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HELMINTHS OF EXOTIC EVEN-TOED UNGULATES (ARTIODACTYLA) IN THE ASKANIA-NOVA BIOSPHERE RESERVE, UKRAINE

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Helminths of Exotic Even-Toed Ungulates (Artiodactyla) in the Askania-Nova Biosphere Reserve, Ukraine. Zvegintsova, N. S., Kharchenko, V. A., Kuzmina, T. A. — More than 30 species of exotic ungulates are currently kept in the Askania-Nova Biosphere Reserve (Kherson Region, Ukraine). During the years 1978–2014, 146 ungulates of 24 species (16 species of Bovidae, 4 — Cervidae, 4 — Camelidae) were examined by partial helminthological dissection; more than 402,700 specimens of helminths were collected and identified. The purpose of the present study was to summarize these data and analyze the species diversity in exotic ungulates. Totally, 38 species of helminths: 3 species of Trematoda, 6 — Cestoda, 29 — Nematoda were found. Ungulates from the family Bovidae were the most infected; they harbored 36 species of helminths, 1–18 species per host. In Camelidae, 15 species were found; 3–10 species per host. Cervidae harbored 9 species; 1–6 species per host. The highest species diversity was detected in the ungulates introduced from regions with climatic conditions similar to those in southern Ukraine: saiga antelope (19 species), European mouflon (18), Barbary sheep (18), and markhor (17). Ten species typical for domestic ruminants (*Haemonchus contortus*, *Nematodirus* sp., *Aonchotheca bovis*, *Moniezia expansa*, *Oesophagostomum venulosum*, *Ostertagia circumcincta, Trichostrongylus axei*, *T. colubriformis, T. probolurus* and *Trichuris ovis*) dominated in the parasite communities. Our results indicated reduction in the species diversity and alteration of the parasite community structures in these exotic ungulates kept in the Askania-Nova Reserve compared to their natural habitats.

Key words: Nematoda, Cestoda, Trematoda, parasite community, ungulates, Askania-Nova Reserve.

Introduction

The Askania-Nova Biosphere Reserve is one of the oldest natural reserves in Eastern Europe. It was established in the steppe area of southern Ukraine (Kherson Region) in the period from 1887 to 1892 as a small zoo on the private estate of the Falz-Fein family (Falz-Fein, 1997). Initially, not more than a dozen species, mostly ungulates and birds, were kept in the Zoo. Currently the collection of the exotic ungulates in the Reserve includes hundreds of animals of which more than 30 species from the families Bovidae Gray, 1821, Cervidae Goldfuss, 1820, Camelidae Gray, 1821 and Equidae Gray, 1821 introduced from different natural zones and continents. Currently there are 17 species of Bovidae in the Askania-Nova Reserve: European mouflon (*Ovis ammon musimo*n), markhor (Capra falconeri heptneri), wild goat (C. aegagrus hircus), Siberian ibex (*C. sibirica*), common eland (*Taurotragus oryx*), American bison (*Bison bison*), Barbary sheep (*Ammotragus lervia*), saiga antelope (*Saiga tatarica*), blackbuck (*Antilope cervicapra*), nilgai (*Boselaphus tragocamelus*), blue wildebeest (*Connochaetes taurinus*), sitatunga (*Tragelaphus spekei gratus*), Arabian oryx (*Oryx leucoryx*), African buffalo (*Syncerus caffer caffer)*, Ankole-Watusi (*Bos taurinus macroceros*), banteng (*B. javanicus*), and gayal (*B. frontalis* dom.). Four species of Cervidae are kept in the Reserve: sika deer (*Cervus nippon*), red deer (*C. elaphus*), Père David's deer (*Elaphurus davidianus*), and fallow deer (*Dama dama*). Four species of Camelidae, namely, Bactrian camel (*Camelus bactrianus*), llama (*Lama glama*), guanaco (*L. guanicoe*), alpaca (*Vicugna pacos*) and several hybrids of alpaca and llama are kept in the Reserve. Other ungulates are represented by six species of Equidae, namely, wild Przewalski's horses (*Equus ferus przewalskii*), Shetland ponies (*E. caballus*), donkeys (*E. asinus*), Turkmenian kulans (*E. hemionus kulan*), plain zebras (*E. burchelli*) and Grevy's zebra (*E. grevyi*) (Treus, 1968).

It is assumed that keeping a large number of different species of exotic ungulates from different natural zones in an enclosed area such as the Askania-Nova Reserve inevitably would lead to the introduction of alien parasite species and, as a consequence, the transformation of natural host–parasite systems of the steppe climatic zone of southern Ukraine (Dvojnos et al., 1990; Zvegintsova & Treus, 2007). The first parasitological study of the ungulates kept in the Askania-Nova Reserve was carried out in 1927 by the researchers of the Second Ukrainian helminthiological expedition guided by Professor S. V. Ivanitsky. Helminths of three taxonomic groups: Nematoda, Cestoda and Trematoda, were found in the ungulates at that time; however, a detailed lists of the parasite species were not published (Zvegintsova, 2003). Until the 1970s, parasitological studies in the Reserve included mostly the parasites of birds. It was only in 1972 that the first parasitological examination of the wild Przewalski's horses, Turkmenian kulans and common elands was carried out (Dvojnos, 1975; Treus & Zvegintsova, 1979; Dvojnos et al., 1990). Until now, the parasites of wild and domestic equids, strongylid nematodes in particular, have been well studied in the Askania-Nova Reserve (Dvojnos & Kharchenko, 1994; Kuzmina et al., 2007, 2009, 2013). As for the species of Bovidae, the parasite community of saiga antelopes has been thoroughly examined (Zvegintsova et al., 2015). Parasites of other ungulate species have also been studied and the results were published partially (Zvegintsova & Treus, 2007; Zvegintsova, 2008, 2009, 2012–2015). Most of these parasitological studies in the Askania-Nova were carried out by coprological methods; thus, the data on the species composition of the parasite communities of exotic ungulates kept in the Reserve are not complete.

The conditions of the Askania-Nova Biosphere Reserve are favorable for animals, and the mortality rate of the ungulates is low. Therefore, the helminthological studies and collection of helminths by *post-mortem* examination are rare and irregular. Extensive parasitological data from ungulates kept in the Reserve has been collected during the last four decades. The objective of this study was to summarize and analyze all of the parasitological data collected from these ungulates. Comparative analysis of the diversity and structure of the parasite communities of these exotic ungulates kept in the Reserve, as well as possible changes in these communities associated with the introduction of alien parasite species were also of the interest in this study.

Material and methods

The investigation was carried out from 1978 till 2014 in the Askania-Nova Biosphere Reserve (Kherson Region, Ukraine; 46°29′ N and 33°58′ E). During this period, 146 specimens of ungulates of 24 different species including three families: Bovidae (16 species), Cervidae (4 species) and Camelidae (4 species) were examined by the partial helminthological dissection technique (Kotelnikov, 1984) (table 1). Most of these animals were kept under semi-free-ranging conditions in large steppe enclosures of 80–2,032 ha. Other ungulates (banteng, sitatunga, markhor, Arabian oryx, Siberian ibex, blackbuck, Blue wildebeest, Bactrian camel, llama and Pere David's deer) were kept in large pens of 0.08 ha in the Askania-Nova Zoo. The animals kept in the zoo were treated with different groups of anthelmintics (mostly with benzimidazoles) one or two times per year according to parasitological examination data.

