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HELMINTH COMMUNITY OF WINTERING GREATER WHITE-FRONTED GEESE, *ANSER ALBIFRONS* (ANSERIFORMES, ANATIDAE), IN THE SOUTH OF UKRAINE

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Helminth Community of Wintering Greater White-Fronted Geese, *Anser albifrons* (Anseriformes, Anatidae), in the South of Ukraine. Greben, O., Dupak, V. & Kuzmina, T. — Twenty-one specimens of greater white-fronted geese, *Anser albifrons,* (Scopoli, 1769), from the Odesa Region in southern Ukraine were examined using parasitological methods. All of the geese were infected with helminths, with nematodes present in 100% of cases. A total of 15 helminth species were identified, comprising six species of nematode, five species of trematode and four species of cestode. The greater white-fronted goose was recorded as a new host for four species: *Echinostoma nordiana*, *Echinostoma sarcinum*, *Microsomacanthus paramicrosoma* and *Heterakis gallinarum*. Four monoxenous nematode species, *Trichostrongylus tenuis*, *Amidostomum anseris*, *Amidostomum spatulatum*, and *Epomidostomum orispinum*, predominated in the helminth community according to their prevalence and abundance. Two congeneric species, *A. spatulatum* and *A. anseris*, demonstrated a negative interspecific association. Three species, *E. orispinum*, *A. spatulatum*, and *T. tenuis*, were found with prevalence higher than 80%. In contrast, trematode and cestode infections were low, likely due to the absence of invertebrates, their intermediate hosts in the greater white-fronted geese's diet during the winter season.

Key words: greater white-fronted geese, helminths of birds, nematodes, trematodes, cestodes, helminth community, Ukraine.

Introduction

Migratory birds contribute to the spread of helminths, facilitating their circulation on both breeding and wintering grounds as well as at stopover sites during migration (Okulewicz, 2014; Rząd et al., 2023). Long-distance migratory species are of particular interest because they can introduce parasites not native to the local fauna, lose some helminth species, acquire new infections at stopover sites, and exchange parasites within mixed flocks on their wintering grounds (Canaris et al., 1981; Wallace and Pence, 1986; Gladden and Canaris, 2009; Vestbo et al., 2019). Therefore, examining the parasite fauna of migratory birds on their wintering grounds allows researchers to indirectly estimate parasite lifespans in their definitive hosts, assessing their ability to circulate under different environmental conditions.

The greater white-fronted goose *Anser albifrons* (Scopoli, 1769) is an abundant and important game-bird species throughout most of the Holarctic (Banks, 2011). It is a long-distance migrant that breeds in the Arctic tundra of Eurasia and North America, and winters in southern regions, including Europe, Asia, and North Africa. One of the migratory routes of this species passes through the territory of Ukraine, where geese may form wintering populations in the southern part of the country (Iliev et al., 2023; Poluda, 2009, 2018). Like most other geese, the greater white-fronted goose has a predominantly plant-based diet of weeds, seeds, leaves, cultivated and wild grasses (Ely & Raveling, 2011). Therefore, its intestinal helminth community is dominated by monoxenous helminth species with direct life cycles that do not require intermediate hosts for transmission. Mass winter gatherings of greater white-fronted geese in relatively limited areas in southern Ukraine may increase the concentration of helminths in the environment. Furthermore, close contacts between migratory geese and local waterfowl may create new pathways for helminth infection. In particular, these dense wintering flocks facilitate contact with faecal matter, potentially increasing the concentration of directly transmitted nematodes.

According to published data, 64 species of helminths are known to parasitise *A. albifrons* in the Holarctic: 25 species of trematodes, 19 species of cestodes, and 20 species of nematodes (Lapage, 1961; Ryzhikov, 1962–1963; Tolkacheva, 1964, 1971; McDonald, 1969; Kamburov & Vasilev, 1972; Bayanov, 1985; Feizulaev and Magomedov, 1985). One unidentified species of acanthocephans, *Polymorphus* sp., has been recorded in the greater white-sided goose in the USA (Fedynich et al., 2005). Among the helminths of *A. albifrons* are species that parasitise various waterfowl, primarily ducks. Some helminths of the greater white-sided goose, such as trematodes *Notocotylus chinois* Baylis, 1928, and *Psilostomum borealis* Ryzhikov, 1963, cestodes *Anserilepis barrowensis* (Schiller, 1952), and nematodes *Amidostomum spatulatum* Baylis, 1932, *Epomidostomum orispinum* (Molin, 1861), and *Tertrameres zakharovi* Petrov, 1926, are known only in geese (Bayanov, 1985; Ryzhikov, 1963; Spasskaya, 1966; McDonald, 1969).

Several studies on helminths of *A. albifrons* were carried out in its breeding grounds in the northern regions of the Holarctic (Schiller, 1952; Ryzhikov, 1962–1963; Tolkacheva, 1971; Regel, 2001; Amundson et al., 2016), while parasites of this host in wintering sites in southern regions of Europe and North America were studied sporadically (Kamburov & Vasilev, 1972; Purvis et al., 1997; Fedynich et al., 2005). Since the presence of the greater white-fronted goose in Ukraine is temporary, occurring along migratory routes in autumn and spring, as well as during its wintering on limited areas of the Black Sea coast, its parasites have not been sufficiently studied. Only two helminth species — the trematode *Notocotylus attenuatus* (Rudolphi, 1809) and the nematode *Amidostomum anseris* (Zeder, 1800) — have been occasionally reported in *A. albifrons* from southern Ukraine five decades ago (Smogorzhevskaya, 1976). Since then, no information on the parasites of the greater white-fronted geese in Ukraine has been published.

