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LACEWINGS AND SNAKEFLIES (NEUROPTERA, RAPHIDIOPTERA) AS PREY FOR BIRD NESTLINGS IN SLOVAKIAN FOREST HABITATS

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Songbirds in their breeding period are among the most important predators of neuropteroid insects. The second author has conducted a long-term study on diet of 40 species of songbirds in the nestling period (May–July) since 1978 in mountainous oak-hornbeam, beech-oak, and beech-coniferous forests in Central Slovakia. More than 60,000 food items were collected predominantly by the neck-ring method and to a lesser extent by pellet, stomach, and dropping content analysis. The proportion of Neuroptera and Raphidioptera in food of nestlings of 17 bird species ranged between 0.1–3.9% and 0.1–4.4%, respectively.
Among the 4 raphidiid, 7 chrysopid, and 5 hemerobiid species recorded in diets, the most abundant were *Dichrostigma flavipes* (adults), *Nineta pallida* (larvae), and *Hemerobius micans* (adults). The chrysopids were present with the greatest dominance (59%) in the food composition of foliage gleaners, while hemerobiids were captured in higher proportions (50%) by bark foragers. The raphidiids were collected mainly by the generalist *Ficedula albicollis* (61%), and by bark foragers (36%). In the diet composition of ground foragers only a low number of neuropteroids were present. The sampled birds caught the highest number of individuals from the three families of neuropteroids in the period between mid-May and early June.

Key words: Neuroptera, Raphidioptera, Chrysopidae, Hemerobiidae, Raphidiidae, songbirds, food of nestlings, foraging mode

INTRODUCTION

In their breeding period, the songbirds may be among the most important predators of neuropteroid insects. According to the numerous data published in the world literature, the proportion of neuropteroid insects in the food composition of birds ranged between 0.4–4.0% (mean: 0.95%) in agricultural habitats, and 0.1–12.0% (mean: 3.5%) in forests. These values show that neuropteroid insects are frequently found with much higher rates among the prey of songbirds than with which (<1%) they are usually represented in insect assemblages of their habitats. Contrary to the many studies on feeding and food preference of birds, only a few lacewings and snakeflies were identified at species level among prey of birds (BETTS 1956, 4 chrysopids; KOŽENÁ 1975, 1 chrysopid, 2 hemerobiids, and 1 raphidiid; SZENTKIRÁLYI and TÖRÖK 1983, 7 chrysopids, 6 hemerobiids, and 4 raphidiids; BUREŠ 1986, 1 hemerobiid, 3 raphidiids). During the last twenty years, the second author has carried out a long-term study on the diet of 40 songbird species in the nestling period in central Slovakian forests. He found that the songbirds can feed on a large amount of homopteran insects (mainly aphids and psyllids) and numerous aphidophagous coccinellids and syrphids (KRIŠTÍN 1988, 1991). Recent study relates to the identification and data analysis of the chrysopids, hemerobiids, and raphidiids captured by birds in central Slovakian mixed forests over 17 years.

The aims of this study

(1) To identify which songbirds captured which neuropteroid species during their breeding period.

(2) To show the extent to which the neuropteroid species composition in the food of birds corresponds to the expected one in the given forest habitats.

(3) To analyse the variation in the proportion of neuropteroid prey groups in relation to the foraging mode (hunting style) of bird species.

(4) To describe the seasonal distribution of the prey neuropteroid families in the diets of nestling.

MATERIAL AND METHODS

Collecting methods

The food samples were taken predominantly by a modified neck-ring method (93.2%). In smaller quantity, pellet and stomach analysis (3.2%), and dropping analysis (3.6%) were also used. The collars around the neck were applied to 3–15 days old bird nestlings. Collection of food samples from birds was carried out between 7^h and 18^h during the nestling period of May, June, and July. A sampling unit means all food (arthropod) items captured by the bird parents during a 2-hour time period. All types of food samples were preserved till examination in 75% alcohol. The numbers of sample units and arthropod food items per studied birds are presented in Table 1.

Sampling sites and periods

The investigations were conducted in the central Slovakian mountains Kremnické Vrchy. The samples were collected in three localities of this mountainous area in oak-hornbeam, beech-oak, and beech-coniferous mixed forests scattered with xerothermous habitat patches, as follows:

Kováčová valley near Zvolen (19°06'E, 48°38'N), SW–SE slope, between 400–530 m a.s.l. Vegetation comprised by relatively homogeneous, 20 ha sized, 80–100 years old stands of *Querco–Fagetum* (80%) and *Fageto–Quercetum* (20%) forest associations. In the vicinity there was also a forest of *Fagetum–Carici pilosae* mixed with coniferous tree (spruce, fir) stands.

