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On food composition and foraging ecology of the Western Yellow Wagtail (*Motacilla flava*) in Western Slovakia

K zloženiu potravy a potravnej ekológii trasochvosta žltého (Motacilla flava) *na západnom Slovensku*

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Abstract*. The Western Yellow Wagtail* (Motacilla flava) *is typical species of agricultural landscapes, where the food supply is significantly limited. The nestling diet composition and its foraging ecology are little known in the entire range. Therefore, we studied the composition of the nestlings' food and some aspects of its foraging ecology by photos from the shelter, in a population on abandoned agricultural land (17 ha) in Western Slovakia near Piešťany town (48,55098° N, 17,805612° E, 150 m asl.) in April–July 2017–2022. Analyzing 177 photos/feedings of young (1–12 days old) by a male and a female in 9 nests, was found a total of 361 prey items (2.7% of them unidentified). The food consisted of invertebrates from 12 orders, 33 families, and approximately 86 species. Spiders (Araneida, 19.4%), crickets and grasshoppers (Orthoptera, 18.6%), and moths (Lepidoptera) and dipterans (Diptera) with the same proportion 15.2%, belonged to the eudominant prey groups. Among the dominant and frequent species were, e. g., the aposematically coloured spider* Argiope bruenichii*, the mayfly* Ephemera danica*, the bush-crickets* Leptophyes albovittata*,* Bicolorana bicolor*, from other taxa there were significantly represented Noctuidae and Geometridae caterpillars, cicadas (Cicadellidae) and flies from the suborder Nematocera. The prey body length varied between 2 mm (snail* Vallonia pulchella*) and 50 mm (dragonfly of the genus* Sympetrum*) (average 17.1±8.6 mm, n = 361), i.e. it was on average longer than the average bill length (11–12 mm). Parents brought 1–10 prey items per feeding (mean = 2.0±1.5 items/ feeding, ca. 50% >1 object/ feeding, n = 177), the species thus belongs to the group of the "multiple prey loaders". The size of foraging territories and the role of the parents in chick feeding was studied in one nest in 2022.*

Key words*: foraging, multiple prey loading, nestling diet, Motacilla flava*

Introduction

Food is one of the basic conditions for the species survival, especially in the case of agricultural landscape species, where quality and quantity of food supply is severely limited (Vickery et al. 2009).

The Western Yellow Wagtail (*Motacilla flava*) is a species breeding in such a landscape and for which the foraging ecology is little known throughout its distribution range, and therefore the data on its food composition and foraging are needed (Dittberner & Dittberner 1984).

Review of data on the nestling diet composition has shown high diversity along the space and time. Flies (Diptera), grasshoppers and crickets (Orthoptera), moth (Lepidoptera), aquatic insects, spiders are frequently mentioned, but the data are very fragmentary and the quantitative assessment of individual taxa in the diet is missing (Glutz 1985, Cramp 1988, Šťastný & Hudec 2011).

The nestling diet composition was studied e. g. in the farmland of Eastern England by faecal analysis (n = 46 samples from 38 nests), when

flies and beetles dominated earlier broods in June, and dragonflies, moths and spiders in later broods in July (Gilroy et al. 2009). Data on prey size and other aspects of its foraging ecology are still practically missing (Glutz 1985, Cramp 1988, Šťastný & Hudec 2011).

Here, we used a relatively dense population of the species in western Slovakia (Kočí 2019), where we focused on nestling food composition and some aspects of species foraging ecology of the species during the breeding season.

Material and methods

The material was collected in the breeding season (April–July) in 2017–2022 near Piešťany town (48.55098° N, 17.805612° E, 150 m a.s.l.), near the Sĺňava water reservoir. The breeding habitats there are eels, meadows and abandoned agricultural land (since 2011 without the management). The study site (17 ha) underwent a radical succession from 2011 and was overgrown with various types of herbs and grasses, thus creating a suitable biotope for nesting yellow wagtails, where a wide range of insects as food could be expected, because after the site abandonment the use of pesticides stopped (Kočí 2019). The breeding density in study period fluctuated considerably between five and 22 nests/17 ha (16, 21, 22, 11, 9, 5 in 2017–2022, mean 12.1/10 ha).