In this study, we had a unique opportunity to collect and examine a sample of *A. albifrons* that died in the Odesa Region, South of Ukraine, from rodenticide poisoning. Since the birds were examined at the end of November and December, the population can be considered as wintering, not migratory (Poluda, 2018). Our work aimed to study the helminths of greater white-fronted geese wintering in the South of Ukraine and analyse the helminth community structure at the infracommunity and component community levels. Additionally, the analysis of interspecific associations, in particular helminth species, was conducted.

Material and Methods

Dead greater white-fronted geese were found on a farmland near the "Tuzlovski Lagoons" National Park (46°10' N 30°10' E) in Bilhorod-Dnistrovskyi district in the Odesa Region, the South of Ukraine, in November–December 2021. The geese died due to poisoning by rodenticides on agricultural land. The birds were collected and transported to the laboratory of the I. I. Schmalhausen Institute of Zoology NAS of Ukraine in Kyiv for pathological and parasitological examination. In total, 21 individuals (10 females and 11 males) of *A. albifrons* were examined; all the geese, except one, were juveniles.

Helminths were collected manually from the digestive tract, parenchymal organs, and the body cavity. They were fixed in 70% ethanol and stored in a refrigerator at +4 °C. Later, all helminth specimens were examined under the light microscope AmScope T690B and identified to the species level based on their morphology. Before the examination, trematodes and cestodes were stained with iron acetocarmine, dehydrated in an ascending alcohol series, cleared in clove oil, and mounted in Canada balsam following Lutz et al. (2017). Some cestode fragments and scolices were cleared in Foura–Berlese's medium (Swan, 1936); these slides were used to study the armament of the rostellum and copulative apparatus. Before morphological identification, nematodes were washed in distilled water and then cleared in a lactophenol solution (a mixture of equal volumes of water, glycerol, phenol, and lactic acid).

The morphological identification of helminths was carried out according to previous publications (Iskova, 1985; Sudarikov, 1984; Spasskaya, 1966; Czapliński, 1956, 1962 a, b; Skrjabin et al., 1954, 1961).

For each helminth species, the infection prevalence (P), intensity (I), total abundance (A), and mean abundance (MA) were calculated as defined by Bush et al. (1997). Relative abundance of each species was calculated as the percentage of its specimens in the whole sample of helminths. The dispersion index (DI) was calculated as the variance-to-mean ratio, following the recommendations of Rósza et al. (2000). Confidence intervals for the infection prevalence and mean abundance were calculated using the Quantitative Parasitology 3.0 software (Rósza et al., 2000). The diversity indices and the estimated species richness (based on Chao1, jackknife, and bootstrap methods) in the helminth component community were calculated in PRIMER 6 software (Clarke and Gorley, 2006).

The raw dataset is available at this link: https://www.researchgate.net/publication/394565271_Helminths_of_Anser_albifrons_Ukraine_2021

Results

Helminth Species

All examined individuals of *A. albifrons* were found infected with helminths. In total, 2,533 specimens of 15 species were collected from examined geese, including six nematode species, five trematode species, and four cestode species (Table 1). Nematodes were the most prevalent group of helminths found in 100% of the birds; 61.9% of geese were infected by cestodes and 47.6% by trematodes. The prevalence of cestode and nematode infections was similar between male and female hosts, 54.5% and 50.0% for cestodes, respectively, and 100% for nematodes. Trematode prevalence was higher in males than in females (63.6% *vs* 20.0%).

The short descriptive information for each helminth species found, including the site of infection, is presented below.

Table 1. **Infection parameters of helminth species from *Anser albifrons*. For infection prevalence (P) and mean abundance (MA), 95% confidence intervals are shown in parentheses; infection intensity (I) is presented as mean followed by a range in parentheses, and median; DI — dispersion index (variance to mean ratio)**

Species	P, %	MA	I	DI
	Plathyhelminthes,Trematoda			
Echinostoma nordiana	4.8 (0.2—23.3)	0.05 (0–0.14)	1*	1
Echinostoma revolutum group	23.8 (9.9–45.5)	0.38 (0.1–0.95)	1.6 (1–4); 1	2.2
Echinostoma sarcinum	4.8 (0.2–23.3)	0.05 (0–0.14)	1*	1
Apatemon gracilis	9.5 (1.7–30.5)	0.24 (0–0.86)	2.5 (1–4); 2.5	3.3
Cotylurus cornutus	4.8 (0.2–23.3)	0.05 (0–0.14)	1*	1
	Plathyhelminthes, Cestoda			
Microsomacanthus compressa	4.8 (0.2–23.3)	0.05 (0–0.14)	1*	1
Microsomacanthus paramicrosoma	4.8 (0.2–23.3)	0.05 (0–0.14)	1*	1
Retinometra longicirrosa	19.0 (6.8–40.3)	0.52 (0.1–1.38)	2.7 (1–5); 2.5	3.5
Tschertkovilepis krabbei	14.3 (4.0–35.4)	0.33 (0.05–1.0)	2.3 (1–4); 2	2,8
	Nematoda, Chromadorea			
Amidostomum anseris	42.9 (23.3–64.6)	5.0 (0.52–21.9)	11.7 (1–91); 1	77.9
Amidostomum spatulatum	81.0 (59.7–93.2)	10.7 (7.0–16.2)	13.2 (1–42); 11	10.8
Epomidostomum orispinum	95.2 (76.7–99.7)	32.1 (21.9–49.0)	33.7 (2–139); 25	30.9
Heterakis gallinarum	4.8 (0.2–23.3)	0.05 (0–0.14)	1*	1
Trichostrongylus tenuis	90.5 (69.5–98.3)	70.4 (43.2–109.6)	77.8 (1–272); 49	89.4
Haemonchus similis	4.8 (0.2–23.3)	0.05 (0–0.14)	1*	1

* One host individual infected.

Phylum Platyhelminthes
Class Trematoda
Family Echinostomatidae Dietz, 1909

Echinostoma nordiana (Baschkirova, 1941) (Fig. 1, *a*).
Site of infection: intestine; P — 4.8% (1 of 21); I — 1 (1).