Stráže-mountain, near Zvolen (19°07'E, 48°34'N), 380–440 m a.s.l. The vegetion type was oak-hornbeam mixed forest association, *Carpinenion betuli–Carici pilosae.*

Polána-mountain, near Zvolen (19°08'E, 48°35'N), 1300 m a.s.l. The vegetation type was *Sorbeto–Piceetum.*

Food material was sampled over the years between 1978 and 1994, during the period May–July.

Bird species studied

A. KRIŠTÍN has studied feeding ecology of 40 European songbird species (Passeriformes, Piciformes, and Coraciiformes). After examination of more than 60,000 food items collected by adult birds in breeding periods, neuropteroid insects were found in diets of 17 bird species (see in Table 1). Only 11 bird species produced higher number of neuropteroid food items in sufficient condition for taxonomic identification. They are as it follows *Certhia familiaris* (Tree Creeper), *Dendrocopos major* (Great Spotted Woodpecker), *Erithacus rubecula* (Robin), *Ficedula albicollis* (Collared Flycatcher), *Fringilla coelebs* (Chaffinch), *Parus ater* (Coal Tit), *Parus major* (Great Tit), *Phylloscopus collybita* (Chiffchaff), *Phylloscopus sibilatrix* (Wood Warbler), *Prunella modularis* (Dunnock), *Sitta europaea* (Nuthatch). The foraging modes of these birds are given in Table 1–2.

Data evaluation

Percentage proportion of each arthropod order in the diet of nestlings was calculated for total samples for each studied bird species (Table 1). Proportions of Neuroptera, (Chrysopidae, Hemerobiidae), Raphidioptera and potential prey of these groups (Homoptera: aphids and psyllids) are shown in Table 1. Bird species are grouped according to their prey foraging mode (hunting style): foliage gleaners, bark foragers, ground foragers, and feeding generalists. The neuropteroid prey-species of the members of these foraging groups are presented on Table 2. Table 3 shows the ecological characteristics, dominance (D%) of individual numbers, and percentage ratio of neuropteroid species found in the diet composition of nestlings arranged by foraging mode of the birds. The individual numbers of Chrysopidae, Hemerobiidae, Raphidiidae occurring in food items were summed within each family according to foraging modes. From these sums two kinds of percentage distribution were calculated: (a) distribution of individuals (as food items) of each neuropteroid family among the 4 diet-groups acquired with the 4 foraging modes; (b) distribution of the 3 neuropteroid prey families in the diet of bird group of each foraging mode, which reflect on a preference of birds to capture a certain family. Results are shown in Table 4. A temporal grouping has also been made on samples of the 3 neuropteroid families collected by birds. For this number of lacewing individuals was summarised both for adults and larvae in 10–day intervals over period of May–June. This seasonal distribution of families in bird food during the breeding period is illustrated in Fig. 1.

RESULTS AND DISCUSSION

Proportion of Neuroptera and Raphidioptera among arthropod food kinds of birds

After examination of more than 60,000 food items it turned out that neuropteroid insects were found only in nestling diets of 17 bird species. Arthro-