The qualitative-quantitative structure of the nestling food delivered by parents was studied by analysing photos taken from a camouflaged shelter, 10 m away from the nest (n = 9 nests, of which 3 from 2022, 6 from 2017–2021). The most of data on the diet (>95%) are from one nest in 2022. Adults ignored the shelter to the point that they sometimes sat on it and then flew to feed the young. All the observations were made without the bird disturbance, when the shelter being built during pre-incubation period, when the males were singing, and where they were defending the future breeding territory, so that they used the shelter even after building a nest. Photo documentation was made using a Canon EOS 7D camera and a Canon ZOOM LENS EF 100–400 mm 1:4.5–5.6 L IS II USM telephoto lens mainly between 5:30 a.m. and 12:00 p.m. and 3:30–7:30 p.m. Break (12:00–3:30 p.m.) was done because of high temperatures (sometimes even 35°C). In total, more than 400 photos were evaluated, of them 177 individual photos (feedings of young aged 1–12 days) in 9 nests could be analysed and a total 361 food objects were found (of which 2.7% could not be identified to the level of any taxon). Altogether >95% of 177 evaluated photos were made in one nest in 2022, and only the rest in the remaining eight nests in 2017–2022. Prey items and prey sizes were identified by common keys to insect and invertebrate identification (e. g. Chinnery 1993) and by the authors' comparative collections. Foraging territory and foraging distances from the nest (n = 196 records) were registered at one nest (in 2022) from shelter, while the distances of sites of food collection from the nest were marked with well visible markers at 20 m distances in two clear directions used by both parents for foraging. The foraging strategy (ground- and air foraging, n = 323 records) was recorded in one nest only in 2022. The role of parents in chick feeding (n = 196) could only be searched in one nest in 2022 (total 480 minutes of observations), until the young were 8 days old, when the female disappeared and only the male finished the young feeding up to time of successful fledging of the four chicks.

Results and Discussion

The food (361 prey items in 177 feedings and 9 nests) consisted of invertebrates from 12 orders, 33 families, and approximately 86 species (Table 1). The eudominant prey groups included spiders (Araneida, 19.4%, about 12 species from 6 families), grasshoppers and crickets (Orthoptera, 18.6%, 16 species and 12 genera), and with the same share 15.2% moths (Lepidoptera, 14 species from 6 families) and dipterans (Diptera, 14 species from 9 families) (Fig. 1). These groups also belonged to the most frequent food groups (Table 1). Planthoppers (Homoptera, Auchenorrhyncha, 9.4%), ants

Table. 1. Food composition of the *Motacilla flava* nestlings near Piešťany, W Slovakia (June–July 2017–2022; N a N% = absolute and relative No. of prey items, F a F% = absolute and relative frequency).
Tab. 1. *Zloženie potravy mláďat* Motacilla flava *pri Piešťanoch (jún – júl 2017 – 2022; N a N% = absolútny a relatívny počet objektov potravy, F a F% = absolútna a relatívna frekvencia).*