This species is a parasite of various Anseriformes. In Ukraine, it was registered in the Whooper Swan (*Cygnus cygnus*) at the Black Sea coast area (Smogorzhevskaya, 1976). *Anser albifrons* is reported as a new host for this species.

Echinostoma revolutum (Fröhlich, 1802) **group** (Fig. 1, *b*).
Site of infection: intestine; P — 23.8%; (5 of 21); I — 1.6 (1–4)

The species complex has a wide host range, including various anseriform birds (including domestic birds), charadriiform, gruiform, columbiform, and passeriform birds, as well as some mammals. This species was found across the territory of Ukraine (Smogorzhevskaya, 1976). In *A. albifrons*, it was previously recorded in Bulgaria and Russia (Kamburov & Vasilev, 1972; Ryzhikov, 1963).

Fig. 1. Trematodes of *Anser albifrons*, wintering in the South of Ukraine: *a* — *Echinostoma nordiana*, general view; *b* — *Echinostoma revolutum* group, general view; *c* — *Echinostoma sarcinum*, general view; *d* — *Apatemon gracilis*, general view; *e* — *Cotylurus cornutus*, general view. Scale bars: *a* — 200 µm; *b, c* — 1000 µm; *d* — 500 µm; *e* — 300 µm

Echinostoma sarcinum Dietz, 1909 (Fig. 1, *c*).
Site of infection: intestine; P — 4.8% (1 of 21); I — 1 (1).

This species parasitises mainly birds of the family Rallidae (Gruiformes), and rarely infects anseriform birds. In Ukraine, this species was registered in Coot (*Fulica atra*) in the Danube Delta and Crimea (Smogorzhevskaya, 1976). *Anser albifrons* is reported as a new host for this species.

Family Strigeidae Railliet, 1919

Apatemon gracilis (Szidat, 1928) (Fig. 1, *d*).
Site of infection: intestine; P — 9.5% (2 of 21); I — 2.5 (1–4).

This species is a parasite of various anseriform birds and, more rarely, of gruiform (Rallidae), charadriiform, pelecaniform, and passeriform birds. This species was registered in various Anseriformes, including the domestic ducks, across the territory of Ukraine (Smogorzhevskaya, 1976). In *A. albifrons*, this species was noted in Europe and the USA (Edelényi, 1974).

Cotylurus cornutus (Rudolphi, 1809) (Fig. 1, *e*).
Site of infection: intestine; P — 4.8% (1 of 21); I — 1 (1).

This species is a parasite of various anseriform birds, and rarely of gruiform (Rallidae), ciconiiform, and falconiform birds. It was registered in various Anseriformes, including domestic ducks and gruiform birds across the territory of Ukraine (Smogorzhevskaya, 1976). In *A. albifrons*, this species was found in Hungary, Azerbaijan, Georgia, and Russia (Sudarikov, 1984).

Class Cestoda

Family Hymenolepididae Perrier, 1897

Microsomacanthus compressa (Linton, 1892) (Fig. 2, *d*).
Site of infection: intestine; P — 4.8% (1 of 21); I — 1 (1).

This species is a parasite of various anseriform birds, including geese. In Ukraine, it was registered in ducks, including domestic birds in Lower Dniester and Western Polissya (Smogorzhevskaya, 1976). In *A. albifrons*, this species was found in Europe (McDonald, 1969).

Microsomacanthus paramicrosoma (Gąsowska, 1932) (Fig. 2, *a–c*).
Site of infection: intestine; P — 4.8 (1 of 21); I — 1 (1).

This species parasitises various anseriform birds. In Ukraine, it was registered in Mallard (*Anas platyrhynchos*), Tufted Duck (*Aythya fuligula*), and domestic geese and ducks in Kyiv Region, Polissya, Forest-steppe, and Carpathians (Smogorzhevskaya, 1976). *Anser albifrons* is reported here as a new host for this species.

Retinometra longicirrosa (Fuhrmann, 1906) (Fig. 2, *e*).
Site of infection: intestine; P — 19.1% (4 of 21); I — 2.7 (1–5).

This species is a parasite of various wild and domestic anseriform birds. It was found in domestic geese and various wild anseriform birds across Ukraine (Smogorzhevskaya, 1976). In *A. albifrons,* the species was registered in Poland, Germany, and Azerbaijan (Czapliński et al., 1992; Lühe, 1910; Shahtahtinskaya, 1959).

