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WINTERING ROOKS, *CORVUS FRUGILEGUS* (AVES, CORVIDAE), AND THEIR HELMINTHS IN POLTAVA AND KYIV, UKRAINE

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Wintering Rooks, *Corvus frugilegus* (Aves, Corvidae), and their Helminths in Poltava and Kyiv, Ukraine. Greben, O., Dupak, V., Lisitsyna, O. & Kuzmin, Y. — Observations of wintering rook populations were carried out from late October till early March in 2020–2021 and 2021–2022 in the cities of Poltava and Kyiv. In Poltava, rooks made up 95 % of the approximately 50,000 wintering corvids, and in Kyiv, more than 93 % of the approximately 90,000 corvids. Up to 10 % of the rooks observed in Poltava were juveniles; no juvenile rooks were observed in Kyiv. Forty-six dead rooks (24 in Poltava and 22 in Kyiv) collected on the ground at roosting sites were used for parasitological studies. We found 13 helminth species in the two samples of rooks, 10 species were recorded in each sample. In both samples, nematodes predominated by their infection prevalence and abundance. At the levels of helminth populations and infracommunities, the differences between the two samples were mostly influenced by the infection parameters of the nematodes *Acuaria anthuris*, *Baruscapillaria resectum*, *Diplotriaena tricuspis*, *Eucoleus frugilegi*, *Microtetrameres* spp., and the cestode *Spiniglans affinis*. In the helminth component community from Poltava, the evenness and diversity indices were comparatively higher than in the component community from Kyiv; *Microtetrameres* spp. was the predominat taxon. In the component community from Kyiv, *E. frugilegi* predominated by its infection prevalence and abundance.
Key words: rook, bird parasites, Ukraine, nematodes, trematodes, cestodes, helminth communities.

Introduction

The rook, *Corvus frugilegus* Linnaeus, 1758 is one of the most common bird species in the Palaearctic occurring from Scandinavia and Western Europe to the Pacific coast in Asia (BirdLife International, 2017). It nests collectively on the trees in woods, parks, and woodland belts, often near roads and in human settlements. The rookeries may comprise hundreds of nests used by the birds for many years. Rooks may stay near the rookeries throughout the year (Patterson et al., 1971) or migrate southwards in winter (Little et al., 2001). In Ukraine, wintering populations of rooks include both local individuals and migrants from other territories. According to bird ringing data, in 1948–1990, a larger part of the rook population in Ukraine spent the winter months in Central and Southern Europe, while only 18 % of birds, mostly adults, stayed in Ukraine (Poluda & Tsukanova, 2012). Published information on the present-day migration of rooks in Ukraine is absent.

Rooks are omnivorous and successfully colonise agricultural lands and human settlements (Benmazouz et al., 2021). At present, rooks are not unusual in towns and large cities also in winter time (Jadczyk & Drzeniecka-Osiadacz, 2013; Dobrev et al., 2014) so the abundance of wintering rook populations in cities may reach thousands of birds (Yanish & Lopariov, 2007). Due to their migrations, colonial life and frequent presence in the human settlements the rooks may participate in the distribution of zoonotic gastro-intestinal pathogens (Söderlund et al., 2019).

Helminths infecting rooks in Ukraine and neighbouring countries were intensively investigated mostly in the second half of the XX century (Kornyushin et al., 1975; Iskova, 1975; Smogorzhevskaya et al., 1978; Salamatin, 1999; Spasskii & Oshmarin, 1939; Zekhnov, 1947, 1949; Bernard, 1960; Pemberton, 1960; Chernobaj, 1969; Andreyko & Shumilo, 1970; Baruš et al., 1972; Rutkowska, 1973; Budkin, 1978). Those studies resulted in the identification of 68 helminth species infecting rooks, including 26 species of trematodes, eight species of cestodes, 29 species of nematodes, and five species of acanthocephalans. Most surveys of helminths parasitic in rooks were performed in the warm seasons, i. e. spring and summer. Only in a few studies, helminths of rooks were investigated throughout the year or in winter (e. g., Zekhnov, 1949; Williams, 1961; Baruš et al., 1972; Rutkowska, 1973; Halajian et al., 2011). Baruš et al. (1972) reported the differences in helminth fauna of wintering and nesting rooks in Slovakia and the Czech Republic. No such studies have been yet performed in Ukraine. Environmental conditions are known to influence the composition and structure of helminth communities in birds (Bush, 1990). Those conditions are different in cold and warm seasons within the distribution area and in wintering and nesting sites of rooks. Helminth communities of wintering rooks are of interest, as their composition demonstrates which helminth species are able to survive in winter, thus indicating the possible localities of infection during the warm season, and giving potential information on the life span of helminths.

In the populations of wintering rooks, some individuals often die in roosting sites at night (Jadczyk, 1994). Dead birds fall on the ground and become food for predators and scavengers including stray dogs and cats. These dead rooks may be effectively investigated by parasitological methods, for low temperature in winter preserves the corpses and the parasites for several days. In the present study, we investigated the populations of wintering rooks in the cities of Kyiv and Poltava and collected and identified helminths from dead bird individuals. The analysis of observations and identifications was focused on the characterisation of rook populations, helminth populations and communities, and the comparison of their parameters between the two localities. We hypothesised that there were significant differences in helminth communities of wintering rooks in Kyiv and Poltava; moreover, those differences might be related to differences in nesting localities of the rooks during warm seasons. The results of the analysis are presented herein.

Material and Methods

The observations of wintering populations of rooks were carried out from late October till early March in 2020–2021 and 2021–2022 in the cities of Poltava and Kyiv. Roosting sites of rooks and other corvids within the cities were identified; rooks were repeatedly counted in and around the sites. Dead rooks found on the ground at roosting sites were counted, collected, and transported to the laboratory for examination. In total, 46 rooks were examined including 24 from Poltava (3 collected in December of 2020; 11 collected in October–December of 2021; 10 collected in January–February of 2022) and 22 from Kyiv (15 collected in February of 2021; collected in February of 2022).

In the laboratory, dead rooks were autopsied and examined; helminths were gathered from the digestive tract and the body cavity of the birds. Collected helminth specimens were fixed and stored in 70 % ethanol and thereafter examined under the light microscope AmScope T690B and identified based on their morphology. Before the examination, nematodes were washed in distilled water and cleared in lactophenol (a mixture of equal volumes of water, glycerine, phenol, and lactic acid). Trematodes were stained with iron acetocarmine, dehydrated in an ascending alcohol series, cleared in clove oil and mounted in Canada balsam (according to Lutz et al., 2017). All collected cestode specimens were without proglottids and represented only by scolices; they were cleared and mounted in Berlese's medium.