Prey taxa / *Skupiny potravy*	N	N%	F	F%
Gastropoda g.sp.	2	0.55	1	0.56
Araneida g.sp.	13	3.59	8	4.52
Thomisidae	1	0.28	1	0.56
Xysticus sp.	5	1.38	5	2.82
Argiope bruenichi	20	5.52	15	8.47
Araneus sp.	5	1.38	5	2.82
Araneus quadratus	3	0.83	2	1.13
Larinioides sp.	2	0.55	2	1.13
Araniella cucurbitina	2	0.55	2	1.13
Tetragnatha sp.	2	0.55	2	1.13
Cheiracanthium sp.	8	2.21	6	3.39
Tibellus sp.	3	0.83	3	1.69
Pisauridae	2	0.55	2	1.13
kokon	2	0.55	2	1.13
Gnaphosidae	2	0.55	2	1.13
Ephemeroptera				
Ephemera danica	11	3.04	11	6.21
Odonata				
Sympetrum fonscolombii	1	0.28	1	0.56
Sympetrum sp.	1	0.28	1	0.56
Orthoptera				
Phaneroptera sp.	1	0.28	1	0.56
Conocephalus fuscus	3	0.83	3	1.69
Isophya sp.	1	0.28	1	0.56
Leptophyes albovittata	11	3.04	11	6.21
Bicolorana bicolor	11	3.04	11	6.21
Tettigonia viridissima L	5	1.38	5	2.82
Oecanthus pellucens	9	2.49	6	3.39
Calliptamus italicus	7	1.93	7	3.95
Chorthippus sp.	4	1.10	4	2.26
Chorthippus albomarginatus	1	0.28	1	0.56
Chorthippus dorsatus	1	0.28	1	0.56
Chorthippus mollis	2	0.55	2	1.13
Chorthippus parallelus	1	0.28	1	0.56
Euthystira brachyptera	3	0.83	3	1.69
Chrysochraon dispar	1	0.28	1	0.56
Euchorthippus declivus	6	1.66	5	2.82
Heteroptera				
Eurygaster maura	2	0.55	2	1.13
Homoptera				
Cicadellidae	34	9.39	5	2.82
Neuroptera				
Chrysopa sp.	10	2.76	5	2.82
Lepidoptera				
Hesperiidae Im	3	0.83	3	1.69
Tortricidae Im	1	0.28	1	0.56
Noctuidae L	22	6.08	15	8.47
Noctuidae Im	3	0.83	3	1.69
Noctua pronuba	3	0.83	3	1.69
Geometridae L	18	4.97	10	5.65
Geometridae IM	4	1.10	4	2.26
Lymantriidae IM	1	0.28	1	0.56
Coleoptera				
Coleoptera L 30 mm 3 sp.	8	2.21	4	2.26
Staphylinidae	1	0.28	1	0.56
Staphylinus caesareus	1	0.28	1	0.56
Carabidae	2	0.55	2	1.13
Amara sp.	1	0.28	1	0.56
Harpalus sp.	2	0.55	1	0.56
Amphimalon solstitiale	1	0.28	1	0.56
Hymenoptera				
Formicidae	12	3.31	7	3.95
Formica sp.	3	0.83	3	1.69
Lasius sp.	11	3.04	3	1.69
Apidae	1	0.28	1	0.56
Diptera				
Nematocera	18	4.97	7	3.95
Tipulidae Im	10	2.76	6	3.39
Tipulidae L	1	0.28	1	0.56
Tipula sp.	8	2.21	5	2.82
Brachycera Im	1	0.28	1	0.56
Brachycera L	2	0.55	2	1.13
Eristalis tenax	6	1.66	6	3.39
Sarcophagidae	8	2.21	8	4.52
Asilidae	1	0.28	1	0.56
Unidentified/ *Neurčené*	10	2.76	8	4.52
N	361	99.72	177	100.00

(Formicidae), mostly winged, swarming forms (7.1%) were also abundant. Some taxa of invertebrates were found in food only occasionally, e. g. tiny snails (Gastropoda), smelly bugs (Heteroptera) and big dragonflies (Odonata). As the dominant and frequent prey species included e. g. the aposematically coloured spider *Argiope bruenichii*, mayflies *Ephemera danica*, bush-crickets *Leptophyes albovittata, Bicolorana bicolor*, from other taxa there were significantly represented Noctuidae and Geometridae caterpillars, planthoppers (Cicadellidae) and flies

