase of large insects such as cicadas. In Yangmingshan area, cicadas began to emerge and became abundant from June on. The increase in insect prey (mostly cicadas) in July and August shifted the relative frequency of different prey classes, but the small sizes of the insects did not have the same effect on the relative proportions of biomass occupied by different prey classes.

Prey delivered to incubating females and nestlings may not represent the complete diet of a raptor. Rutz (2003) reported that adult Northern Goshawks tended to consume larger prey items at the place of kill, while bringing only the smaller prey back to the nestlings. We have no evidence suggesting that Besra Sparrowhawk delivered prey differentially to the nests. However, our sample sizes were very small for the incubation period and the first week after the hatching of the young. This was mostly due to the fact that female Besra Sparrowhawk generally left the nests to receive food from males at non-specific locations and consumed the prey away from the nests during incubation. During the hatchling stage, parents often brought back plucked prey items and fed the young small pieces of meat that could not be identified during observation and that did not produce pellets. Still, even though diet information obtained at nests may be incomplete, it is better than relying on unpredictable and sporadic observations of raptors foraging over wide home ranges.

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陽明山地區台灣松雀鷹 (*Accipiter virgatus*) 於繁殖期間之食性探討

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摘　　要

本研究於 1993 年至 2002 年在北台灣陽明山地區監測了 25 個台灣松雀鷹 (*Accipiter virgatus*) 的巢，紀錄此種鳥在繁殖期之食性。結果顯示台灣松雀鷹不論以帶回巢之食物種類、頻律、或生物量而言，鳥類均為其主食。被獵捕的鳥種多在樹冠層、中層、及灌木叢中活動，在地面活動的鳥種相對較少。台灣松雀鷹的食性相當廣，會隨機捕捉多種獵物，食性有季節間的轉移，利用隨季節大發生的昆蟲，故食物的組成與食物多樣性指數會隨月份而有差異。

關鍵詞：獵物組成、食性、台灣松雀鷹、*Accipiter virgatus*、陽明山、台灣。

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