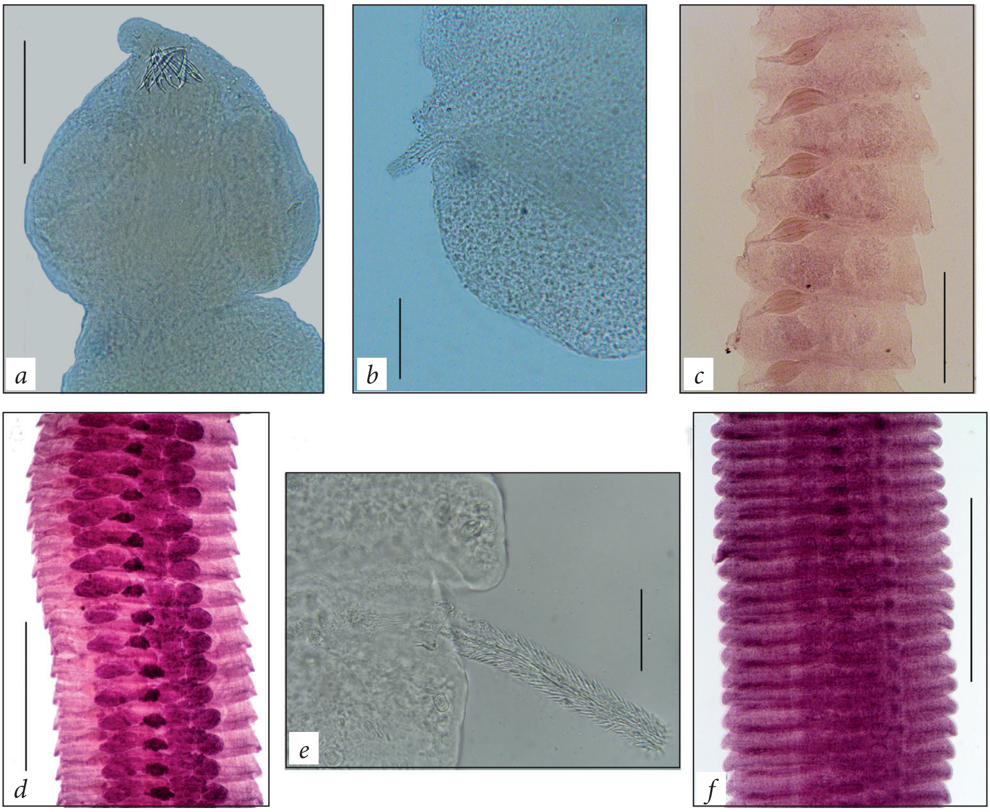

Fig. 2. Cestodes of *Anser albifrons*, wintering in the South of Ukraine: *a* — *Microsomacanthus paramicrosoma*, scolex; *b* — *Microsomacanthus paramicrosoma*, cirrus; *c* — *Microsomacanthus paramicrosoma*, strobila; *d* — *Microsomacanthus compressa*, strobila; *e* — *Retinometra longicirrosa*, cirrus; *f* — *Tschertkovilepis krabbei*, strobila. Scale bars: *a* — 100 µm; *b, e* — 50 µm; *c* — 300 µm; *d* — 1000 µm; *f* — 500 µm

Tschertkovilepis krabbei (Kowalewski, 1895) (Fig. 2, *f*).
Site of infection: intestine; P — 14.3% (3 of 21); I — 2.3 (1–4).

This species is a parasite of various anseriform birds, often found in geese. It was found in domestic geese across Ukraine (Smogorzhevskaya, 1976). In *A. albifrons*, the species was reported in the USA, Hungary, Poland, Bulgaria, and Russia (McDonald, 1969; Czapliński et al., 1992; Kamburov & Vasilev, 1972; Spasskaya, 1966).

Phylum Nematoda
Class Chromadorea
Family Amidostomatidae Travassos, 1919

Amidostomum anseris (Zeder, 1800) (Fig. 3, *a–d*).
Site of infection: gizzard, in koilin layer; P — 42.9%; (9 of 21); I — 11.7 (1–71).

This species is a parasite of various geese and, less commonly, domestic ducks. Accidentally, it can be registered in gruiform, podicipediform, ciconiiform, columbiform, and passeriform birds. In Ukraine, this species was previously found in *A. albifrons* on the Black Sea coast (Smogorzhevskaya, 1976) and in domestic geese across the country (Shevtsov, 1969). Additionally, this species has been recorded in *A. albifrons* in the USA,