For each helminth species in each host sample, the infection prevalence, intensity, and mean abundance were identified following the definitions of Bush et al. (1997). Confidence intervals (95 %) were calculated for the infection prevalence and mean abundance using the Quantitative Parasitology 3.0 software (Rósza et al., 2000). The same program was used for the comparison between the infection prevalence and mean abundance of each species found in the two samples using the unconditional exact test (UET) and the bootstrap-t test (BTT), correspondingly. A statistical comparison of the infection intensity in the two samples was not performed because of the small sample size of infected hosts.

In helminth infracommunities (all helminth specimens in one host individual), species richness (number of helminth species) and abundance (number of all helminth specimens) were calculated; mean, median and range were identified for each of the parameters in each sample. A comparison of median values of helminth species richness and abundance was performed using the Mann-Whitney U-test in the PAST 3.1 software (Hammer et al., 2001). Calculations of the similarity between the infracommunities based on the Bray-Curtis and Sørensen indices, nMDS, ANOSIM and SIMPER analyses were performed in the PRIMER 6 software (Clarke & Gorley, 2006). The same program was used for the calculation of the estimated species richness and diversity indices in the helminth component communities.

Results

Characterisation of wintering rook populations in Poltava and Kyiv

Both in Poltava and in Kyiv, rooks were predominating among the wintering corvids in the roosting sites. In Poltava, wintering rooks roosted on the outskirts of the city, in the remnants of the “Hryshkiv lis” woodland (49°35'01.4" N; 34°28′36.8" E). There, the overall number of roosting corvids was about 50,000; 5 % (about 2500) of them were jackdaws, *Corvus monedula* (Linnaeus, 1758). In 2020–2021, we found 35 dead rooks in the roosting site in winter; in 2021–2022, 37 dead rooks were found. On average, 69 rooks died monthly during the wintering season in Poltava. In Kyiv, corvids roosted on the territory of Kyiv Zoo (50°27′24.3" N; 30°27′58.6" E) in the winter of 2020–2021. In 2021–2022, the birds were intentionally scared away by the Zoo staff because they were supposed to spread pathogens among birds in the aviaries and roosted in Pushkin Park, 1 km away from the Zoo (50°27′26.4" N; 30°27′15.7" E). The total number of roosting corvids was about 90,000; 8 % (about 7,200) of them were jackdaws, and 0.6 % (about 500) were hooded crows, *Corvus cornix* Linnaeus, 1758. The total number of dead rooks was not calculated in the roosting sites in Kyiv.

In the flocks of wintering rooks in Poltava, up to 10 % were observed to be juvenile (subadult) individuals identified by the presence of nasal bristles. In Kyiv, juvenile birds were not observed in wintering rook population in 2020–2022. In the sample of dead birds collected in the roosting locality in Poltava, 10 specimens (42 %) were juveniles. Bursa Fabricii was observed only in four juvenile birds collected in October and November. Probably it is reduced in subsequent months. No juveniles were present in the sample of dead rooks from Kyiv. Male: female ratio was similar in the samples collected in Poltava and Kyiv and equalled 0.7:1. Sex of two juvenile specimens in the sample from Poltava was not identified due to their underdeveloped gonads. In the sample from Poltava, the weight of collected rooks (20 specimens weighed) was 442 ± 13.6 g; in the sample from Kyiv, the average weight of 9 weighed specimens was 487 ± 24.2 g.

In three dead rooks (adult males) from Poltava, sharp pieces of plastic were found in the digestive tract. In those birds, numerous haemorrhages in the intestine walls were observed and possibly contributed to the death. In other dead rooks, the causes of death remained uncertain. None of the birds examined post-mortem showed signs of emaciation; on the contrary, fat was observed under the skin and/or on the surface of internal organs and on the mesentery of the majority of rooks.

Helminth species, populations and communities in wintering rooks

Forty-one of 46 examined individuals of rooks (89 %) were found infected with helminths. In the sample from Poltava, only one rook was free from helminth infection, 23 individuals (96 %) were infected. In the sample from Kyiv, 82 % of rooks (18 of 22 individuals) were infected. In total, 427 specimens (289 in Poltava and 138 in Kyiv) of 13 species of helminths were collected from examined hosts (table 1). One nematode species, *Microtetrameres helix* Cram, 1927 was represented by two subspecies, *M. helix helix* and *M. helix asiaticus*. The subspecies were distinguished based on the length of the left spicule, distinctly longer in *M. helix asiaticus* (fig. 1). One unidentified nematode larva in the intestine of the host was assigned to the order Spirurida based on the morphology of the anterior extremity and the oesophagus. Larval nematodes and female specimens found without males in the proventriculus of separate host individuals were all assigned to *Microtetrameres* sp. (table 1). Presumably, those specimens belonged to one or both species of *Microtetrameres* found in each locality, however, they could not be identified based on their morphology. In the further characterisation of helminth populations and communities, all *Microtetrameres* spp. are treated as one taxon.

Table 1. Helminth species collected from wintering rooks, *Corvus frugilegus* in Poltava and Kyiv

Species	Site of infection	n, Poltava	n, Kyiv
Plathyhelminthes, Trematoda			
Prosthogonimus ovatus (Rudolphi, 1803)	bursa Fabricii	1 (0.35 %)	0
Lyperosomum longicauda (Rudolphi, 1809)	liver	0	1 (0.72 %)
Plathyhelminthes, Cestoda			
Spiniglans affinis (Krabbe, 1869)	intestine	18 (6.2 %)	31 (22.5 %)
Passerilepis crenata (Goeze, 1782)	intestine	1 (0.35 %)	0
Passerilepis stylosa (Rudolphi, 1809)	intestine	0	1 (0.72 %)
Nematoda, Enoplea			
Baruscapillaria resectum (Dujardin, 1845)	intestine	52 (18.0 %)	3 (2.2 %)
Eucoleus frugilegi (Czaplinski, 1962)	oesophagus	37 (12.8 %)	59 (42.8 %)
Nematoda, Chromadorea			
Microtetrameres helix asiaticus Oschmarin, 1956	proventriculus wall and mucosa	58 (20.1 %)	3 (2.2 %)
Microtetrameres helix helix Cram, 1927	proventriculus wall and mucosa	17 (5.9 %)	0
Microtetrameres contorta (Weidman, 1913)	proventriculus wall and mucosa	0	10 (7.2 %)
Microtetrameres sp.	proventriculus wall and mucosa	59 (20.4 %)	27 (19.6 %)
Diplotriaena tricuspis (Fedtschenko, 1874)	body cavity	11 (3.8 %)	1 (0.72 %)
Acuaria anthuris (Rudolphi, 1819)	gizzard, under koilin layer	30 (10.4 %)	1 (0.72 %)
Dispharynx nasuta (Rudolphi, 1819)	gizzard, under koilin layer	5 (1.7 %)	0
Spirurida gen. sp. (L3)	intestine	0	1 (0.72 %)

Note. For each species, the number of specimens (n) is shown as the total number followed by the percentage in the whole helminth sample in parentheses.