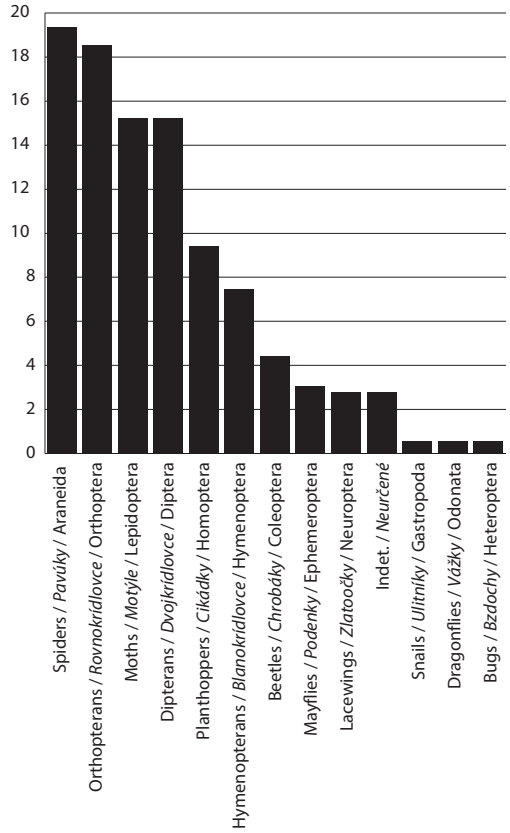

Fig. 1. Abundance of main prey groups in the food (N%, N = 177) of *Motacilla flava* nestlings near Piešťany, W Slovakia (June–July 2017–2022).
Obr. 1. *Početnosť hlavných skupín potravy (N%, N = 177) mláďat* Motacilla flava *pri Piešťanoch (jún – júl 2017 – 2022).*

from the suborder Nematocera (Table 1). Beetles (Coleoptera) and dragonflies (Odonata) were less represented in the nestling food in Slovakia than in the agricultural land of Eastern England, and on the contrary, spiders, and orthopterans dominated in Slovak study site, while flies and moths had a similar frequency as in England (Gilroy et al. 2009). The lower food diversity in England could also be caused by a different methodological approach of data collection, since in England the method of faecal analysis was used, and in our study, more precise, photo analysis (Moreby & Stoate 2000). The wide spectrum of prey taxa (not only in the breeding season), also mentioned in European compendia, confirms different methods of species foraging strategy from ground foraging, foliage- and watersurface-gleaning to hunting in the air (cf. Glutz 1985, Cramp 1988). The food composition near Oxford was strongly affected by the food supply, when during the breeding season flies from the families Chironomidae and Drosophilidae dominated, in the vicinity of waters, and the flies of the family Scatophagidae around the dunghills, and the foraging strategy and substrate varied in different environments (Davies 1977).

We found that the prey size (length) varied between 2 and 50 mm (average 17.1±8.6 mm, n = 361), i. e. it was larger than the mean bill length (11–12 mm, Šťastný & Hudec 2011). The smallest prey items (2 mm) included tiny gastropods, or their shells (*Vallonia pulchella*, Fig. 2), and the largest (50 mm) dragonflies of the genus *Sympetrum* (Fig. 3). In England, the Yellow Wagtail prefers small prey with the mean length 7 mm (Davies 1977). Overall analyses of prey size in this species have not been reported, but in the most cases the mean prey size increases with the age of the young in passerines (Naef-Daenzer et al. 2000) and for energetic reasons the mean prey tends to be longer than the mean bill length (Brandl et al. 1994).