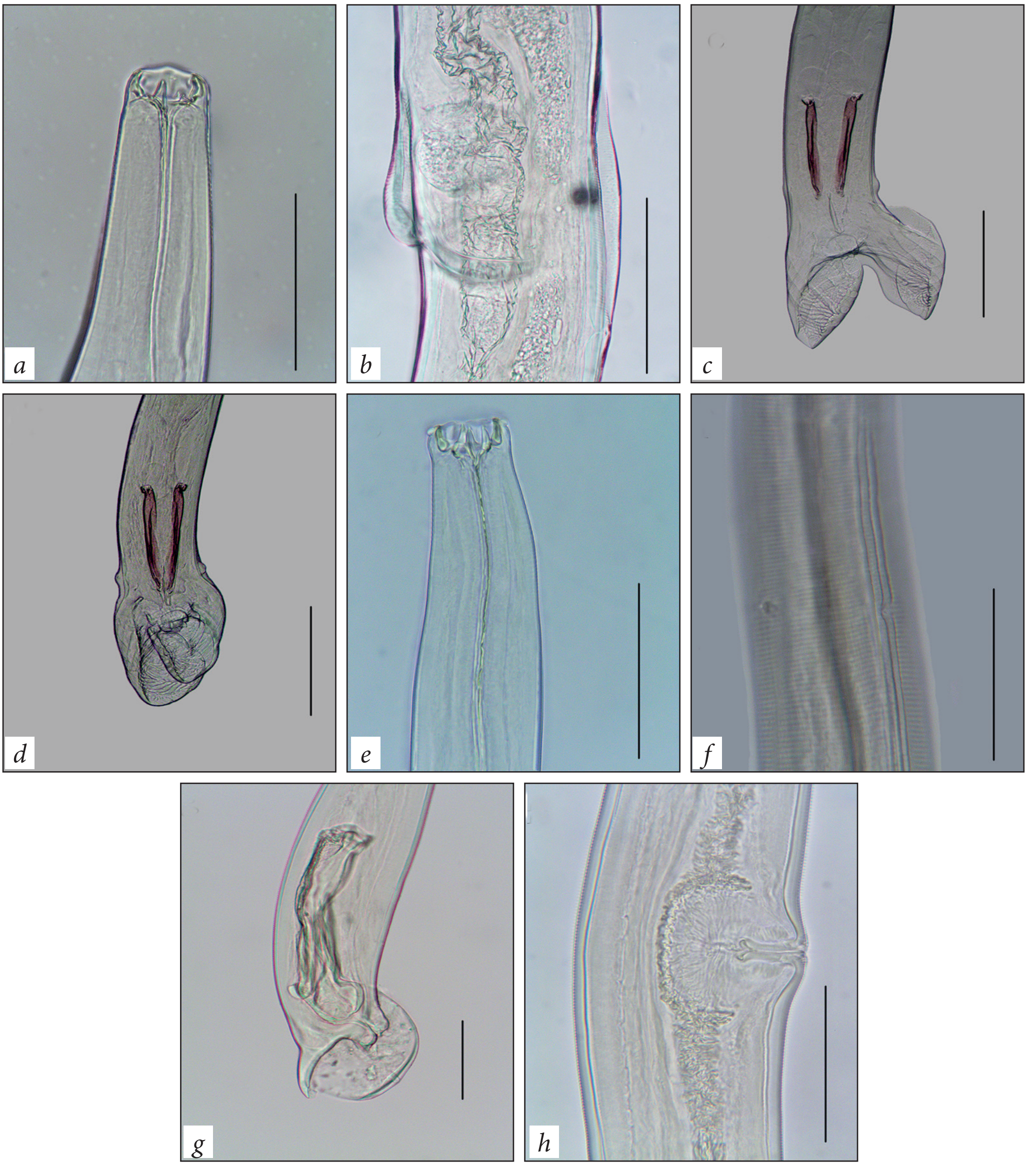

Fig. 3. Nematodes of the genus *Amidostomum* from *Anser albifrons*, wintering in the South of Ukraine: *a* — *A. anseris*, anterior end, lateral view; *b* — *A. anseris*, vulva, lateral view; *c* — *A. anseris*, posterior end of male, ventral view; *d* — *A. anseris*, spicules, lateral view; *e* — *A. spatulatum*, anterior end, lateral view; *f* — *A. spatulatum*, deirid, lateral view; *g* — *A. spatulatum*, spicules, lateral view; *h* — *A. spatulatum*, vulva, lateral view. Scale bars: *a, e, f, g, h* — 100 μm; *b* — 200 μm; *c, d* — 300 μm

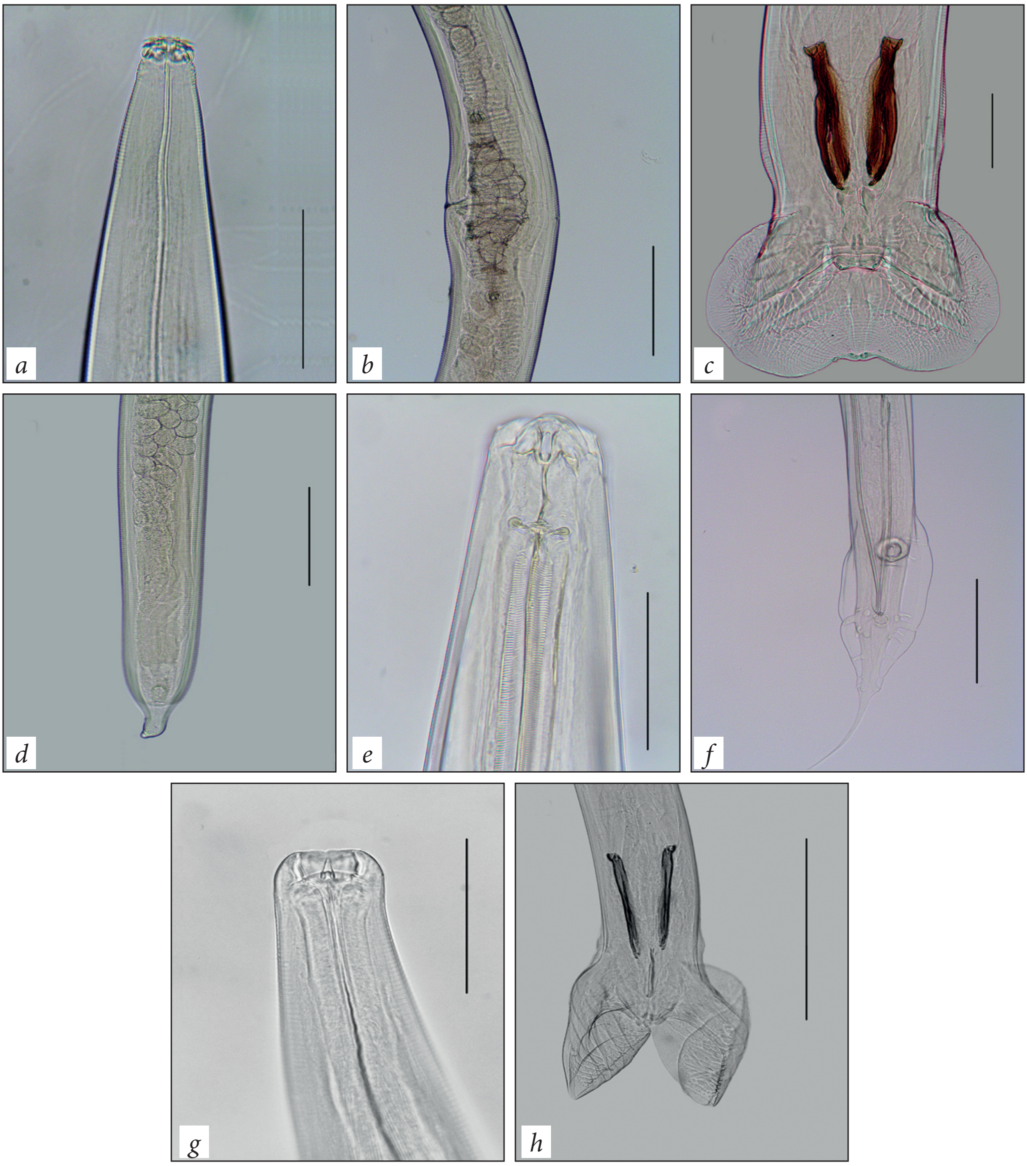

Fig. 4. Nematodes of *Anser albifrons*, wintering in the South of Ukraine: *a* — *Epomidiostomum orispinum*, anterior end, lateral view; *b* — *E. orispinum*, vulva, lateral view; *c* — *E. orispinum*, posterior end of male, ventral view; *d* — *E. orispinum*, posterior end of female, lateral view; *e*— *Heterakis gallinarum*, anterior end, ventral view; *f* — *H. gallinarum*, posterior end of male, ventral view; *g* — *Haemonchus similis*, anterior end, lateral view; *h* — *H. similis*, posterior end of male, ventral view. Scale bars: *a, c, e, g* — 100 µm; *b, d, f* — 300 µm; *h* — 500 µm

Poland, Bulgaria, Azerbaijan, Georgia, and Russia (McDonald, 1969; Czapliński et al., 1992; Kamburov & Vasilev, 1972; Kurashvili, 1957; Vaidova, 1978; Lebedeva et al., 2014).