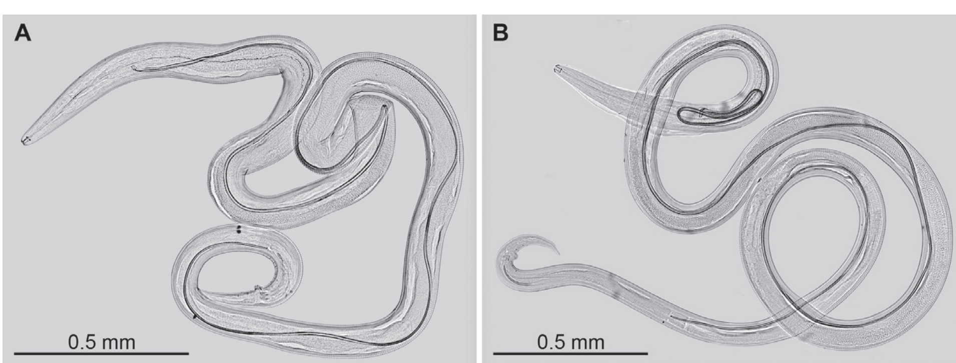

Fig. 1. Males of *Microtetrameres helix* Cram, 1927 subspecies: A — *Microtetrameres helix helix*; B — *Microtetrameres helix asiaticus*.

Trematodes were represented by two species, *Prosthogonimus ovatus* (Rudolphi, 1803) and *Lyperosomum longicauda* (Rudolphi, 1809). Each was found in one host in Poltava and Kyiv, correspondingly. Fifty-one specimens of cestodes belonged to three species (table 1) and infected 13 hosts (28 %) in total. Nematodes appeared to be the most abundant (374 specimens in total) and diverse group of helminths in examined samples of rooks. They were represented by eight species and were found in 40 hosts (87 %) in total.

The number of helminth taxa (species and subspecies) was the same in the two examined samples: 10 in Poltava and 10 in Kyiv (table 1). The trematode *P. ovatus*, the cestode *P. crenata* (Goeze, 1782), and the nematodes *M. helix helix* and *D. nasuta* (Rudolphi, 1819) were found only in the sample from Poltava, whereas the trematode *L. longicauda*, the cestode *P. stylosa* (Rudolphi, 1809), and the nematodes *M. contorta* (Weidman, 1913) and a larval Spirurida were found in the sample from Kyiv only. Six taxa were represented in both samples; accordingly, the similarity between the samples based on the Sørensen index was 60 %.

The faunistic difference between the samples was found to be lower if the occurrence of helminths in hosts (infection prevalence) was considered. Each of six out of eight species which were unique in either of the two samples infected one host specimen only. The infection prevalence of such species was as low as 4.2 % (CI 0.2–20.4 %) in the sample from Poltava or 4.5 % (CI 0.2–22.2 %) in the sample from Kyiv (table 2). Moreover, the minimum value of the confidence intervals of the mean abundance of those species was 0, which made their presence in the host population statistically uncertain. Therefore, the difference between the two samples based on the presence/absence of those species may be considered statistically insignificant.

The infection parameters of some helminth species added to the differences between the two samples. The infection prevalence of *B. resectum* (Dujardin, 1845), *A. anthuris* (Rudolphi, 1819), and *Microtetrameres* spp. was significantly higher in the sample from Poltava than in the sample from Kyiv (table 2). Infection prevalence of *B. resectum* and *A. anthuris* was still higher in the rooks from Poltava even when juvenile specimens were excluded from the calculations; in 14 adult rooks the infection prevalence was 21.4 % and 28.6 %, correspondingly. However, the differences were not statistically significant (UET $p > 0.05$). The infection prevalence of *Microtetrameres* spp. in adult rooks from Poltava was 78.6 %, similar to that in the entire sample (79.2 %), and significantly higher than that in the sample from Kyiv (UET $p < 0.01$). The infection prevalence of *D. tricuspis* was higher in the sample from Poltava (20.8 % versus 4.5 % in the sample from Kyiv); however, the UET did not confirm the statistical significance of the difference. The infection prevalence of *S. affinis* and *E. frugilegi* (Czaplinski, 1962) was somewhat higher in the sample from Kyiv (table 2). Statistical difference in mean abundance was significant for *Microtetrameres* spp. and *D. tricuspis*; both were more abundant in the sample from Poltava (table 2). The number of helminth specimens per host in the sample from Poltava was higher also in *B. resectum* and *A. anturis*, while *S. affinis* and *E. frugilegi* were more numerous in the studied rooks from Kyiv (table 2).

Helminth infracommunities (all helminths in each separate host individual) included 1–5 species (mean 2.8; median 3) and 2–36 specimens (mean 12.6; median 10) in the sample from Poltava. In the sample from Kyiv, the species richness in helminth infracommunities ranged from 1–3 (mean 1.8; median 2), and helminth abundance ranged from 1–25 (mean 7.7; median 5). The Mann-Whitney test confirmed a significant difference in the species richness ($p = 0.02$) between the two samples, while the difference in helminth abundance was not significant ($p = 0.054$). Species richness and abundance in helminth infracommunities from adult hosts in the sample from Poltava ($n = 13$) were similar to those

Table 2. Parameters of infection of helminth species collected from wintering rooks, *Corvus frugilegus* in Poltava and Kyiv

Species	P, %		*p* (UET)	MA		*p* (BTT)	I	
	Poltava	Kyiv		Poltava	Kyiv		Poltava	Kyiv
P. ovatus	4.2 (0.2–20.4)	0	–	0.04 (0–0.13)	0	–	1 [1] (1–1)	0
L. longicauda	0	4.5 (0.2–22.2)	–	0	0.05 (0–0.14)	–	0	1 [1] (1–1)
S. affinis	20.8 (8.6–41.5)	31.8 (15.2–54.6)	0.46	0.75 (0.21–1.54)	1.41 (0.55–3.23)	0.4	3.6 [4] (1–5)	4.4 [3] (1–13)
P. crenata	4.2 (0.2–20.4)	0	–	0.04 (0–0.13)	0	–	1 [1] (1–1)	0
P. stylosa	0	4.5 (0.2–22.2)	–	0	0.05 (0–0.14)	–	0	1 [1] (1–1)
B. resectum	45.8 (26.7–66.1)	4.5 (0.2–22.2)	< 0.01*	2.17 (1.0–4.75)	0.14 (0–0.41)	0.09	4.7 [2] (1–18)	3 [3] (3–3)
E. frugilegi	54.2 (33.9–73.3)	63.6 (41.8–81.3)	0.54	1.54 (0.83–2.71)	2.68 (1.55–4.18)	0.18	2.8 [2] (1–9)	4.2 [4] (1–11)
Microtetrameres spp.	79.2 (58.5–91.4)	27.3 (12.6–50.0)	< 0.01*	5.58 (3.54–10.08)	1.82 (0.5–5.5)	0.04*	7.1 [5] (1–34)	6.7 [3.5] (1–21)
D. tricuspis	20.8 (8.6–41.5)	4.5 (0.2–22.2)	0.12	0.46 (0.13–1.04)	0.05 (0–0.14)	0.04*	2.2 [2] (1–4)	1 [1] (1–1)
A. anthuris	37.5 (20.4–58.5)	4.5 (0.2–22.2)	0.01*	1.25 (0.58–2.58)	0.05 (0–0.14)	0.1	3.3 [2] (1–11)	1 [1] (1–1)
D. nasuta	4.2 (0.2–20.4)	0	–	0.21 (0–0.63)	0	–	5 [5] (5–5)	0
Spirurida gen. sp. (L3)	0	4.5 (0.2–22.2)	–	0	0.05 (0–0.14)		0	1 [1] (1–1)

*Significant differences.