After necropsy of the hosts, all helminths were manually collected from different organs and from all parts of the digestive system, washed with the saline or tap water and fixed with the Barbagallo solution (4 % formalin solution in saline), or with 70 % ethanol (Ivashkin et al., 1971). Totally, 402,722 specimens of helminths were collected and identified according to morphological criteria using the light microscopy (Boev et al., 1963;

Table 1. Species of even-toed ungulates (Artiodactyla) included in the study, regions of their natural habitats (according to IUCN, 2017) and number of helminths collected

	Species of ungulates	Regions of their natural habitats	Number of infected animals	Number of helminth specimens	Number of helminth species
		Family Bovidae			
1.	Markhor (*Capra falconeri*)	Afghanistan, India, Pakistan, Tajikistan, Turkmenistan, Uzbekistan	11	55,453	17
2.	European mouflon (*Ovis musimon*)	Caucasus, Anatolia, Iraq, Iran, Armenia, Mediterranean islands	5	20,268	18
3.	Common eland (*Taurotragus oryx*)	Southern Africa (Ethiopia, Sudan, Angola, Namibia, South Africa)	38	24,755	9
4.	American bison (*Bison bison*)	North America (originally from north Mexico to Alaska)	11	1,016	12
5.	Barbary sheep (*Ammotragus lervia*)	North Africa (Morocco, Algeria, Tunisia, Egypt)	5	86,605	18
6.	Saiga antelope (*Saiga tatarica*)*	Central Asia (Kazakhstan, Uzbekistan, Turkmenistan, Mongolia, southern Russia)	31	63,959	19
7.	Blackbuck (*Antilope cervicapra*)	Asia (India, Pakistan, Nepal, south of the Himalayas)	8	5,676	10
8.	Nilgai (*Boselaphus tragocamelus*)	Asia (India, Nepal, Pakistan)	7	29	4
9.	Blue wildebeest (*Connochaetes taurinus*)	Africa (from Kenya, Tanzania, Botswana, Zambia to South Africa)	1	5	1
10.	Sitatunga (*Tragelaphus spekei gratus*)	West and Central Africa, (swamp systems in the savanna zones)	3	40	3
11.	Arabian oryx (*Oryx leucoryx*)	Asia (Arabian Peninsula, Kuwait and Iraq)	1	2,516	4
12.	Ankole-Watusi (*Bos taurinus macroceros*)	Central Africa (Ankole group of Sanga cattle breeds)	1	601	7
13.	Banteng (*Bos javanicus*)	Asia (Southern China, India, Malaysia, Borneo, Java, Bali)	1	20	3
14.	African buffalo (*Syncerus caffer caffer*)	Sub-Saharan Africa	1	4	3
15.	Gayal (*Bos frontalis dom.*)	Asia (Northeast India, Bangladesh, Myanmar, China)	1	3	1
16.	Siberian ibex (*Capra sibirica*)	Central Asia (Afghanistan, Kazakhstan, Kyrgyzstan, Tajikistan, Mongolia, northern China, south Russia)	1	5	2
		Family Cervidae			
17.	Sika deer (*Cervus nippon*)	East Asia (central China, Japan, Korea, the Far East of Russia)	3	55	3
18.	Red deer (*Cervus elaphus*)	Europe, North Africa, the Middle East	6	237	6
19.	Pere David's deer (*Elaphurus davidianus*)	China (endemic)	2	0	0
20.	Fallow deer (*Dama dama*)	Southern Europe, Turkey, Middle East	1	1	1
		Family Camelidae			
21.	Bactrian camel (*Camelus bactrianus*)	Central Asia	1	140,628	6
22.	Llama (*Lama glama*)	South America (Andes mountains)	3	556	10
23.	Guanaco (*Lama guanicoe*)	South America (Peru, Chile, Andes)	3	267	10
24.	Alpaca (*Vicugna pacos*)	South America (Peru, Chile, Andes)	1	23	3
	TOTAL:		146	402,722	

*Data were published in Zvegintsova et al. (2015).

Govorka et al., 1988; Ivashkin et al., 1989). Before identification all helminths were clarified in a solution of phenol in glycerin (80 % of phenol, 20 % of glycerin).

The results obtained were analyzed using the Microsoft™ Excel (Microsoft Excel, Redmond, Washington: Microsoft, 2003, Computer Software). The proportion of each species in the parasite community was calculated as the number of specimens of the particular species in relation to the total number of helminths collected from each host. The Bray–Curtis cluster analysis was performed using the Biodiversity Professional v.2.04 (McAleece et al., 1997).

Table 2. Distribution of the helminth species found in the ungulates in the Askania-Nova Reserve, Ukraine

	Helminth species	Families of ungulates		
		Bovidae	Cervidae	Camelidae
		Trematoda		
1	*Paramphistomum cervi* (Schrank, 1790)	–	*sika deer*	–
2	*Paramphistomum* sp.	banteng	–	–
3	*Fasciola hepatica* (Linnaeus, 1758)	European mouflon	–	–
		Cestoda		
4	*Avitellina centripunctata* (Rivolta, 1874)	saiga antelope	–	—
5	*Echinococcus granulosus* (Batsch, 1786), larvae	Siberian ibex	–	Bactrian camel
6	*Moniezia expansa* (Rudolphi, 1810)	European mouflon, saiga, common eland, markhor, Barbary sheep, nilgai, American bison	red deer	guanaco
7	*M. benedeni* (Monies, 1879)	American bison, banteng, gayal, saiga	–	–
8	*Taenia hydatigena* (Pallas, 1766) = *Cysticercus tenuicollis*	European mouflon, Arabian oryx, blackbuck, Barbary sheep, markhor	sika deer, fallow deer	–
9	*Taenia multiceps* (Leske, 1780) = *Coenurus cerebralis*	European mouflon	–	–
		Nematoda		
10	*Aonchotheca bovis* (Schnyder, 1906)	European mouflon, markhor, saiga, Barbary sheep, sitatunga	–	–
11	*Camelostrongylus mentulatus* (Railliet et Henry, 1909)	Barbary sheep, saiga, Arabian oryx, markhor, Ankole-Watusi, blackbuck	–	Bactrian camel, guanaco, llama
12	*Chabertia ovina* (Fabricius, 1788)	European mouflon, saiga	–	–
13	*Cooperia oncophora* (Railliet, 1898)	Ankole-Watusi, American bison, saiga	red deer	alpaca, llama
14	*C. pectinata* Ransom, 1907	American bison	–	–
15	*C. verrucosa* Mönnig, 1932	common eland, sitatunga	–	–
16	*C. zurnabada* Antipin, 1931	American bison	–	–
17	*Dictyocaulus filaria* (Rudolphi, 1809)	European mouflon	–	–
18	*Haemonchus contortus* (Rudolphi, 1808)	Barbary sheep, American bison, saiga, common eland, blue wildebeest, markhor, sitatunga	–	guanaco, llama
19	*Marshallagia marshalli* (Ransom, 1907)	European mouflon, saiga, markhor, Barbary sheep	–	guanaco, llama
20	*Nematodirus abnormalis* (May, 1920)	European mouflon	–	–
21	*Nematodirus* sp.	Barbary sheep, Ankole-Watusi, American bison, saiga, Siberian ibex, blackbuck, markhor, common eland	red deer	guanaco, llama, alpaca
22	*Oesophagostomum venulosum* (Rudolphi, 1809)	European mouflon, American bison, markhor, Barbary sheep, saiga, Ankole-Watusi, African buffalo	sika deer, red deer	guanaco
23	*Oesophagostomum* sp.	common eland	–	–
24	*Ostertagia circumcincta* (Stadelmann, 1894)	European mouflon, common eland, markhor, saiga, Barbary sheep	–	guanaco