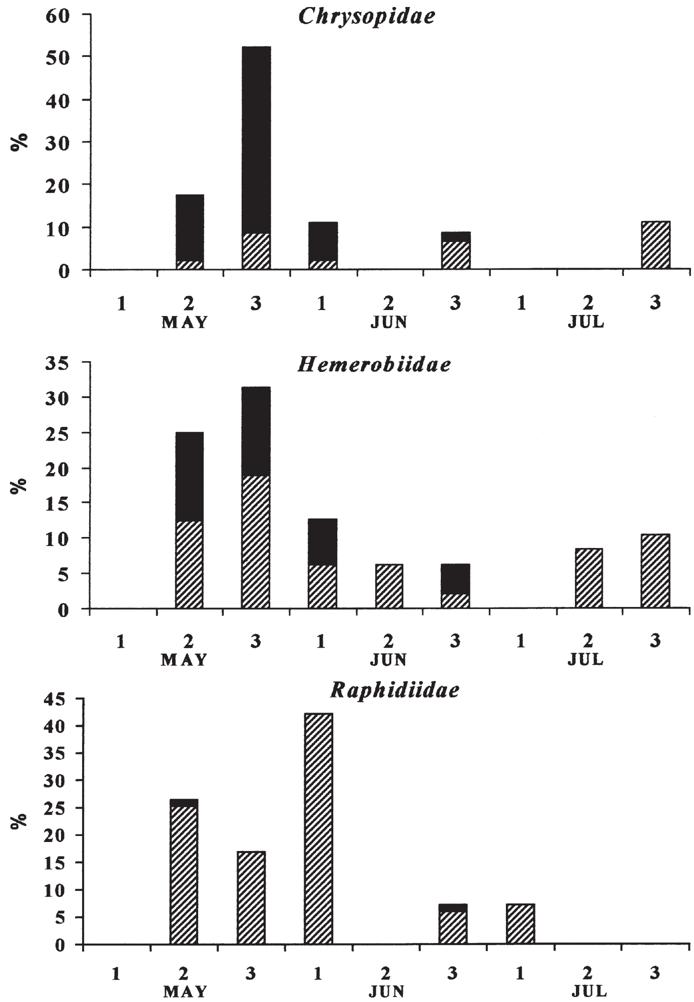

Fig. 1. Seasonal distribution (%) of neuropteroid insect families in the food of bird nestlings in central Slovakian forests collected over 1987–1993 (The data were calculated by the three 10-day periods per month. Black columns: percent of larvae, striped columns: percent of adults.)

Table 1. Proportion of Neuroptera (NE), Raphidioptera (RA), Homoptera and other food kind groups in the diet of bird nestlings collected by the neck–ring method in Slovakia during period of 1978–1993 (FM = foraging mode; FS = number of food sample; FI = number of food items)

Bird species	FM	FS	FI	Kind of food items (%)													
				NE	**RA**	**HO**	GL	IDC	AR	OR	HE	LE	CO	HY	DI	OT	PS
Parus ater	FG	206	1104	0.8	–	44.9	0.8	–	15.9	3.7	1.1	27.6	1.2	0.9	2.4	0.6	–
Parus caeruleus	FG	250	550	0.5	–	4.2	1.1	–	31.3	–	1.1	56.9	4.2	–	0.7	–	–
Parus major	FG	773	1287	0.1	–	2.3	1.8	–	18.9	1.1	–	60.3	5.4	0.2	9.5	0.2	0.4
Phylloscopus collybita	FG	233	1365	2.5	–	23.7	2.6	0.1	11.5	0.8	8.4	15.5	0.2	2.2	25.1	7.3	–
Phylloscopus sibilatrix	FG	90	312	3.9	0.6	10.6	4.5	–	17.6	–	4.1	11.2	5.8	1.6	38.8	1.3	–
Remiz pendulinus	FG	260	856	0.3	–	46.3	1.6	–	35.2	–	0.8	14.2	1.2	0.2	–	–	–
Certhia familiaris	BF	82	809	1.1	0.7	40.7	1.4	0.1	12.9	–	2.1	15.1	1.4	1.2	9.6	17.2	–
Dendrocopos major	BF	31	1390	0.1	0.5	14.9	0.1	0.4	4.7	–	0.7	6.3	8.2	47.8	11.5	0.1	5.0
Sitta europaea	BF	1585	10892	0.5	0.1	9.6	0.7	0.4	9.1	0.1	17.2	28.7	15.0	2.4	14.7	1.4	0.1
Erithacus rubecula	GF	150	457	1.5	–	11.8	0.7	6.6	17.5	0.2	0.7	16.6	14.0	8.8	16.6	4.8	0.2
Oenanthe oenanthe	GF	65	234	0.4	–	5.5	0.8	0.8	5.1	11.9	–	28.5	22.1	13.6	11.1	–	–
Prunella modularis	GF	173	3957	1.7	0.3	38.7	1.6	0.8	20.6	0.1	0.4	7.7	3.4	2.3	9.0	13.3	–
Troglodytes troglodytes	GF	94	522	–	0.2	15.1	–	6.9	29.1	–	1.0	7.1	1.5	–	29.9	9.2	–
Turdus merula	GF	86	160	1.2	–	0.6	18.8	10.7	4.9	–	0.6	34.4	12.4	4.4	8.8	0.1	3.1
*Merops apiaster**	AF	125	2174	0.1	–	–	–	–	–	0.2	2.6	2.9	16.3	70.5	5.1	2.3	–
Ficedula albicollis	GE	451	3432	1.6	4.4	4.3	0.3	2.7	12.3	0.4	5.6	16.3	19.3	14.4	18.0	0.4	–
Passer montanus	GE	1120	5820	0.1	–	25.8	0.8	–	4.4	0.2	1.3	29.0	20.8	0.7	12.4	0.1	4.4