Note. Infection prevalence (P) and mean abundance (MA) are shown with 95 % confidence intervals; infection intensity (I) is shown as mean followed by median in brackets and range in parentheses.

in the sample from Kyiv: range 1–5, mean 2.5, median 2; range 2–36, mean 10, median 6, correspondingly. Juvenile rooks in the sample from Poltava (n = 10) harboured the most abundant infracommunities of helminths. There, the helminth abundance ranged from 4–26 specimens (mean 15.5; median 16), while the helminth species richness was close to that in the whole sample: range 1–5, mean 3.3, median 3.

The resemblance between the infracommunities in the two samples combined ranged from 0–100 % based on the Bray-Curtis index of similarity. Visualisation of the resemblance using nMDS (fig. 2) did not demonstrate a distinct difference between the two samples of infracommunities. However, according to the ANOSIM routine, the difference between the two samples was slight but significant: ANOSIM R = 0.23, p = 0.002. The same analysis applied to the resemblance matrix based on the Sørensen index of similarity resulted in a slightly higher difference between the groups of infracommunities: ANOSIM R = 0.24, p = 0.001. According to the SIMPER analysis, the within-the-group average similarity between the helminth infracommunities was rather similar in the samples from Poltava and Kyiv: 38.4 % and 37.0 %, correspondingly. In the sample from Poltava, the following taxa contributed to the similarity: *Microtertrameres* spp. (58.2 %), *E. frugilegi* (18.6 %), *B. resectum* (13.2 %), and *A. anthuris* (6.0 %). In the sample from Kyiv, the following taxa contributed to the similarity: *E. frugilegi* (74.1 %), *S. affinis* (14.4 %), and *Microtetrameres* spp. (11.5 %). Four species made the largest contribution (cumulative contribution of 82 %) to the average dissimilarity between the two groups of infracommunities: *E. frugilegi* (29.6 %), *Microtetrameres* spp. (25.6 %), *S. affinis* (14.2 %), and *B. resectum* (12.6 %).

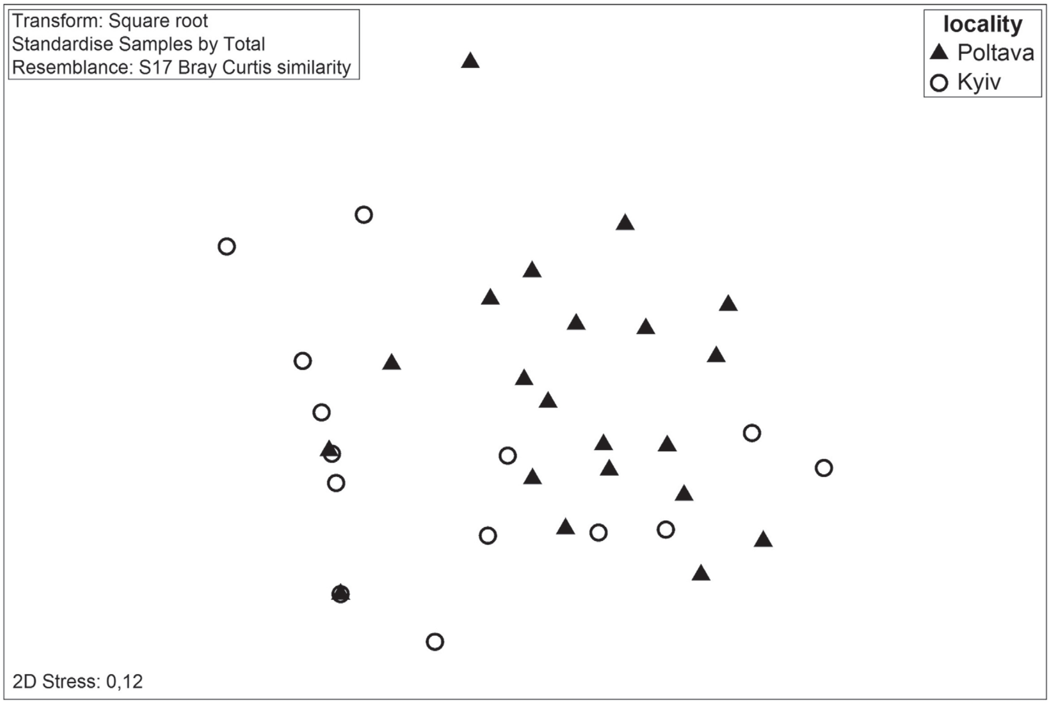

Fig. 2. Two-dimensional view of nMDS distribution of helminth infracommunities of *Corvus frugilegus* from two localities.

In both localities, the observed species richness in helminth component communities was equal. Nine taxa were recorded in each helminth community, considering *Microtetrameres* spp. as a single taxon. In the sample from Poltava, the estimated species richness in the helminth component community was 9 (Chao1, Chao2), 10 (bootstrap), or 12 (jackknife1). In the sample from Kyiv, the estimated species richness was slightly higher according to some estimators: 9 (Chao1, Chao2), 11 (bootstrap), or 15 (jackknife1). Also, Margalef's index of species richness was higher in the sample from Kyiv (1.6) than in the sample from Poltava (1.4).

In the helminth component community from Poltava, six taxa had an infection prevalence higher than 10 % (fig. 3); they constituted 66.7 % of all helminth specimens in the sample. *Microtetrameres* spp. predominated in the sample by occurrence (P = 79.2 %) and relative abundance (31.7 %). In the helminth community from Kyiv, only three taxa had an infection prevalence higher than 10 % (fig. 3); they constituted 73.0 % of all helminth specimens in the sample. *Eucoleus frugilegi* had the highest occurrence (P = 63.6 %) and relative abundance (33.1 %). Similar relative abundance of the predominat taxon in the two samples resulted in similar values of the Berger-Parker index of dominance: 0.32 in the sample from Poltava and 0.33 in the sample from Kyiv. However, the predominat taxon in the sample from Poltava, *Microtetrameres* spp. included more than one species; therefore, the actual dominance in the component community was lower.