25	*O. ostertagi* (Stilles, 1892)		Barbary sheep, saiga, Ankole-Watusi, American bison	–	–
26	*O. trifurcata* (Ransom, 1907)		European mouflon, common eland, saiga, markhor, Barbary sheep, blackbuck	–	–
27	*Parabronema skrjabini* (Rassowska, 1924)		-	–	llama
28	*Setaria labiatopapillosa* Railliet et Henry, 1911		Barbary sheep, African buffalo, American bison	–	–
29	*Skrjabinema ovis* (Skrjabin, 1915)		African buffalo, blackbuck, markhor, saiga	red deer	–
30	*Trichostrongylus axei* (Cobbold, 1879)		European mouflon, markhor, saiga, Barbary sheep, blackbuck, Ankole-Watusi	red deer	guanaco, Bactrian camel, llama
31	*T. colubriformis* (Giles, 1892)		European mouflon, markhor, saiga, Barbary sheep, blackbuck, Arabian oryx	–	Bactrian camel, llama
32	*T. probolurus* (Railliet, 1896)		European mouflon, markhor, saiga, Barbary sheep, blackbuck, Arabian oryx	–	Bactrian camel, guanaco
33	*T. vitrinus* (Lios, 1905)		European mouflon, Barbary sheep, Blackbuck	–	–
34	*Trichostrongylus* sp.		Common eland	–	–
35	*Trichuris ovis* (Abildgaard, 1795)		European mouflon, Barbary sheep, saiga, markhor, African buffalo, American bison	red deer	Bactrian camel, alpaca
36	*T. skrjabini* (Baskakov, 1924)		American bison, European mouflon, Barbary sheep, markhor, banteng	–	–
37	*T. cervicaprae* Kreis, 1935		blackbuck, markhor, common eland	–	–
38	*Trichuris* sp.		nilgai	–	guanaco, llama
Number of helminth species per host family		minimum	1	1	3
		18	*6*	10	
	maximum	7.5	*3.3*	7.3	
	average				

Results

Species diversity of parasites of even-toed ungulates in the Askania-Nova Reserve

Thirty-eight helminth species were found in 24 species of ungulates examined: 3 species of trematodes, 6 species of cestodes and 29 species of nematodes (table 2). One species of the digenean trematodes from the genus *Paramphistomum* and three species of nematodes from the genera *Nematodirus*, *Oesophagostomum* and *Trichuris,* were identified only to the genus level.

The helminth species found in the even-toed ungulates from the Askania-Nova Biosphere reserve, their prevalence (P) and intensity (I), are listed below.

Class TREMATODA Rudolphi, 1808
Order ECHINOSTOMIDA La Rue, 1957
Family PARAMPHISTOMIDAE Fischoeder, 1901
Genus *Paramphistomum* Fischöder, 1901
Paramphistomum cervi (Schrank, 1790)
Hosts: sika deer (P = 33.3 %; I = 50).
Site of infection: rumen.
***Paramphistomum* sp.**
Hosts: banteng (P = 100 %; I = 7).
Site of infection: large intestine.

Family FASCIOLIDAE Railliet 1895
Genus *Fasciola* Linnaeus, 1758
Fasciola hepatica Linnaeus, 1758
Hosts: European mouflon (P = 10 %; I = 48).
Site of infection: liver.

Class CESTODA Rudolphi, 1808
Order CYCLOPHYLLIDEA Braun, 1900
Family ANOPLOCEPHALIDAE (Kholodkovskii, 1902)
Genus *Avitellina* Gough 1911
Avitellina centripunctata (Rivolta, 1874)
Hosts: saiga antelope (P = 4.3 %; I =2).
Site of infection: small intestine.

Genus *Moniezia* Blanchard, 1891
Moniezia expansa (Rudolphi, 1805)
Hosts: European mouflon (P = 20 %; I = 17.5 (1–34)); common eland (P = 21.1 %; I = 2.9 (1–10)); markhor (P = 9.1 %; I = 1); saiga antelope (P = 21.7 %; I =1.2 (1–4)); Barbary sheep (P = 40 %; I = 1.5 (1–2)); American bison (P = 45.5 %; I = 2.2 (1–4)); nilgai (P = 28.6 %; I = 1); red deer (P = 16.7 %; I = 1); guanaco (P = 16.7 %; I = 1).
Site of infection: small intestine.
M. benedeni (Monies, 1879)
Hosts: American bison (P = 18.2 %; I = 2 (1–3)); banteng (P = 100 %; I = 1); gayal (P = 100 %; I = 3).
Site of infection: small intestine.

Family TAENIIDAE (Ludwig, 1886)
Genus *Taenia* Linnaeus, 1758
Taenia hydatigena (Pallas, 1766), larvae
Hosts: Arabian oryx (P = 100 %; I = 2); blackbuck (P = 12.5 %; I = 6); saiga antelope (P = 17.4 %; I =1); Barbary sheep (P = 20 %; I = 1); European mouflon (P = 20 %; I = 5.5 (1–10)); markhor (P = 27.3 %; I = 1.3 (1–2)); fallow deer (P = 100 %; I = 1); sika deer (P = 33.3 %; I = 1).
Site of infection: mesentery, liver.
Taenia multiceps (Leske, 1780), larvae
Hosts: European mouflon (P = 100 %; I = 1).
Site of infection: brain.

Genus *Echinococcus* Rudolphi, 1801
Echinococcus granulosus (Batsch, 1786), larvae
Hosts: Siberian ibex (P = 100 %; I = 1); Bactrian camel (P = 100 %; I = 3).
Site of infection: liver.

Phylum NEMATODA Diesing, 1861
Class NEMATODA Rudolphi, 1808
Order ENOPLIDA Filipjev, 1929
Family CAPILLARIIDAE Neveu-Lemaire, 1936
Genus *Aonchotheca* López-Neyra, 1947
Aonchotheca bovis (Schnyder, 1906)
Hosts: markhor (P = 45.5 %; I = 43.8 (22–65)); European mouflon (P = 10 %; I = 10); saiga antelope (P = 4.3 %; I =3); Barbary sheep (P = 20 %; I = 1); sitatunga (P = 66.7 % (2 from 3); I = 1.5 (1–2)).
Site of infection: abomasum, small intestine.