Abbr.: FG= foliage gleaning, BF= bark foraging, GF= ground foraging, AF= aerial foraging, GE= generalist forager; NE= Neuroptera; RA= Raphidioptera; HO= Homoptera; GL= Gastropoda, Lumbricidae; IDC= Isopoda, Diplopoda, Chilopoda; AR= Araneae, Opiliones; OR= Orthoptera; HE= Heteroptera; LE= Lepidoptera; CO= Coleoptera; HY= Hymenoptera; DI= Diptera; OT= other insect groups; PS= plant seeds; * : food studied by pellet and stomach content analysis.

pod diet composition (%) of these 17 bird species is presented on Table 1. All birds preyed on Neuroptera except for one species, contrary to Raphidioptera, which could be found only in the food of 7 bird species. The proportion of Neuroptera and Raphidioptera ranged between 0.1–3.9% and 0.1–4.4%, respectively. The majority of bird species captured relatively few individuals from order Neuroptera, and lacewing dominance in their diet was below 1%. Neuropteran insects were represented with the highest (at least 1.5%) ratio in food of the 5 following bird species: *Phylloscopus sibilatrix* (3.9%), *Ph. collybita* (2.5%), *Prunella modularis* (1.7%), *Ficedula albicollis* (1.6%), and *Erithacus rubecula* (1.5%). These rates of Neuroptera are higher in bird food than their expected natural proportion within arthropod assemblages, which usually does not exceed 1% dominance value. Preference for lacewings found in food composition of House Martins (*Delichon urbica*) was explained by Bryant (1973) with their higher amount of fat. This factor might be responsible for the higher ratio in nestling diets of our study. We can observe that the ratio of homopteran insects is also generally higher (at least 10%) in cases of greater Neuroptera proportions (Table 1). It means that if birds hunt from plants strongly infected with aphid or psyllid colonies, than they also can encounter and prey on aphidophagous insects more frequently. Ratios of Raphidioptera stay under 1% except for one case (Table 1). They are mainly preyed upon by bark foragers. The exception *Ficedula albicollis*, which bird is a generalist forager, captured the individuals of Raphidiidae among arthropods in rate of 4.4%.

Species composition and dominance of neuropteroid insects in the food of birds

Table 2 shows the number of individuals of identifiable lacewing species collected by birds. Four species of Raphididiiae were recorded, overwhelming majority of them were imagines. *Dichrostigma flavipes* (D = 62%) and *Phaeostigma notata* (D = 31%) were represented with the highest dominance within the snake flies group (Table 3, column D). Birds captured individuals from seven species of the family of green lacewings. *Nineta pallida* was the most dominant (D = 70%), birds caught mainly its well-developed L_3 stage larvae. The proportion of *N. pallida* larvae was about three times greater than that of adults. In dominance rank of order *Dichochrysa prasina* was the second with nearly rate of 12%. Predominantly ground forager birds preyed on the latter lacewing species.

Five species were identified from the family of brown lacewings. Among them, *Hemerobius micans* proved to be the most dominant species (D = 69%). *Drepanepteryx phalaenoides* (14%) and *H. humulinus* (11%) followed it in the dominance rank order. While for chrysopids the larval stage was represented in the

Table 2. Number of individuals of identifiable neuropteroid species from food of birds collected in Central Slovakian forests over 1987–1993

Neuropteroid species	Bird species										
	Foliage gleaner					Bark forager			Ground forager		Gen.
	PMA	PAT	PCO	PSI	FCO	SEU	DMA	CFA	ERU	PMO	FAL
RAPHIDIIDAE											
Phaeostigma notata (FABRICIUS)				1		13					12
Dichrostigma flavipes (STEIN)				1	1	7	3	2			38
Xanthostigma xanthostigma (SCHUMMEL)								3			
Puncha ratzeburgi (BRAUER)						2					1
CHRYSOPIDAE											
Nineta pallida (SCHNEIDER)	1	6	17			4		1			1
Nineta flava (SCOPOLI)											2
Dichochrysa prasina (BURMEISTER)			1							4	
Chrysopa viridana SCHNEIDER			1								
Chrysopa abbreviata CURTIS											1
Peyerimhoffina gracilis (SCHNEIDER)									1		
Chrysoperla lucasina (LACROIX)						1					2
HEMEROBIIDAE											
Hemerobius micans OLIVIER			4	4		9			3	3	2
Hemerobius humulinus LINNAEUS						3					1
Hemerobius marginatus STEPHENS			1								
Sympherobius elegans (STEPHENS)			1								
Drepanepteryx phalaenoides (LINNAEUS)						5					