Lower dominance and, consequently, higher evenness in the helminth component community from Poltava compared to the helminth community from Kyiv was confirmed by the Pielou's evenness index: 0.72 in the sample from Poltava versus 0.60 in the sample from Kyiv. The diversity indices in the sample from Poltava appeared to be also somewhat higher than those in the sample from Kyiv: 1.57 versus 1.32 (Shannon), and 0.72 versus 0.68 (Simpson).

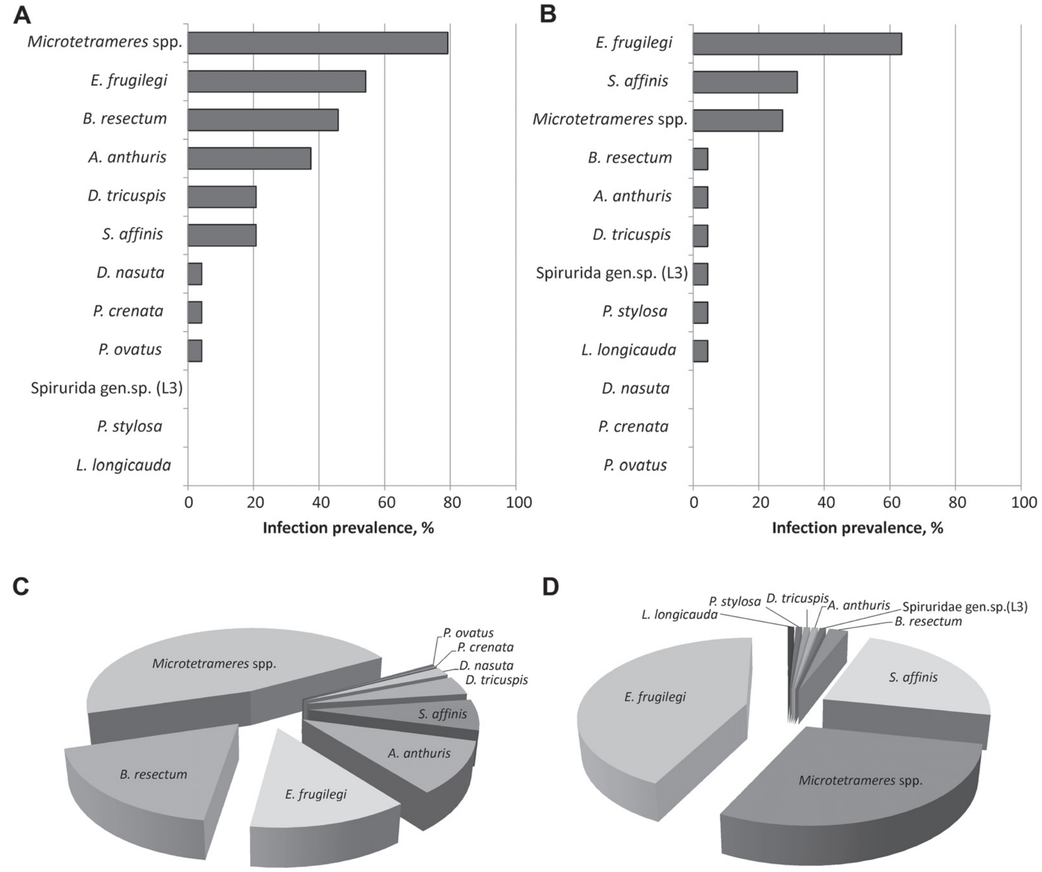

Fig. 3. Prevalence (A, B) and relative abundance (C, D) of helminths in the samples collected from wintering rooks, *Corvus frugilegus* in Poltava (A, C) and Kyiv (B, D).

Discussion

In recent decades, a decrease in the number of wintering corvids was observed in various urban localities in Ukraine. In Kyiv, 163.5–170 thousand wintering corvids were calculated in 2004–2005 (Yanish & Lopariov, 2007), while in 2018–2019 their number was about 140 thousand (Yanish & Dupak, 2020). In the present study, we observed just about 90 thousand corvids wintering in Kyiv. In Poltava, there were about 80 thousand wintering *Corvus* spp. in 2015–2016 and 2016–2017 (our unpublished observations), while in 2020–2021 we calculated only 50 thousand of these birds. Interestingly, the abundance of wintering jackdaws and hooded crows remained rather constant during this period in Poltava. A similar decrease in the number of wintering rooks was recorded in the town of Melitopol in southern Ukraine: from 30 thousand in 2001–2010 to 15 thousand in 2019 (Koshelev et al., 2020). The reduction in the number of wintering rooks may be either due to the decreasing migratory activities of birds or because of the reduction of the number of nesting populations of the rook observed in different parts of its range including Ukraine (Orłowski and Czapulak, 2007; Kitowski, 2011; Kopylova et al., 2011; Redinov & Petrovich, 2011; Poluda & Tsukanova, 2012; Andryushchenko et al., 2016).

The percentage of juvenile rooks in wintering population in Poltava observed in the present study (up to 10 %) was slightly higher than that previously observed in Wroclaw (Poland), 5–6 % (Jadczyk & Jakubiec, 1995). The larger percentage of juveniles in the examined sample of dead rooks from Poltava compared to that observed in the population (42 % vs. 10 %) is apparently due to the high mortality of juveniles. Busse (1969) reported 54–73 % mortality of rooks during the first year of life. The observed absence of juvenile wintering rooks in Kyiv and their presence in Poltava may be explained by the tendency of younger birds to cover longer distances during seasonal migrations, especially in northern regions of Ukraine (Poluda & Tsukanova, 2012).

Previous studies of the helminth of the rook in Ukraine were performed mostly in the warm seasons; 18 helminth species were recorded: seven trematode species, two cestode species, seven nematode species, and two acanthocephalan species (Issaitschikoff, 1927; Cherniak, 1929; Ivanizky, 1940; Vasylevska, 1956; Kornyushin et al., 1975; Iskova, 1975; Smogorzhevskaya et al., 1978; Smogorzhevskaya, 1990). In the present study, we found fewer helminth species: only two species of trematodes out of seven recorded previously, and no acanthocephalans. On the other hand, we first report *E. frugilegi*, *D. tricuspis*, *M. contorta*, and *M. helix asiaticus* in Ukraine. Cestodes *P. crenata* and *P. stylosa*, and the nematode *M. helix helix* were previously recorded in other birds in Ukraine; we found them in the rook for the first time. Therefore, the present study expands the number of helminths known in rooks from Ukraine to 24 species. Only two of them, namely, the nematode *E. frugilegi* and the cestode *S. affinis* are specific parasites of the rook (Barus et al., 1972; Salamatin, 1999). All helminth species found in the present study, except the trematode *P. ovatus*, are supposed to be able to survive winter months and resume their transmission in spring. The trematode *P. ovatus* was found in the bursa Fabricii of one bird in November. This species cannot remain in rooks till the warm season, since the bursa Fabricii disappears in young birds by the end of the winter. Interestingly, all specimens of cestodes from wintering rooks were observed to lack strobilae; their growth and reproduction apparently ceased in winter.