Order STRONGYLIDA Molin, 1861
Family TRICHOSTRONGYLIDAE *Leiper, 1912*
Genus *Camelostrongylus* Orloff, 1933
Camelostrongylus mentulatus (Railliet et Henry, 1909)

Hosts: Arabian oryx (P = 100 %; I = 585); Ankole-Watusi (P = 100 %; I = 5); blackbuck (P = 50 %; I = 487.5 (20–1,091)); saiga antelope (P = 61.9 %; I =52.1 (5–187)); Barbary sheep (P = 40 %; I = 12 (3–21)); markhor (P = 81.8 %; I = 472.4 (4–2,212)); guanaco (P = 33.3 %; I = 5); llama (P = 66.7 %; I = 11.5 (1–22)); Bactrian camel (P = 100 %; I = 600).

Site of infection: abomasum, small intestine, caecum.

Genus *Cooperia* Ransom, 1907
Cooperia oncophora (Railliet, 1898)

Hosts: American bison (P = 18.2 %; I = 292.5 (5–580)); Ankole-Watusi (P = 100 %; I = 396); saiga antelope (P = 34.7 %; I = 373.8 (12–2,260)); red deer (P = 16.7 %; I = 1); llama (P = 33.3 %; I = 1); alpaca (P = 100 %; I = 2).

Site of infection: small intestine, caecum.

C. pectinata Ransom, 1907

Hosts: American bison (P = 9.1 %; I = 7).

Site of infection: small intestine.

C. verrucosa Mönnig, 1932

Hosts: common eland (P = 18.4 %; I = 851.9 (1–5,265)); sitatunga (P = 66.7 %; I = 16 (3–29)).

Site of infection: small intestine, caecum.

C. zurnabada Antipin, 1931

Hosts: American bison (P = 18.2 %; I = 59 (14–104)).

Site of infection: small intestine.

Genus *Haemonchus* Cobb, 1898
Haemonchus contortus (Rudolphi, 1808)

Hosts: American bison (P = 45.5 %; I = 21.2 (2–86)); common eland (P = 86.8 %; I = 268.5 (1–2,470)); saiga antelope (P = 21.7 %; I = 1.6 (1–3)); blue wildebeest (P = 100 %; I = 5); markhor (P = 36.7 %; I = 8.3 (2–16)); Barbary sheep (P = 40 %; I = 9.5 (3–16)); sitatunga (P = 33.3 %; I = 5); guanaco (P = 33.3 %; I = 4); llama (P = 33.3 %; I = 1).

Site of infection: abomasum, small intestine.

Genus *Marshallagia* Orloff, 1933
Marshallagia marshalli (Ransom, 1907)

Hosts: markhor (P = 54.5 %; I = 251.3 (1–756)); European mouflon (P = 40 %; I = 163.8 (4–260)); Barbary sheep (P = 40 %; I = 261.5 (171–352)); saiga antelope (P = 95.7 %; I = 456.1 (2–2113)); guanaco (P = 33.3 %; I = 4); llama (P = 33.3 %; I = 1).

Site of infection: abomasum, small intestine.

Genus *Ostertagia* Ransom, 1907
Ostertagia circumcincta (Stadelmann, 1894)

Hosts: common eland (P = 28.9 %; I = 2–539 (107.2 ± 168.2)); markhor (P = 45.5 %; I = 2–188 (71 ± 76.1)); European mouflon (P = 30 %; I = 2,341.7 (740–3,355)); Barbary sheep (P = 40 %; I = 583.5 (271–896)); saiga antelope (P = 26.1 %; I = 17.7 (4–65)); Ankole-Watusi (P = 100 %; I = 93); guanaco (P = 33.3 %; I = 1).

Site of infection: abomasum, small intestine.

O. ostertagi (Stilles, 1892)

Hosts: American bison (P = 45.5 %; I = 15.8 (3–39)); Barbary sheep (P = 40 %; I = 6.5 (2–11)); saiga antelope (P = 52.2 %; I = 85.8 (1–202)).

Site of infection: abomasum.

O. trifurcata (Ransom, 1907)

Hosts: common eland (P = 7.9 %; I = 6.3 (2–14)), blackbuck (P = 50 %; I = 75.8 (5–183)), markhor (P = 9.1 %; I = 13); European mouflon (P = 30 %; I = 791.7 (350–1,050), Barbary sheep (P = 40 %; I = 343 (61–625)); saiga antelope (P = 13 %; I = 2.3 (2–3)).

Site of infection: abomasum, small intestine.

Genus *Trichostrongylus* Looss, 1905

Trichostrongylus axei (Cobbold, 1879)

Hosts: markhor (P = 36.4 %; I = 303.5 (5–1,180)); European mouflon (P = 30 %; I = 1,802 (890–3,275)); Barbary sheep (P = 100 %; I = 4,075 (1–15,707)); saiga antelope (P = 87 %; I = 780.1 (3–2042)); blackbuck (P = 25 %; I = 21.5 (11–32)); Ankole–Watusi (P = 100 %; I = 64); red deer (P = 66.7 %; I = 39.5 (2–123)); guanaco (P = 33.3 %; I =1); llama (P = 33.3 %; I =10); Bactrian camel (P = 100 %; I = 860).

Site of infection: abomasum, small intestine.

T. colubriformis (Giles, 1892)

Hosts: markhor (P = 81.8 %; I = 3,328 (5–26,356)); European mouflon (P = 30 %; I = 37 (4–87)); Barbary sheep (P = 80 %; I = 13,075 (8–38,354)); saiga antelope (P = 69.6 %; I = 127.8 (1–510)); blackbuck (P = 50 %; I = 288.3 (29–837)); Arabian oryx (P = 100 %; I = 1738); llama (P = 66.7 %; I = 5 (3–7)); Bactrian camel (P = 100 %; I = 30,201).

Site of infection: abomasum, small intestine.

T. probolurus Railliet, 1896)

Hosts: markhor (P = 63.6 %; I = 2,356 (1–15,410)); European mouflon (P = 30 %; I = 11.3 (5–20)), Barbary sheep (P = 60 %; I = 2,181 (2–4,340)); saiga antelope (P = 91.3 %; I = 644.4 (1–4746)); blackbuck (P = 37.5 %; I = 163.7 (30–427)); Arabian oryx (P = 100 %; I = 191); guanaco (P = 66.7 %; I = 4 (3–5)); Bactrian camel (P = 100 %; I = 108,840).

Site of infection: abomasum, small intestine.

T. vitrinus (Lios, 1905)

Hosts: European mouflon (P = 30 %; I = 789 (160–2,027)); Barbary sheep (P = 40 %; I = 2,193 (1,115–3,271); blackbuck (P = 25 %; I = 164 (44–284)).

Site of infection: abomasum, small intestine.

***Trichostrongylus* sp.**

Hosts: common eland (P = 28.9 %; I = 79.1 (2–243)).

Site of infection: small intestine.

Family CHABERTIIDAE Popova, 1952

Genus *Chabertia* Railliet & Henry, 1909

Chabertia ovina (Fabricius, 1788)

Hosts: European mouflon (P = 10 %; I = 32); saiga antelope (P = 8.7 %; I =2.5 (2–3)).

Site of infection: large intestine.