Parents brought 1–10 prey items per feeding (mean = 2.0±1.5 objects/feeding). Altogether 49.7% of feedings consisted of feedings with 2 or more food objects. We distinguished so called heterospecific multiple feedings (feedings with several prey taxa) and homospecific multiple feedings (feedings with single prey taxa). We found 11.9% homospecific multiple feedings (feedings with 2–10 prey items, n = 177) and 37.9% heterospecific multiple feedings (of them 7.4% with three prey taxa, and 30.5% with two prey taxa, feedings with 2–10 prey items). The Yellow Wagtail therefore belongs to the group of so-called "multiple prey loaders" (Orians & Pearson 1979, Houston 1985, Gaglio et al. 2018). The number of prey items per feeding thus significantly differs between the species bringing mainly one prey item per feeding ("single prey loader"), such as e. g. the Great Tit *Parus major* (Naef-Daenzer et al. 2000, Barba et al. 2009), Eurasian Hoopoe *Upupa epops* (Nuhlíčková et

al. 2016), raptors (Chavko & Krištín 2017) and other bird taxa, which feed with a higher number of prey items per feeding only exceptional. We found that higher number of prey items (5–10 in the bill) per feeding consisted mainly of the same prey taxa, e. g. smaller (<10 mm) cicadas (Cicadellidae), but also larger (≥25 mm) Geometridae caterpillars (Fig. 4), goldeneyes (*Chrysopa* sp.) and tipulids (Tipulidae). Such higher numbers of the same prey taxa caught per feeding are explained e. g. by scaring them away from the same food source and substrate, e. g. flies from the dung, mosquitoes from the water surface (Davies 1977), or by simultaneous abundant occurrence on a smaller surface of the hunting substrate (cicadas, moth caterpillars, fish – Gaglio et al. 2018). We recorded that the

Fig. 2. Snails (Gastropoda) and planthoppers (Homoptera, Auchenorrhyncha) are among the smallest prey items (Photo by J. Kočí).
Obr. 2. *Ulitníky (Gastropoda) a cikádky (Homoptera, Auchenorrhyncha) patria k najmenším potravným objektom druhu (Foto: J. Kočí).*

Fig. 3. Dragonfly S*ympetrum* sp., one of the biggest prey items in the bill of female (a) and male (b) (Photo by J. Kočí).
Obr. 3. *Vážka* Sympetrum sp.*, jeden z najväčších objektov potravy v zobáku kŕmiacej samice (a) a samca (b) (Foto: J. Kočí).*

Fig. 4. Simultaneous feeding by several prey items, in this case Geometridae caterpillars, is typical in this species (Photo by J. Kočí).
Obr. 4. *Kŕmenie viacerými potravnými objektami naraz, v tomto prípade húsenice Geometridae, je pre druh typické (Foto: J. Kočí).*

Fig. 5. The male feeds with three prey items simultaneously (cricket *Oecanthus pellucens* 2 and bushcricket *Leptophyes albovittata* 1) (Photo by J. Kočí).
Obr. 5. *Samec prináša 3 potravné objekty súčasne, 2 jesienky* Oecanthus pellucens *a kobylku* Leptophyes albovittata *(Foto: J. Kočí).*

larger orthopterans and difficult-to-catch prey such as larger dragonflies (Odonata, Fig. 3) and beetles (*Amphimalon solstitiale*) were brought in one specimen each. However, we also found regular feedings with multiple taxonomically and ecologically different prey, and it is questionable how the parents caught them and kept them in their bills while hunting, since multiple food objects are more typical in e. g. piscivorous birds that hunt fish in flocks (Gaglio et al. 2018), or other foraging specialists, hunting locally abundant and taxonomically related prey. For example, in several cases, we found three different taxa per feeding, often with a different life style, movement strategy and different habitat requirements (ant *Formica* sp. 1, fly *Tipula* sp. 1 and goldeye *Chrysopa* sp.1), or (mayfly *Ephemera danica* 1, bushrcicket *Bicolorana bicolor* 1 and fly *Sarcophaga* sp. 1), two taxa e. g. spider *Xysticus* sp. 1 and bush-cricket *Tettigonia viridissima* 1). Sometimes there were also ecologically and taxonomically related prey species, e. g. crickets *Oecanthus pellucens* and *Leptophyes albovittata* (Fig. 5; Online Appendix 1).