A total of 47 helminth species were reported to parasitise rooks in other European countries. Thirteen of them were found in Moldova (Andreyko & Shumilo, 1970), 22 in the Czech Republic and Slovakia (Macko, 1956; Baruš et al., 1972), 23 in Poland (Rutkowska, 1973), eight in Bulgaria and nine in Romania (Stoican et al., 1972; Chiriac & Udrescu, 1973), and 10 in the United Kingdom (Pemberton, 1960; Williams, 1961). *Spiniglans affinis*, *B. resectum*, and *A. anthuris* were among the most common parasites of rooks reported in previous studies. However, *S. affinis* was previously often identified as *Spiniglans* (= *Choanotaenia*) *constricta* (see Salamatin, 1999), and *B. resectum* was often identified as *Capillaria* (= *Trichosoma*) *corvorum* (see Moravec et al., 1994).

Williams (1961) recorded three helminth species in wintering rooks in the United Kingdom. Two of them, *L. longicauda* and *P. crenata* were present in our material. Species of cestodes and trematodes found in wintering rooks in the Czech Republic and Slovakia (Baruš et al., 1972) were the same as recorded in the present study: *L. longicauda*, *P. ovatus*, *S. affinis*, and *P. crenata*. Four of seven nematode species reported by Baruš et al. (1972) were found in wintering rooks from Poltava: *B. resectum*, *A. anthuris*, *E. frugilegi*, and *D. nasuta*; all except *D. nasuta* were also present in the sample from Kyiv. The occurrence of separate helminth species was similar in wintering rooks from the Czech Republic and Ukraine. In both countries, *L. longicauda*, *P. ovatus*, *P. crenata*, and *D. nasuta* were rare, while *S. affinis*, *A. anthuris*, *B. resectum*, and *E. frugilegi* were common.

We found nematodes predominating in the total sample of helminths collected from wintering rooks. Eight of the 13 species found were nematodes, they were found in 87 % of hosts and comprised 88 % of all helminth specimens in the sample. A similar predomination of nematodes was reported in helminthological studies of rooks from different localities in different seasons, e. g. in the Kherson region of Ukraine (Kornyushin et al., 1975) and in Moldova (Shumilo, 1961) in spring and summer, in Poland (Rutkowska, 1973) throughout the year, in Czech Republic and Slovakia (Baruš et al., 1972) both in winter and in the warm season. Interestingly, Baruš et al. (1972) recorded exactly the same numbers of species of nematodes and other helminths in wintering rooks as we did in the present study: eight nematode species and five species of other helminths. Apparently, the predomination of nematodes in the helminth samples collected from rooks is related rather to the diet of the birds than to the season or locality.

We found the differences between the two studied helminth samples in infection parameters of separate species and in some parameters of helminth communities. In the sample from Poltava, both the occurrence in the host (infection prevalence) and abundance were higher in the nematodes *A. anthuris*, *B. resectum*, *D. tricuspis*, and *Microtetrameres* spp., while the infection parameters of the nematode *E. frugilegi* and the cestode *S. affinis* were higher in the sample from Kyiv. At the infracommunity level, quantitative differences between the samples were strongly influenced by the presence of juvenile rooks in the sample from Poltava and their absence in the sample from Kyiv. Juvenile rooks from Poltava harboured more helminth specimens than adult birds from both samples. On the other hand, age differences between the samples of hosts did not contribute significantly to the differences in the infracommunity composition. The helminth species richness was similar in the samples from juvenile and adult hosts, and the parameters of infection in separate species from Poltava did not differ in juvenile and adult rooks. Therefore, the differences between helminth infracommunities from Poltava and Kyiv revealed by ANOSIM and SIMPER analyses are significant, in our opinion.

A comparison of the infection prevalence and relative abundance of separate helminth species in each sample and the diversity indices evidenced the higher evenness in the component community of helminths in the sample from Poltava compared to that from Kyiv. Presumably, the component community of helminths in the rooks wintering in Poltava originated from a less transformed and more “healthy” ecosystem. Almost all helminth species found in rooks in the present study are heteroxenous parasites; only the nematode *B. resectum* is monoxenous (Okulewicz & Frońcka, 1998). Transmission of heteroxenous helminths using invertebrates as intermediate hosts is hardly possible in winter. More likely, the rooks are infected in the warm season, in nesting sites and during migration. Based on the information about helminth infection, one may assume that the summer diet of the rooks wintering in Poltava includes more orthopterans, the intermediate hosts of *A. anthuris* and *Microtetrameres* spp. (Cram, 1934; Rietschel, 1973; Anderson, 2000) and fewer earthworms, the intermediate hosts of *E. frugilegi* (Rietschel, 1973). Intermediate hosts are unknown for the cestode *S. affinis* that was more abundant in the sample from Kyiv. However, the related species *S. constricta* (Molin, 1858) is known to use darkling beetles (Tenebrionidae) in its transmission (Gabrion, 1975). Presumably, earthworms and darkling beetles are a substantial part of the summer diet of rooks wintering in Kyiv. We assume that future investigation of parasites of rooks in the nesting sites, as well as along migration routes may verify the reasons for the differences in helminth communities of rooks observed in the present study.

References

Anderson, R. C. 2000. *Nematode Parasites of Vertebrates: Their Development and Transmission*. CABI Publishing, Wallingford, UK, 1–672. DOI: 10.1079/9780851994215.0000.

Andreyko, O. F. & Shumilo, R. P. 1970. *Parasites of corvids, rodents and lagomorphs of Moldova*. Kartya Moldovenyaske, Kishinev, Moldova, 1–58 [In Russian].

Andryushchenko, Yu. A., Diadicheva, E. A., Popenko, V. M., Chernichko, R. N. & Busel, V. A. 2016. Spring-summer population of birds of Azov Upland. *Branta: Transactions of the Azov-Black Sea Ornithological Station*, **19**, 7–30 [In Russian].

Baruš, V., Ryšavý, B., Groschaft, J. & Folk, Č. 1972. *The helminth fauna of Corvus frugilegus L. (Aves, Passeriformes) in Czechoslovakia and its ecological analysis*. Praha, Academia. Acta scientiarum naturalium Academiae scientiarum Bohemoslovacae Brno. Tomus VI, Nova series, Fasc. 3.