Genus *Oesophagostomum* Molin, 1861

Oesophagostomum venulosum (Rudolphi, 1809)

Hosts: American bison (P = 18.2 %; I = 24 (13–35)); markhor (P = 18.2 %; I = 13.5 (1–26)); European mouflon (P = 40 %; I = 14 (5–21)); Barbary sheep (P = 60 %; I = 37.7 (2–99)); saiga antelope (P = 8.7 %; I = 9 (8–10)); Ankole–Watusi (P = 100 %; I = 28); African buffalo (P = 100 %; I = 2); sika deer (P = 50 %; I = 4); red deer (P = 50 %; I = 3.7 (1–6)); guanaco (P = 33.3 %); I = 10); nilgai (P = 28.6 %; I = 3).

Site of infection: abomasum (in markhor), small intestine, caecum.

***Oesophagostomum* sp.**

Hosts: common eland (P = 28.9 %; I = 9.7 (1–29)).

Site of infection: caecum.

Family DICTYOCAULIDAE Skrjabin, 1941
Genus *Dictyocaulus* Railliet & Henry, 1907
Dictyocaulus filaria (Rudolphi, 1809)
Hosts: European mouflon (P = 10 %; I = 37).
Site of infection: lungs.

Genus *Nematodirus* Ransom, 1907
Nematodirus abnormalis (May, 1920)
Hosts: European mouflon (P = 20 %; I = 1015 (1–2029)).
Site of infection: abomasum, small intestine.
Nematodirus sp.
Hosts: American bison (P = 9.1 %; I = 4); Ankole-Watusi (P = 100 %; I = 3); Siberian ibex (P = 100 %; I = 2); common eland (P = 28.9 %; I = 686.2 (1–4,420)); blackbuck (P = 62.5 %; I = 272.8 (5–599)); Barbary sheep (P = 60 %; I = 55 (14–131)); saiga antelope (P = 34.8 %; I = 42.4 (1–194)); markhor (P = 63.6 %; I = 167.6 (2–340)); red deer (P = 33.3 %; I = 2 (1–3)); guanaco (P = 66.7 %; I = 102.1 (75–130)); llama (P = 66.7 %; I = 234 (12–456)); alpaca (P = 100 %; I = 8); nilgai (P = 14.3 %; I = 1).
Site of infection: abomasum, small intestine, caecum.

Order Spirurida Chitwood, 1933
Family Habronematidae Chitwood & Wehr, 1932
Genus *Parabronema* Baylis, 1921
Parabronema skrjabini (Rassowska, 1924)
Hosts: llama (P = 33.3 %; I = 2).
Site of infection: abomasum.

Family Onchocercidae Chabaud & Anderson, 1959
Genus *Setaria* Viborg, 1795
Setaria labiatopapillosa Railliet et Henry, 1911
Hosts: American bison (P = 45.5 %; I = 5.6 (1–14)); Barbary sheep (P = 20 %; I = 1); African buffalo (P = 100 %; I = 1); red deer (P = 16.7 %; I = 1).
Site of infection: abdomen, caecum (in Barbary sheep and red deer).

Order Oxyurida Weinland, 1858.
Family Oxyuridae Cobbold, 1864
Genus *Skrjabinema* Werestchajin, 1926
Skrjabinema ovis (Skrjabin, 1915)
Hosts: markhor (P = 27.3 %; I = 15.7 (2–31)); saiga antelope (P = 43.5 %; I = 64.9 (2–245)); blackbuck (P = 12.5 %; I = 9).
Site of infection: small intestine, ceacum.

Order Enoplida Filipjev, 1929
Family Trichuridae (Railliet, 1911) Railliet, 1915
Genus *Trichuris* Roederer, 1761
Trichuris ovis (Abildgaard, 1795)
Hosts: American bison (P = 9.1 %; I = 5); Barbary sheep (P = 60 %; I = 81 (2–204)); saiga antelope (P = 87 %; I = 77.3 (4–334)); European mouflon (P = 40 %; I = 8.5 (1–28)); markhor (P = 45.5 %; I = 17.2 (1–47)); Ankole-Watusi (P = 100 %; I = 12); African buffalo (P = 100 %; I = 1); red deer (P = 50 %; I = 16.7 (12–26)); alpaca (P = 100 %; I = 13); Bactrian camel (P = 100 %; I = 125).
Site of infection: caecum.

Tr. cervicaprae Kreis, 1935

Hosts: common eland (P = 21.1 %; I = 23 (1–83)); markhor (P = 18.2 %; I = 17.5 (2–33)); blackbuck (P = 25 %; I = 14.5 (12–17)).

Site of infection: caecum.

Tr. skrjabini (Baskakov, 1924)

Hosts: American bison (P = 9.1 %; I = 21); Barbary sheep (P = 40 %; I = 21 (1–41)), European mouflon (P = 10 %; I = 2), markhor (P = 18.2 %; I = 20 (12–28)); banteng (P = 100 %; I = 12).

Site of infection: caecum.

***Trichuris* sp.**

Hosts: guanaco (P = 100 %; I = 9.3 (1–25)); llama (P = 66.7 %; I = 20 (7–33)); nilgai (P = 57.1 %; I = 5 (3–9)).

Site of infection: caecum.

Distribution of the helminth species among ungulates

The distribution of helminth species amount their ungulate hosts from different families was unequal (tabl. 2). Ungulates from the family Bovidae were found to be the most infected with helminths — 36 species were documented in the bovids; from 1 to 18 (mean = 7.5) species parasitized one host species. In the family Camelidae, 15 helminth species were found; from 3 to 10 (mean = 7.3) species parasitized one host species. In Cervidae, 9 helminth species were found; from 1 to 6 species (mean = 3.3) per host. The number of helminth species was also distributed unevenly among ungulate species (fig. 1).

Analysis of the occurrence of different helminth species, especially, nematodes, showed that nematodes of the genus *Trichuris* parasitized 15 species of ungulates; nematodes of the genus *Nematodirus* — 13 species, *Trichostrongylus* — 12, *Oesophagostomum* — 11, of the genera *Heamonchus* and *Camelostrongylus* — 9, *Cooperia* — 8 ungulate species. The most widespread cestodes were from the genus *Moniezia* which were found in 11 species of ungulates, and *Taenia* – in 7 host species (table 2). All of these helminths are typical parasites of domestic ruminants.

The ungulates introduced from the regions with natural and climatic conditions similar to those of the southern Ukraine were found to possess a greater helminth diversity comparing to the ungulates introduced from more arid or more humid regions of the world (tables 1, 2).

Helminth community of Bovidae

In 16 ungulate species from the family Bovidae included in our study (table 1), 260,955 helminths of 35 species were found. The largest helminths diversity was recorded in saiga antelopes (19 species), Barbary sheep (18 species), European mouflons (18), markhors (17), American bisons (12), blackbucks (10) and common elands (9) (fig. 1). The structure of the helminth communities in all these ungulates was found to be disrupted; commonly 1–3 of the most abundant species composed the "core" of the community, and consisted of 50 % to 80 % of the total helminth number; while the intensity of other species was low (fig. 2).