Regarding the foraging territory size, the parents collected the food 5–250 m from the nest (mean 45.7±44.0 m, n = 196 records), departures were almost exclusively in two directions. The male flew further (mean 52 m, n = 123) than the female (mean 34 m, n = 73). The direct arrival of parents with the food to the nest was never observed, they stopped before the feeding in different perching sites for secure feeding.

Data on the foraging territory size for this species are missing in the literature, but males mark territories with an area of 300 × 300 m and the nests are usually only 17–20 m apart (Dittberner & Dittberner 1984, Cramp 1988).

When the parents feed together, the male fed the young more frequently (63.3%) than the female (36.7%, n = 196 feedings in one nest), and the amount of food brought by the male was also larger. In one case, the male was observed passing food to the female, who then fed the young. After the chicks were eight days old, the female disappeared, and the reason for the absence remained unknown. The male then intensively fed himself until the 12th day of the young's age in the nest and after fledging for about 4 days in the surrounding area. Data on parental care are lacking in the literature, it is only known that both parents feed (Dittberner & Dittberner 1984, Cramp 1988).

Birds were mostly ground-, less air-foraging (97.2 vs 2.8%, n = 323 observations), what is in agreement with published data (Cramp 1988).

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Súhrn

Trasochvost žltý (*Motacilla flava*) patrí k typickým druhom poľnohospodárskej krajiny, kde je potravná ponuka výrazne obmedzená. Zloženie potravy a jeho potravná ekológia sú málo známe v celom areáli. V hniezdnej sezóne (apríl – júl) v rokoch 2017 – 2022 sme preto študovali zloženie potravy mláďat analýzou fotografií a niektoré aspekty jeho potravnej ekológie z krytu, v populácii na opustenej poľnohospodárskej pôde (17 ha) západného Slovenska pri Piešťanoch (48,55098° N, 17,805612° E, 150 m n. m.). Analýzou 177 fotografií/ samostatných kŕmení mláďat (vo veku 1 – 12 dní) samcom a samicou na 9 hniezdach sme zistili celkom 361 objektov potravy (2,7 % z toho neidentifikovaných). Potravu tvorili bezstavovce z 12 radov, 33 čeľadí, a približne 86 druhov. K eudominantným skupinám koristi patrili pavúky (Araneida, 19,4 %), kobylky a koníky (Orthoptera, 18,6 %) a s rovnakým podielom 15,2 % motýle (Lepidoptera) a dvojkrídlovce (Diptera). K dominantným a frekventovaným druhom patrili napr. aposematicky sfarbený pavúk *Argiope bruenichii*, podenka *Ephemera danica*, kobylky *Leptophyes albovittata*, *Bicolorana bicolor*, z iných taxónov boli významne zastúpené húsenice môr a piadiviek (Noctuidae a Geometridae), cikádky

(Cicadellidae) a dvojkrídlovce z podradu Nematocera. Dĺžka tela koristi sa pohybovala medzi 2 mm (ulitník *Vallonia pulchella*) a 50 mm (vážka rodu *Sympetrum*) (priemer 17,1±8,6 mm, n = 361), teda bola priemerne väčšia ako je priemerná dĺžka zobáka (11 – 12 mm). Rodičia prinášali 1 – 10 potravných objektov na jedno kŕmenie (priemer = 2,0±1,5 objektu/kŕmenie, cca 50 % > 1 objekt/kŕmenie, n = 177), druh patrí tak skôr do skupiny „multiple prey loaders". Na jednom hniezde boli sledované aj veľkosti potravných teritórií a podiel rodičov na kŕmení mláďat.

***Online Appendix** is available on the journal webpage.*
Elektronická príloha je dostupná na webovej stránke časopisu.

Online Appendix 1. Prey items per feeding.
***Elektronická príloha 1.** Počet potravných objektov na kŕmenie.*

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