Benmazouz, I., Jokimäki, J., Lengyel, S., Juhász, L., Kaisanlahti-Jokimäki, M.-L., Kardos, G., Paládi, P. & Kövér, L. 2021. Corvids in urban environments: a systematic global literature review. *Animals*, **11**, 3226. DOI: 10.3390/ani11113226

Bernard, J. 1960. Quelques helminthes parasites du freux, *Corvus frugilegus* L., en Belgique. *Bulletin de l'Institut Agronomique et des Stations de Recherches de Gembloux*, **28** (4), 345–357 [In French].

BirdLife International. 2017. *Corvus frugilegus*. The IUCN Red List of Threatened Species 2017: e.T22705983A118782308. DOI: 10.2305/IUCN.UK.2017-3.RLTS.T22705983A118782308.en

Budkin, R. D. 1978. Helminths of the common rook *Corvus frugilegus* of the fauna of the Soviet Union. *In*: *Fauna, Taxonomy, Biology and Ecology of Helminths and Their Intermediate Hosts*. Gorky State Pedagogical Institute Publish: Gorky, Russia, 14–20 [In Russian].z

Bush, A. O. 1990. Helminth communities in avian hosts: determinants of a pattern. *In*: Esch, E. G., Bush, A. O. & Aho, J. M., eds. *Parasite communities: patterns and processes*. Chapman & Hall, London, 197–232.

Bush, A. O., Lafferty, K. D., Lotz, J. M. & Shostak, A. W. 1997. Parasitology meets ecology on its own terms: Margolis et al. revisited. *Journal of Parasitology*, **83** (4), 575–583. DOI: 10.2307/3284227.

Busse, P. 1969. Results of ringing of European Corvidae. *Acta Ornitologica*, **11** (8), 263–328.

Cherniak, V. Z. 1929. Sketches of the helminth fauna of the Plisky district of the Nizhyn region. *Veterinarnoye dyelo*, **11** (72), 31–35 [In Russian].

Chernobaj, V. F. 1969. Parasites of corvid birds from the Lower Volga River area. *In: Sbornik kaphedry zoologii Volgogradskogo pedagogicheskogo instituta*. Volgograd, 1969, 166–197. (Parasiticheskiye zjivotnye Volgogradskoy oblasty) [In Russian].

Chiriac, E. & Udrescu, M. 1973. *Fauna republicii socialiste România. Plathelminthes,* **2** (4). Trematoda. Editura Academiei Repulicii Socialiste România, Bucuresti, Romania, 1–485 [In Romanian].

Clarke, K. R. & Gorley, R. N. 2006. *PRIMER v6: User Manual/Tutorial (Plymouth Routines in Multivariate Ecological Research)*. PRIMER-E, Plymouth.

Cram, E. B. 1934. Orthopterans and pigeons as secondaryand primary hosts, respectively for the crow stomach-worm *Microtetrameres helix* (Nematoda: Spiruridae). *Proceedings of Helminthological Society of Washington*, **1** (2), 1–50.

Dobrev, D., Dobrev, V. & Gerdzhikov G. 2014. Data on the wintering of the rook, *Corvus frugilegus* Linnaeus, 1758 (Aves: Corvidae) in Plovdiv, Bulgaria. *Ecologia Balkanica*, **6** (2), 105–107.

Gabrion, C. 1975. Étude expérimentale du développement larvaire *d'Anomotaenia constricta* (Molin, 1858) Cohn, 1900 ehez un Coléoptère Pimelia sulcata Geoffr. *Zeitschrift für Parasitenkunde*, **47** (4), 249–262 [In French]. doi: 10.1007/bf00389884

Halajian, A., Eslami, A., Mobedi, I., Amin, O., Mariaux, J., Mansoori, J. & Tavakol, S. 2011. Gastrointestinal Helminths of Magpies (*Pica pica*), Rooks (*Corvus frugilegus*) and Carrion Crows (*Corvus corone*) in Mazandaran Province, North of Iran. *Iranian Journal of Parasitology*, **6** (2), 38–44.

Hammer, Ø., Harper, D. A. T. & Ryan, P. D. 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica*, 4, 9 p. http://palaeo-electronica.org/2001_1/past/issue1_01.htm

Iskova, N. I. 1975. Materials for the study of trematodes of corvids in Ukraine. *In: Problemy parazitologii. Materialy VIII nauchnoy konferencii parazitologov USSR, Part 1*, Naukova dumka, Kyiv, 201–202 [In Russian].

Issaitschikoff, I. M. 1927. 8th Russian helminthological expedition to the Crimea. *In: Deyatelnost' 28 helmintologicheskoy expedicii v SSSR.* Moskow, 110–125 [In Russian].

Ivanizky, S.V. 1940. Material of helminthofauna of Vertebrates of Ukraine. (Fauna of Cestodes, Nematodes and Acanthocephala). *Sbornik trudov Har'kovskogo veterinarnogo instituta*, **19** (1), 129–155 [In Russian].

Jadczyk, P. 1994. Winter roosting of rooks *Corvus frugilegus* in Wroclaw. *Acta Ornithologica*, **29** (1), 39–47.

Jadczyk, P. & Drzeniecka-Osiadac, A. 2013. Feeding strategy of wintering rooks *Corvus frugilegus* L. in urban habitats. *Polish Journal of Ecology*, **61** (3), 587–596.

Jadczyk, P. & Jakubiec, Z. 1995. Zimowe zgrupowania gawronów *Corvus frugilegus* w Europie. *Przegląd Zoologiczny*, **39** (3–4), 297–312 [In Polish].

Kitowski, I. 2011. The breeding population of the rook *Corvus frugilegus* in Chełm (eastern Poland). A comparison of the surveys of 1991 and 2011. *Teka Komisji Ochrony i Kształtowania Środowiska Przyrodniczego*, **8** (1), 56–62.

Kopylova, T. V., Koshelev, A. I. & Koshelev, V. A. 2011. Number dynamics of breeding Corvidae on control plots during 2000-2010 in the south of Zaporizhzhia region (North Azov area). *Branta: Transactions of the Azov-Black Sea Ornithological Station*, **14**, 94–105 [In Russian].

Kornyushin, V. V., Smogorzhevskaya, L. A., Iskova, N. I., Voinstvensky, M. A. & Boyko, E. M. 1975. Materials on the helminth fauna of the rook nesting in the area of the Black Sea Reserve. *Materialy VIII nauchnoy konferencii parazitologov USSR, Part 1*, Naukova dumka, Kyiv, 251–254 [In Russian].

Koshelev, A., Koshelev, V., Kopylova, T. & Borisov, V. 2020. Monitoring of Crowbird in Melitopol: nest and winter aspects. *Ecological Sciences,* **2** (29), 2, 31–39 [In Ukrainian].

Little, D. I. & Little, A. E., Levell, D. 2001. A review of rook status, with new South Pembrokeshire data, 1986–1996. *Field Studies*, **10** (1), 37–56.