Ten most abundant species (*H. contortus*, *Nematodirus* sp., *A. bovis*, *M. expansa*, *Oe. venulosum*, *O. circumcincta*, *T. axei, T. colubriformis, T. probolurus*, *Tr. ovis*) were found in more than 30 % of the animals. These species are all typical parasites of domestic ruminants in southern Ukraine (Trach, 1986; Ivashkin et al., 1989). One introduced species *Ca. mentulatus*, typical for camels, saigas, and small domestic ruminants in Asia (Hilton et al., 1978) infected six species of Bovidae; it was the dominant species in the parasite community of blackbucks. Two species of nematodes (*C. verrucosa* and *T. cervicaprae*) that had been introduced into the Askania-Nova with common elands (Zvegintsova & Treus, 2007), infected different species of exotic bovids (table 2).

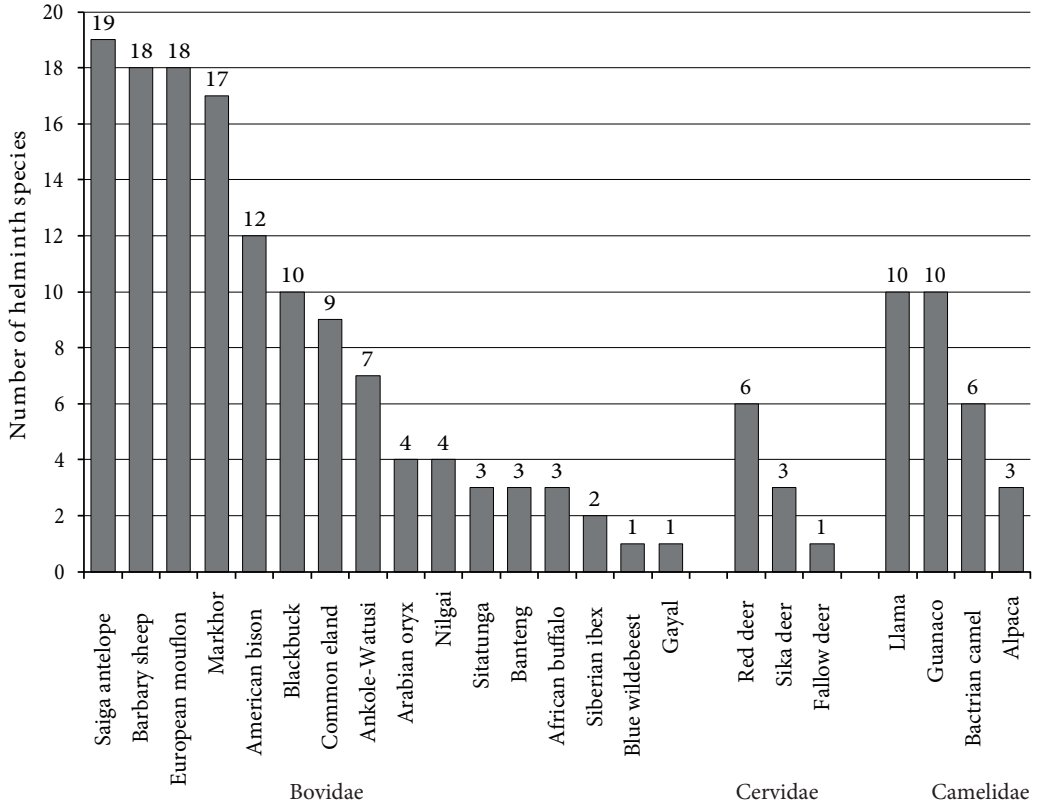


Fig. 1. Number of helminth species found in various species of ungulates in the Askania-Nova Biosphere Reserve, Ukraine.

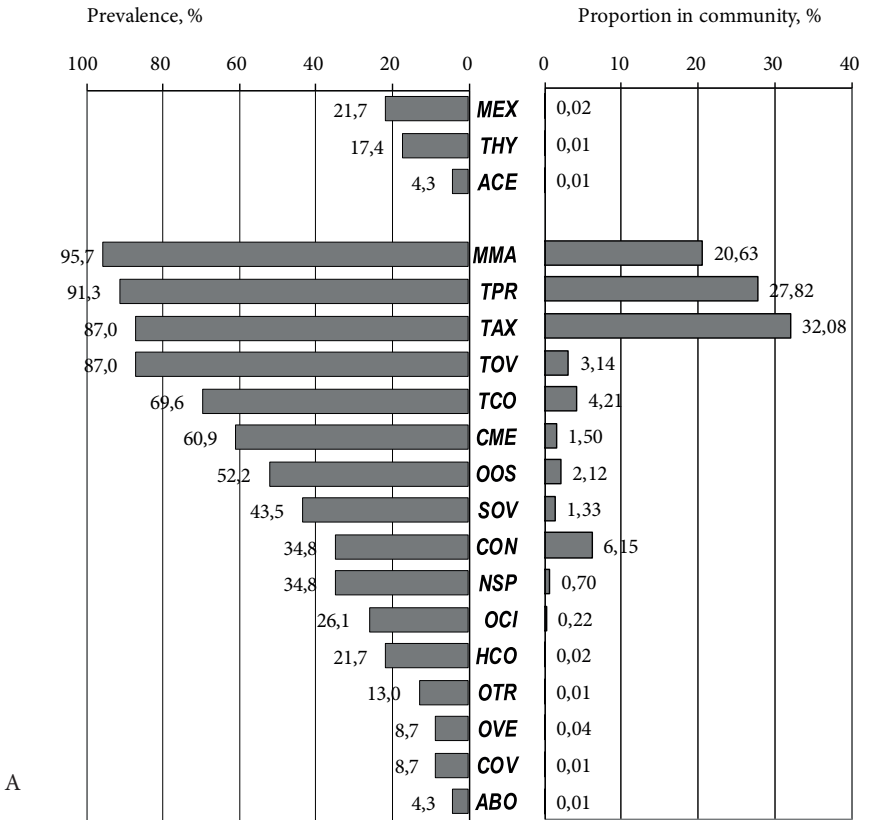
Exotic Bovidae species introduced from Africa, Central and South-East Asia (blue wildebeest, African buffalo, gayal, sitatunga, banteng, Siberian ibex) had the lowest helminth diversity, from one to three species were found in these ungulates (fig. 1).