Amidostomum spatulatum Baylis, 1932 (Fig. 3, *e–h*).
Site of infection: gizzard, in koilin layer; P — 81.0% (17 of 21); I — 13.2 (1–42).

This species is a parasite of various geese and ducks, including domestic ones. Here, this is the first registration of *A. spatulatum* in Ukraine. In *A. albifrons,* the species was noted in the USA, Poland, Bulgaria, and Russia (Fedynich et al., 2005; Amundson et al., 2016; Czapliński, 1962 a; Petrova, 1987; Leonov, 1975).

Epomidiostomum orispinum (Molin, 1861) (Fig. 4, *a–d*).
Site of infection: gizzard, in koilin layer; P — 95.2% (19 of 21); I — 33.7 (2–139).

This species is a parasite of various geese and, less commonly, ducks. Our record is the first registration of the species in Ukraine. In *A. albifrons,* the species was noted in Poland, Azerbaijan, and Russia (Czapliński, 1962 b; Vaidova, 1978; Bayanov, 1985).

Family Heterakidae Railliet et Henry, 1912

Heterakis gallinarum (Schrank, 1788) (Fig. 4, *e, f*).
Site of infection: caeca; P — 4.8% (1 of 21); I — 1 (1).

Typically, it is a parasite of galliiform birds, and is rarely noted in gruiform, anseriform, strigiform, and passeriform birds. In Ukraine, this species has been found in domestic geese and ducks in the Steppe and Forest-Steppe natural zones, as well as in Zakarpattia and Crimea (Shevtsov, 1969; Smogorzhevskaya, 1976). *Anser albifrons* is identified as a new host for this species.

Family Trichostrongylidae Leiper, 1912

Haemonchus similis Travassos, 1914 (Fig. 4, *g, h*).
Site of infection: caeca; P — 4.8% (1 of 21) I — 1 (1).

This species is a typical parasite of cattle (Gibbs and Herd, 1986); here, it is considered an accidental helminth found in *A. albifrons*.

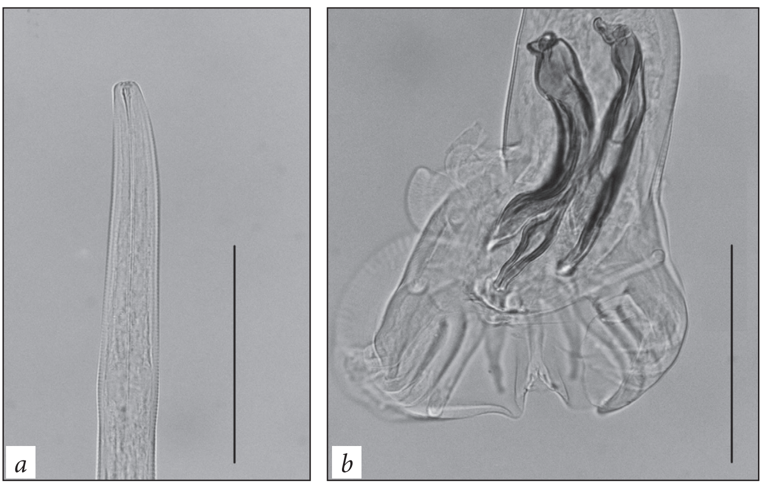

Fig. 5. *Trichostrongylus tenuis* from *Anser albifrons*, wintering in the South of Ukraine: *a* — anterior end, lateral view; *b* — posterior end of male, lateral view. Scale bars: *a, b* — 100 µm

Trichostrongylus tenuis (Mehlin, 1846) (Fig. 5, *a, b*).
Site of infection: intestine, caeca; P — 90.5% (20 of 21) I — 77.8 (1–272).

This species is a parasite of various geese, including domestic ones, and is rarely recorded in gruiform, galliiform, and passeriform birds. In Ukraine, this species has been found in domestic geese in the country (Shevtsov, 1969; Smogorzhevskaya, 1976). In *A. albifrons*, the species was noted in the USA, Poland, Bulgaria, and Russia (Fedynich et al., 2005; Amundson et al., 2016; Czapliński, 1962 b; Kamburov & Vasilev, 1972; Lebedeva et al., 2014).

Helminth infracommunities

In the whole sample of hosts (n = 21), the species richness in infracommunities ranged from 2 to 7 species per goose (mean 4.4; median 4.0). Helminth abundance in the infracommunities was from 14 to 366 specimens in one goose (mean 120.6; median 88.0). The dispersion index of 92.9 indicated a high level of aggregation of helminths in the studied host sample.

Male host individuals (n = 11) harboured more helminth species (3–7; median 5) and specimens (I = 14–366; median 123) than females (2–6 species; median 3.5; I = 19–343 specimens; median 60.5). However, the differences were not found to be statistically significant, apparently due to the small sample size (Mann-Whitney test, $p > 0.05$).