Abbreviation: Gen. = generalist forager; PMA = *Parus major*, PAT = *Parus ater*, PCO = *Phylloscopus collybita*, PSI = *Phylloscopus sibilatrix*, FCO = *Fringilla coelebs*, SEU = *Sitta europaea*, DMA = *Dendrocopos major*, CFA = *Certhia familiaris*, ERU = *Erithacus rubecula*, PMO = *Prunella modularis*, FAL = *Ficedula albicollis* majority (73%) of food items against adults, in the case of hemerobiids the adults were dominant (64%), against larvae. Raphidiids was represented almost exclusively by imagines with a ratio of 98%.

Species composition of neuropteroids found in nestling food reflects well on forest vegetation of the given habitats, climatic conditions, preference for vertical distribution and abundance level of lacewings (see Table 3). There were mixed forests at the sampling sites, where both stands of deciduous tree species (*Quercus*, *Carpinus*, and *Fagus*) and coniferous trees (*Picea*, *Abies*, and *Pinus*) also occurred. These forests, especially their bushy borders, frequently have ecotones with drier and warmer microclimate. Comparing these characteristics of sites with the ecological requirements of recorded neuropteroid species, a noticeable coincidence can be found. Members of family Raphidiidae prefer xerothermous, lighter oak and coniferous forest stands living at shrub and foliage-crown level. Representatives of family Chrysopidae consist of mainly such abundant species that are ubiquitous. Two green lacewing species strongly indicate coniferous trees, namely *N. pallida* (prefers *Picea abies*) and *Peyerimhoffina gracilis* (prefers trees of *Picea* and *Abies* species). Other green lacewings are mainly inhabitants of deciduous forests. The brown lacewings found are ubiquitous and thermophilous species without exception, and they are usually abundant in deciduous forests and prefer vertically the foliage crown level. Those neuropteroid species, which are generally abundant in their habitats (*D. flavipes, N. pallida, Dichochrysa prasina,* or *H. micans*, Table 3), were also represented in greater proportion in the food of birds. The generalist feeder *F. albicollis* during its breeding period collects prey mainly by foliage-gleaning and bark-foraging hunter techniques. Snake flies often rest on tree barks, therefore they easily become preys of this bird. This explains the higher proportion of the two raphidiid species in the diet of *F. albicollis*.

Neuropteroid prey distributions among foraging modes and within foraging modes of birds

Table 4 and 5 summarises the two distribution types of neuropteroid foods. From the two distributions it can be see that foliage gleaners collected chrysopid prey at the highest rate (59.1 and 66.7%). This is understandable, since larvae of *N. pallida* living on pine foliage formed the majority of lacewing prey of birds. Hemerobiids were rather recorded in the diet of bark foragers (50 and 40%). The rate of brown lacewings in neuropteroid food of ground foragers was relatively high (61%), however it means only a few individuals (<10), mainly *H. micans*. A smaller proportion of hemerobiids (20 and 26%) appeared among prey of foliage gleaners, represented by the previous species as well. In both distribution types, the

Table 3. Characteristics of tree preference (TP), abundance level (ABL), xerothermo-preference (XTP), and vertical habitat preference (VHP) of the neuropteroid species and their percentage distribution in the food of bird nestlings captured by different foraging modes (FG: foliage gleaning, BF: bark foraging, GF: ground foraging, GE: generalist; D: species dominance% within neuropteroid family in food of birds) in Slovakia during 1987–1993