Helminth community of Cervidae

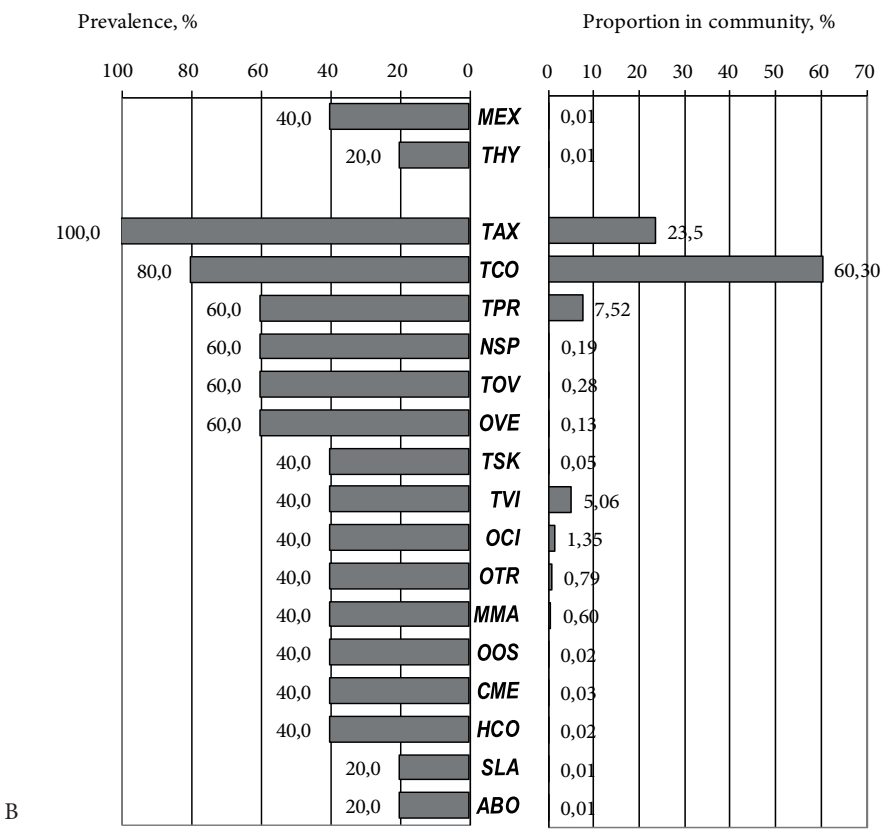
Nine species of helminths were found in four species of Cervidae: one species of trematodes, two species of cestodes, and six species of nematodes (table 2). From one to four species parasitized simultaneously one host species; two Pere David's deer examined were not infected with any helminths. All the species found are typical parasites of domestic ruminants; helminths specific for Cervidae in their natural habitats were not found.

Helminth community of Camelidae

Fifteen species of helminths were found in four species of Camelidae: two species of cestodes and 13 species of nematodes (table 2); from three to 10 species parasitized one host species. The largest species diversity (10 species) was recorded in guanacos and llamas (fig. 3). The structure of the helminth community in the Camelidae was also disrupted — nematodes of the genus *Nematodirus*, typical for domestic ruminants, made up the "core" of both parasite communities and composed more than 75 % of the total helminth number in guanacos and llamas. *Camelostrongylus mentulatus,* a typical parasite of camels in Asia, was found in three species: Bactrian camel, guanaco and llama; its prevalence was high only in the Bactrian camel, up to 600 specimens per host.


Prevalence, %
Proportion in community, %
100 80 60 40 20 0
0 10 20 30 40
21,7 MEX 0,02
17,4 THY 0,01
4,3 ACE 0,01
95,7 MMA 20,63
91,3 TPR 27,82
87,0 TAX 32,08
87,0 TOV 3,14
69,6 TCO 4,21
60,9 CME 1,50
52,2 OOS 2,12
43,5 SOV 1,33
34,8 CON 6,15
34,8 NSP 0,70
26,1 OCI 0,22
21,7 HCO 0,02
13,0 OTR 0,01
8,7 OVE 0,04
8,7 COV 0,01
4,3 ABO 0,01

A


Prevalence, %
Proportion in community, %
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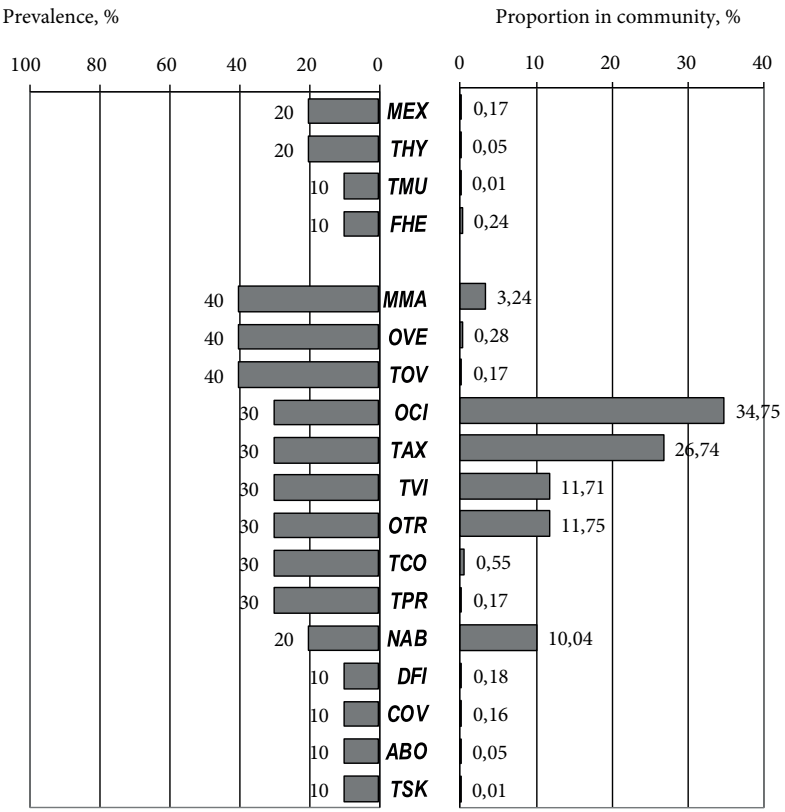
0 10 20 30 40 50 60 70
40,0 MEX 0,01
20,0 THY 0,01
100,0 TAX 23,5
80,0 TCO 60,30
60,0 TPR 7,52
60,0 NSP 0,19
60,0 TOV 0,28
60,0 OVE 0,13
40,0 TSK 0,05
40,0 TVI 5,06
40,0 OCI 1,35
40,0 OTR 0,79
40,0 MMA 0,60
40,0 OOS 0,02
40,0 CME 0,03
40,0 HCO 0,02
20,0 SLA 0,01
20,0 ABO 0,01