We tested the hypothesis on antagonistic relationships between the two species of the genus *Amidostomum*, *A. spatulatum* and *A. anseris*, and *E. orispinum* inhabiting the gizzard. Significant negative interspecific covariation between *A. spatulatum* and *E. orispinum* was observed (Spearman's correlation, $\rho = -0.5$; $p = 0.04$), while the covariation between *A. spatulatum* and *A. anseris* was not statistically significant (Spearman's correlation, $\rho = -0.2$; $p = 0.4$). Surprisingly, the covariation between *E. orispinum* and *A. anseris* appeared to be positive and statistically significant (Spearman's correlation, $\rho = 0.5$; $p = 0.02$). Of the six hosts infected with both *Amiostomum* species, in four cases, the intensity of *A. spatulatum* infestation was 12–42 times higher than that of *A. anseris*. Two congeneric species, *A. spatulatum* and *A. anseris*, demonstrated the signs of negative interspecific association; of 20 geese infected, only six geese harboured specimens of both species, three were infected with only *A. anseris*, and 11 were infected with only *A. spatulatum*. Expected co-occurrence of the two species (7.3) was higher than the observed co-occurrence (6), which evidences the negative interspecific association. However, the Chi-square test did not confirm the statistical significance of the association ($\chi^2 = 2.08$; $p = 0.15$) between the two species. Interestingly, in the six hosts infected with both species, the mean intensity of *A. anseris* was 1.3 (compared to 11.7 in the whole sample), while the mean intensity of *A. spatulatum* was 18 (compared to 13.2 in the whole sample).

In the studied sample of 21 greater white-fronted geese, 15 helminth species were recorded, excluding 11 unidentified specimens of cestodes (immature strobilae without scolices) and three unidentified specimens of *Amidostomum* sp. (juvenile females). The estimated species richness was 15 (Chao1), 22 (jackknife), or 18 (bootstrap). In other words, up to seven additional species potentially present in the helminth community of the examined *A. albifrons* population were not found in the

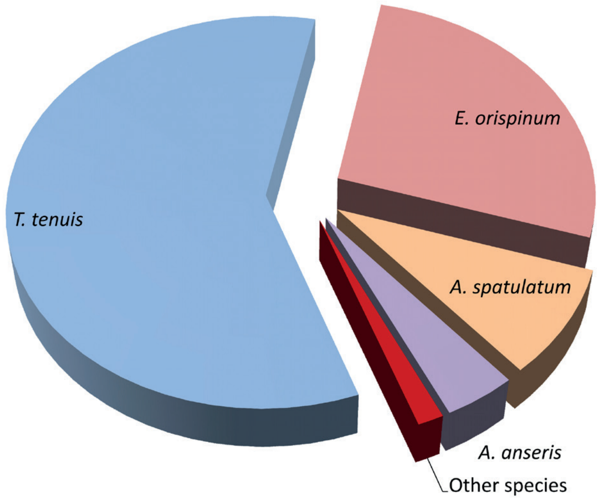

Fig. 6. Relative abundance of helminths in the sample of *Anser albifrons*, wintering in the South of Ukraine

studied sample. Margalef's index of species richness in the studied helminth sample was 1.79. The diversity indices calculated based on the sample data were as follows: Pielou's index, 0.41; Shannon index, 1.11; Gini–Simpson index (1 − λ), 0.57; and Berger-Parker index, 0.59.

Helminth component community

Three species, *E. orispinum* and *A. spatulatum* from the gizzard and *T. tenuis* from the caeca, were dominant in the helminth component community; they were found with infection prevalence exceeding 80%. Five additional species had infection prevalence rates ranging from 9% to 43%. Almost half of the found species (7) infected only one host (P = 4.8%) with an intensity of infection of one specimen. These species are considered rare or random/occasional parasites of geese; most of them use the invertebrate intermediate hosts in their life cycles, which are absent during winter.

In the studied sample of helminths (n = 2,519), nematoda *T. tenuis* strongly predominated by its abundance (1,478 specimens) and relative abundance (58.7%). Three nematode species had their relative abundance higher than 1%: *E. orispinum* (26.8%), *A. spatulatum* (8.9%), and *A. anseris* (4.2%). The rest of the species were much less abundant in the sample, with a total abundance of 1.5% (Fig. 6).

Discussion

This work is the first contemporary report of helminths parasitising the wintering population of the greater white-fronted goose in Ukraine. Previously published data on the parasites of *A. albifrons* included only sporadic reports on some helminth species; to date, no analysis of the parasite community has been conducted (Smogorzhevskaya, 1976). In our study, 15 helminth species were found in greater white-fronted geese wintering in southern Ukraine. Among them, two species were registered in Ukraine for the first time, and for four species, *A. albifrons* was reported as a new host. Additionally, we recorded a higher prevalence of helminth infection in greater white-fronted geese wintering in southern Ukraine (100%) compared to those wintering in Texas (59%) (Fedynich et al., 2005).

Unlike previous studies, our examined material was collected as a result of a bird's death from poisoning, not as a result of its being shot. Since all collected helminths were localized in the digestive tract, rodenticides that entered the host's body could have influenced the parasites and our results. We were unable to find any publications on the effect of rodenticides on helminths in a poisoned host. However, since the birds died relatively quickly, the helminths did not have time to leave the host. The used rodenticides had an anticoagulant effect; the geese were affected by hemorrhages under the skin, in the body cavity, in the pericardium, lungs, and rarely in the digestive tract. Therefore, these hemorrhages probably did not affect the number of helminths.