Neuropteroid species	TP	ABL	XTP	VHP	Foraging mode				D (%)
					FG	BF	GF	GE	
RAPHIDIIDAE									
Phaeostigma notata	Co,Q		XT	C	2.6	24.5		20.0	30.9
Dichrostigma flavipes	P,Q	A	XT	S,H	5.0	22.6		63.3	61.9
Xanthostigma xanthostigma	Co,Q		X	S		5.7			3.6
Puncha ratzeburgi	Co,Q		XT	C		3.8		1.7	3.6
Total					7.6	56.6		85.0	100
CHRYSOPIDAE									
Nineta pallida	P	A		C	61.5	9.4		1.7	69.8
Nineta flava	D	A	U	C,S				3.3	4.7
Dichochrysa prasina	D	A	U	C,S	2.6		36.4		11.6
Chrysopa viridana	Q		T	C,S	2.6				2.3
Chrysopa abbreviata				H				1.7	2.3
Peyerimhoffina gracilis	P,Ab			C			9.1		2.3
Chrysoperla lucasina		A	U	C,S,H		1.9		3.3	7.0
Total					66.7	11.3	45.5	10.0	100
HEMEROBIIDAE									
Hemerobius micans	Q,F,C	A	U	C	20.5	17.0	54.5	3.3	69.4
Hemerobius humulinus	D	A	U	C,S		5.7		1.7	11.1
Hemerobius marginatus	D		XT	S	2.6				2.8
Sympherobius elegans	Q,F		T	C	2.6				2.8
Drepanepteryx phalaenoides	Q,F	A	U	C		9.4			13.9
Total					25.7	32.1	54.5	5.0	100

Abbr.: Co: coniferous trees, D: deciduous trees, Ab: *Abies alba*, C: *Carpinus betulus*, F: *Fagus silvatica*, P: *Picea abies*, Q: *Quercus* spp.; A: abundant, U: ubiquist, T: thermophilous, X: xerophilous, XT: xero-thermophilous, C: tree-crown layer, S: shrub-layer, H: herbaceous-layer

Table 4. Distribution (%) of neuropteroid families as prey among different foraging groups of birds

Foraging mode	Neuropteroid family		
	Chrysopidae	Hemerobiidae	Raphidiidae
Foliage gleaners	59.1	20	3.6
Bark foragers	15.9	50	35.7
Ground foragers	11.4	16	0
Generalists	13.6	14	60.7
Total	100	100	100

family Raphidiidae was represented in considerable proportions (61 and 80%) in the food of generalist birds. However, as we earlier referred to the change in hunting mode of *F. albicollis* during its breeding season, this high rate of snake flies among the neuropteroid foods is probably a consequence of its prey collecting activity on bark surfaces. The remaining proportion of snake flies (36 and 48%) was found in food of bark foragers.

Seasonal distribution of neuropteroid insects in food of nestlings

The seasonal distribution patterns of the three neuropteroid families in diets of nestlings are similar to each other (Fig. 1). Birds collected most larvae and imagines in the main breeding period, from mid-May to the first decade of June. A smaller proportion of lacewings were still among prey-items in the second half July, snake flies even in the late June – early July period. Among chrysopids the high frequency of larvae of *N. pallida* in food items is reasonable, since this species overwinters in its larval stage. At the same time the hemerobiid, *D. phalaenoides* was also found by birds in early season because it overwinters as an imago. There is no significant difference between the seasonal distributions of neuropteroid families (Fig. 1), which indicates that they were depended mainly on food collecting frequency of birds, contrary to Hungarian study (SZENTKIRÁLYI & TÖRÖK 1983),

Table 5. Proportion (%) of abundance of the neuropteroid families in the nestling foods of bird groups with the same foraging mode

Neuropteroid family	Foraging mode			
	Foliage gleaners	Bark foragers	Ground foragers	Generalists
Chrysopidae	66.7	11.3	38.5	9.4
Hemerobiidae	25.6	40.3	61.5	10.9
Raphidiidae	7.7	48.4	0	79.7
Total	100	100	100	100

where the 3 families appeared in bird foods with a distribution reflecting their natural seasonality.

CONCLUSIONS

(1) In prey composition of nestlings, 4 raphidiid, 7 chrysopid, and 5 hemerobiid species were recorded. The most abundant neuropteroid species in diets were *Dichrostigma flavipes*, *Nineta pallida* and *Hemerobius micans*.

(2) The proportion of different neuropteroid groups varied according to the foraging mode of the birds. Within neuropteroid food composition of foliage gleaners, the chrysopids were represented by the greatest dominance (68%), while hemerobiids had lower proportion (26%). The bark foragers collected the snakeflies and brown lacewings almost in equal portions, 48% and 40%, respectively. In the diet composition of ground foragers only a few number of neuropteroids were present (chrysopids 43% and hemerobiids 57%). The generalist feeding birds captured predominantly raphidiids (79%).

(3) Investigated birds caught the most individuals from the three neuropteroid families in the period between second ten days of May and first ten days of June. The seasonal distribution pattern of neuropteroids in foods depended on collecting frequency of birds.

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