Lutz, H. L., Tkach, V. V. & Weckstein, J. D. 2017. Methods for specimen-based studies of avian symbionts. *In*: Webster, M. S., ed. *The Extended Specimen: Emerging Frontiers in Collections-based Ornithological Research*. Studies in Avian Biology (no. 50), CRC Press, Boca Raton, FL, 157–183.

Macko, J. K. 1956. K faune cestódov havranovitých východného Slovenska. *Biologia*, **11** (8), 457–465 [In Slovak].

Moravec, F., Scholz, T. & Našincová, V. 1994. The systematic status of *Trichosoma carbonis* Rudolphi, 1819 and a description of *Baruscapillaria rudolphii* n. sp. (Nematoda: Capillariidae), an intestinal parasite of cormorants. Systematic Parasitology, **28** (2), 153–158.

Okulewicz, A. & Frońska, A. 1998. *Capillaria resecta* (Duj., 1845) (Nematoda) — specific parasite of *Corvus monedula* (Corvidae). *Wiadomości Parazytologiczne*, **44**, *PTP 18th Congress, Abstracts*, 480.

Orłowski, G. & Czapulak, A. 2007. Different Extinction Risks of the Breeding Colonies of Rooks *Corvus frugilegus* in Rural and Urban Areas of SW Poland. *Acta Ornithologica*, **42** (2), 145–155. http://dx.doi.org/10.3161/068.042.0209

Patterson, I. J., Dunnet, G. M. & Fordham, R.A. 1971. Ecological studies of the rook, *Corvus frugilegus* L., in northeast Scotland. Dispersion. *Journal of Applied Ecology*, **8** (3), 815–833. DOI: 10.2307/2402685

Pemberton, R. T. 1960. Helminth parasites of some British birds. *Annales and Magazine of Naturale History*, **13**, 3 (32), 455–463. https://doi.org/10.1080/00222936008651044

Poluda, A. M. & Tsukanova, S. V. 2012. Characteristics of space-time distribution of the rook (*Corvus frugilesus*) related to the territory of Ukraine. *Branta: Transactions of the Azov-Black Sea Ornithological Station,* **15**, 103–120 [In Russian].

Redinov, K. O. & Petrovych, Z. O. 2011. Rook *Corvus frugilegus* in Mykolaiv region. *Zbirnyk prats ZUOT "Troglodytes"*, **2**, 19–30 [In Ukrainian].

Rietschel, G. 1973. Untersuchungen zur Entwicklung einiger in Krähen (Corvidae) vorkommender Nematoden. *Zeitschrift für Parasitenkunde*, **42** (4), 243–250 [In German]. DOI: 10.1007/bf00328886

Rósza, L, Reiczigel, J., Majoros, G. 2000. Quantifying parasites in samples of hosts. *Journal of Parasitology*, **86** (2), 228–232. DOI: 10.1645/0022-3395(2000)086[0228:QPISOH]2.0.CO;2

Rutkowska, M. A. 1973. A study of the fauna of Corvidae in Poland. *Acta Parasitologica Polonica*, **21** (11), 183–237.

Salamatin, R. V. 1999. The cestodes of the genus *Spiniglans* (Dilepididae) from the corvid birds (Corvidae) from Ukraine. *Vestnik Zoologii*, **33** (1–2), 75–81 [In Ukrainian].

Shumilo, R. P. 1961. Roundworms of Corvidae from Cental Moldavia. *Izvestiya Moldavskogo filiala AN SSSR*, **3** (81), 13–32 [In Russian].

Smogorzhevskaya, L. A. 1990. *Fauna of Ukraine. Volume 32. Nematodes. Issue 3. Acuarioidea*. Naukova dumka, Kyiv, 1–188 [In Russian].

Smogorzhevskaya, L. A., Iskova, N. I., Kornyushin, V. V. & Shalimova, F. N. 1978. The materials to helminthofauna of birds from the Black Sea Biosphere Reserve. *In: 50 years of Black Sea Biosphere Reserve.* Naukova dumka, Kyiv, 141–152 [In Russian].

Söderlund, R., Skarin, H., Börjesson, S., Sannö, A., Jernberg, T., Aspán, A., Ågren, E. A. & Hanssona, I. 2019. Prevalence and genomic characteristics of zoonotic gastro-intestinal pathogens and ESBL/pAmpC producing *Enterobacteriaceae* among Swedish corvid birds. *Infection Ecology & Epidemiology*, **9** (1), 1701399. DOI: 10.1080/20008686.2019.1701399.

Spasskii, A. A. & Oshmarin, P. G. 1939. Parasitic worms of Corvidae. *Trudy Gor'kovskogo gosudarstvennogo pedagogicheskogo instituta*, **4**, 45–70 [In Russian].

Stoican, E., Mastacan, D., Cuciu, M., Micu, N., Wagner, G. & Eustafievici, V. 1972. Helminthosen bei einigen Vogelarten im zoologischen Garten Bukarest und unsere Erfahrungen bei der Beliandlung. *Erkankungen der Zootiere Verhandlungsbericht des XIV Internationalen Symposiums über die Erkarankungen der Zootiere*, 14–18, Juni, Wrocław, 1972. Akademie Verlag, Berlin, 105–108 [In German].

Vasylevska, E. V. 1956. To the study of helminthofauna of hunting and industrial birds of the Chernihiv Region. *Research Notes (Nizhyn Mykola Gogol State Pedagogical Institute)*, **7** 88–93 [In Ukrainian].

Williams, I. C. 1961. A list of parasitic worms, including twenty-five new records, from British birds. *Annals and Magazine of Natural History*, **13**, 4 (44), 467–480. DOI: 10.1080/00222936108651165

Yanish, Ye. Yu. & Dupak, V. S. 2020. The dynamics of the abundance of Corvids in the central regions of the forest-stepp belt of Ukraine. *In: Ornithological research in the countries of Northern Eurasia: theses XV International. ornithologist. conf. of Northern Eurasia, dedicated to the memory of Acad. M. A. Menzbir*. Belaruskaya navuka, Minsk, 1920, 519–520 [In Russian].

Yanish, Ye. Yu. & Lopariov, S. A. 2007. Wintering of the Corvid Birds (Corvidae) on the territory of Kyiv. *Vestnik Zoologii*, **41** (2), 143–152 [In Ukrainian].

Zekhnov, M. I. 1947. The age-related changes of growth in the rook (*Corvus frugilegus* L.) infested with endoparasites. *Zoologicheskiy zhurnal*, **26** (2), 133–142 [In Russian].

Zekhnov, M. I. 1949. The seasonal and yearly changes of the helminth fauna of the rook (*Corvus frugilegus* L.). *Zoologicheskiy zhurnal*, **28** (3), c. 231–242 [In Russian].

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