Four nematode species, *A. anseris*, *A. spatulatum*, *E. orispinum*, and *T. tenuis*, predominated in the helminth community by their prevalence (more than 80%) and intensity. All these parasites were monoxenous species, meaning they have direct life cycles (McDonald, 1969). The high level of infection by these nematodes in examined geese may be explained by congregation in flocks during wintering, which facilitates parasite transmission, and the absence of intermediate hosts in their life cycles. The greater white-fronted geese nest in solitary pairs; however, they form large congregational flocks during migration and wintering (Fox et al., 1998; Tesky, 1993), which significantly contributes to the accumulation of monoxenous parasites in their hosts. Similar results have been observed in other regions where helminths in wintering populations of *A. albifrons* have been studied. In Europe, the investigation of a small sample (9 individuals) of *A. albifrons* wintering in the Don Region of Russia (Petrov, 1926) showed 100% infection with nematodes, with the highest prevalence of monoxenous nematodes: *A. anseris* — 5/9 (2–46), *Epomidostomum skrjabini* (Petrov, 1926) (syn. *E. orispinum*) — 4/9 (1–84), and *T. tenuis* — 3/9 (1–12). Gizzard nematodes were predominant in the helminth communities of the greater white-fronted geese studied during wintering in Texas (USA) (Purvis et al., 1997; Fedynich et al., 2005) with the infection rates in 1997 and 2005 for *A. spatulatum* — 68.2% (1–16) and 67.0% (1–25), respectively, for *A. anseris* — 22.7% (1–4) and 41.0% (1–11), respectively, and for *Epomidostomum crami* Wetzel, 1931 — 100.0% (1–58) and 96.0% (1–82), respectively. *Epomidostomum orispinum,* which was dominant in our study, has not been reported in geese in the Western Hemisphere; its habitat is limited to Europe and Western Asia (Chaplinski, 1962), while *E. crami* was found in the greater white-fronted goose in the Far East and North America (Skrjabin et al., 1954). Morphologically, these are very similar species, occupying the same ecological niche and potentially being synonyms.

In our study, co-parasitism of two nematode species, *A. anseris* and *A. spatulatum,* demonstrated the dominance of *A. spatulatum* in a sample from the Odesa Region. However, this dominance was not statistically significant. In our sample, the prevalence of *A. spatulatum* was higher than that of *A. anseris*, at 81.0% vs 42.9%. A high level of infection intensity (91 specimens) of *A. anseris* was observed only in one goose in the absence of *A. spatulatum*. When these two species co-occurred, in four of six birds the intensity of *A. spatulatum* infection was 12–42 times higher than that of *A. anseris*, while in the other two birds, the intensity of both *Amidostomum* species was low. Similar co-parasitism patterns of these two species have been recorded in Texas in several wintering goose species, including *A. albifrons* (Purvis et al., 1997). The authors observed a negative relationship between *A. anseris* and *A. spatulatum*, although not statistically significant ($p = 0.051$). In other studies, these two nematode species have not been recorded in greater white-fronted geese together (Kamburov & Vasilev, 1972; Ryzhikov, 1962–1963; Gubanov & Daja, 1967; Petrov, 1926; Tolkacheva, 1964; Leonov, 1975). In our opinion, this indirectly suggests possible competition between these nematodes, since both are parasites of the gizzard and share the same feeding niche. Interestingly, in a study of gizzard nematodes in the lesser snow goose (*Chen caerulescens caerulescens*) in Canada (Tuggl and Crites, 1984), such coinfection patterns for *A. anseris* and *A. spatulatum* were not observed; the prevalence of both species was the same (84%) with an average intensity of 9.8 and 11.2, respectively. As these nematodes are not specific to any species of geese, we suppose that the host species did not affect their co-parasitism. However, in studying the pathology of parasite invasion, Tuggl and Crites (1984) noted a partial separation of these nematodes: *A. anseris* was most commonly found in the epithelial lining and, less often, in the lining at the periphery of the koilin layer, while *A. spatulatum* was also localised under koilin. It should be noted that in our study, as in the studies of *A. albifrons* wintering in Texas (Purvis et al., 1997; Fedynich et al., 2005), both *A. anseris* and *A. spatulatum* were found in the exact location, in the cuticle of the gizzard. Therefore, we presume that a separation in localisation of these gizzard nematodes, even if insignificant, can reduce competition between *A. anseris* and *A. spatulatum* and affect their occurrence in communities.

In greater white-fronted geese examined in the summer period at nesting sites in Chukotka, Russia (Ryzhikov, 1962–1963), the infection of monoxenous nematodes was high (73%), which is associated with the plant-based diet of the geese and the low proportion of invertebrates in their diet. However, during this period, high levels of geese infection with cestodes ($P = 70\%$) and trematodes ($P = 81\%$) were observed (Ryzhikov, 1963). In subsequent studies in the same region in the 1970s during the summer period, a high infection with trematodes (83.3%) and cestodes (62.5%) was again recorded, while nematodes were found in 20% (Kontrimavichus et al., 1975) or in 14.7–61.7% of greater white-fronted geese (Leonov, 1975). In similar studies on helminths of the greater white-fronted geese at nesting sites in Alaska (Shiller, 1952; Amundson et al., 2016), a high infection prevalence (70.7%) with the cestode *Tschertkovilepis setigera* (Froelich, 1789) was recorded, while the prevalences with monoxenous nematode species *T. tenuis* and *A. anseris* were lower — 63.8% and 34.5%, respectively. Additionally, a higher intensity of adult birds' infection with nematodes and a high prevalence of trematodes and cestodes in juvenile birds were recorded in Alaska, USA (Amundson et al., 2016), which was attributed to the higher proportion of invertebrates, intermediate hosts of flatworms, in the diet of juvenile geese. During the nesting season, the greater white-fronted geese form solitary pairs, which helps reduce the circulation of monoxenous nematodes. At the same time, during nesting season, the proportion of invertebrates in the geese's diet increases, especially for juvenile birds, which have greater protein requirements (Ely &

Raveling, 2011). Our sample of white-fronted geese wintering in Ukraine consisted predominantly of juvenile individuals; however, their infection rates with trematodes (P = 4.8%) and cestodes (P = 23.8%) were low, which probably indicates that the geese lose these helminths during their long autumn migration. In contrast, high levels of monoxenous nematode infections are associated with their circulation in goose populations in wintering grounds. Thus, the results obtained in this study not only expanded the existing information on the helminths parasitising the white-fronted goose during its winter migrations to the southern regions of Europe, but also revealed some trends in the structure of helminth communities.

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