B


Prevalence, %
Proportion in community, %
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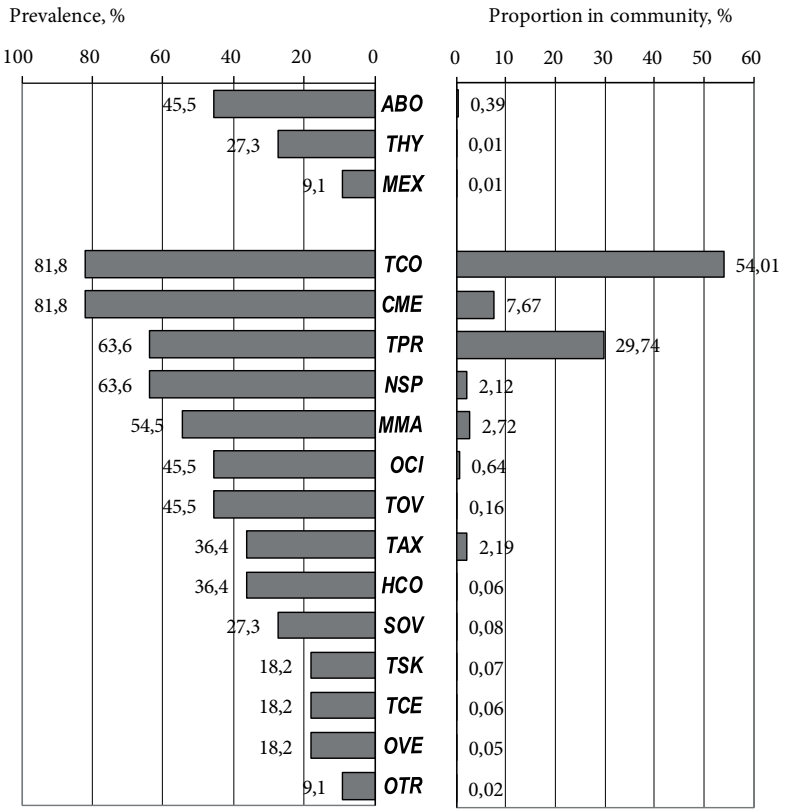
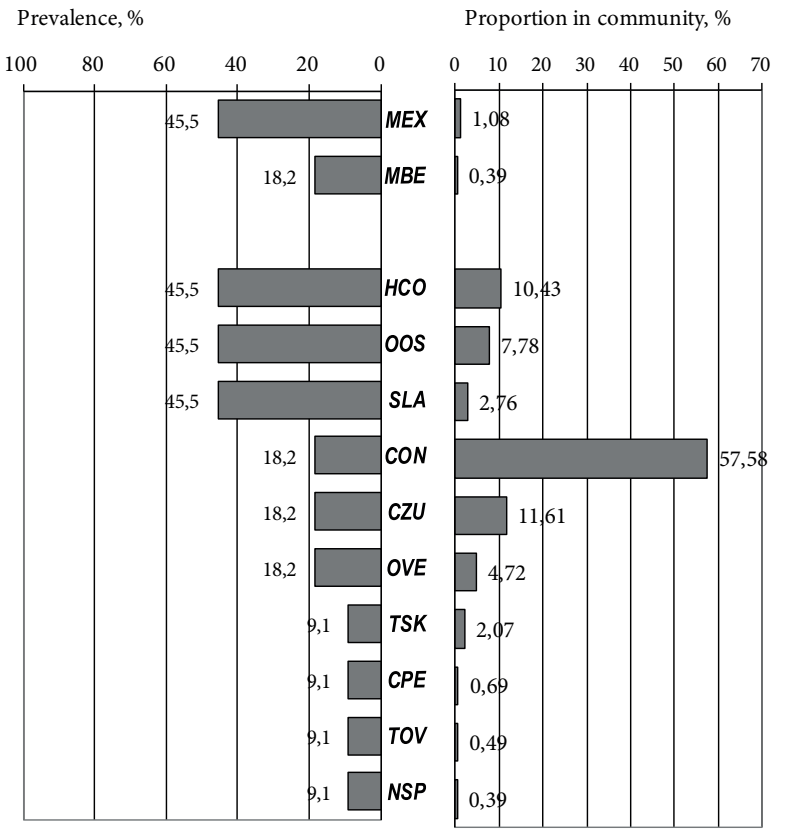
0 10 20 30 40
20 MEX 0,17
20 THY 0,05
10 TMU 0,01
10 FHE 0,24
40 MMA 3,24
40 OVE 0,28
40 TOV 0,17
30 OCI 34,75
30 TAX 26,74
30 TVI 11,71
30 OTR 11,75
30 TCO 0,55
30 TPR 0,17
20 NAB 10,04
10 DFI 0,18
10 COV 0,16
10 ABO 0,05
10 TSK 0,01

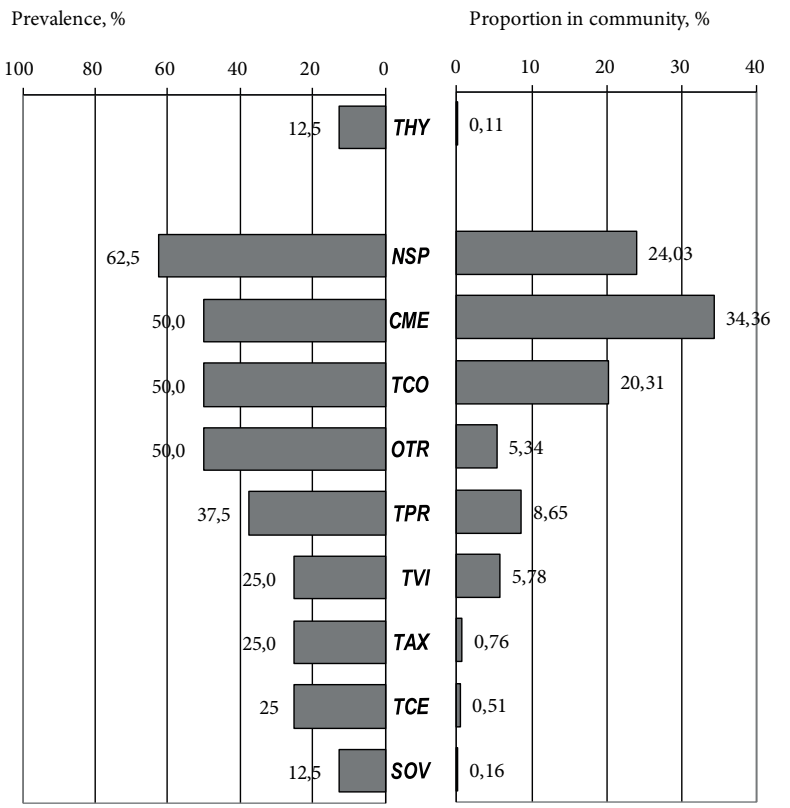
C


Prevalence, %
Proportion in community, %
100 80 60 40 20 0
0 10 20 30 40 50 60
45,5 ABO 0,39
27,3 THY 0,01
9,1 MEX 0,01
81,8 TCO 54,01
81,8 CME 7,67
63,6 TPR 29,74
63,6 NSP 2,12
54,5 MMA 2,72
45,5 OCI 0,64
45,5 TOV 0,16
36,4 TAX 2,19
36,4 HCO 0,06
27,3 SOV 0,08
18,2 TSK 0,07
18,2 TCE 0,06
18,2 OVE 0,05
9,1 OTR 0,02

D


Prevalence, %
100 80 60 40 20 0
Proportion in community, %
0 10 20 30 40 50 60 70
45,5 MEX 1,08
18,2 MBE 0,39
45,5 HCO 10,43
45,5 OOS 7,78
45,5 SLA 2,76
18,2 CON 57,58
18,2 CZU 11,61
18,2 OVE 4,72
9,1 TSK 2,07
9,1 CPE 0,69
9,1 TOV 0,49
9,1 NSP 0,39

E


Prevalence, %
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Proportion in community, %
0 10 20 30 40
12,5 THY 0,11
62,5 NSP 24,03
50,0 CME 34,36
50,0 TCO 20,31
50,0 OTR 5,34
37,5 TPR 8,65
25,0 TVI 5,78
25,0 TAX 0,76
25 TCE 0,51
12,5 SOV 0,16

F

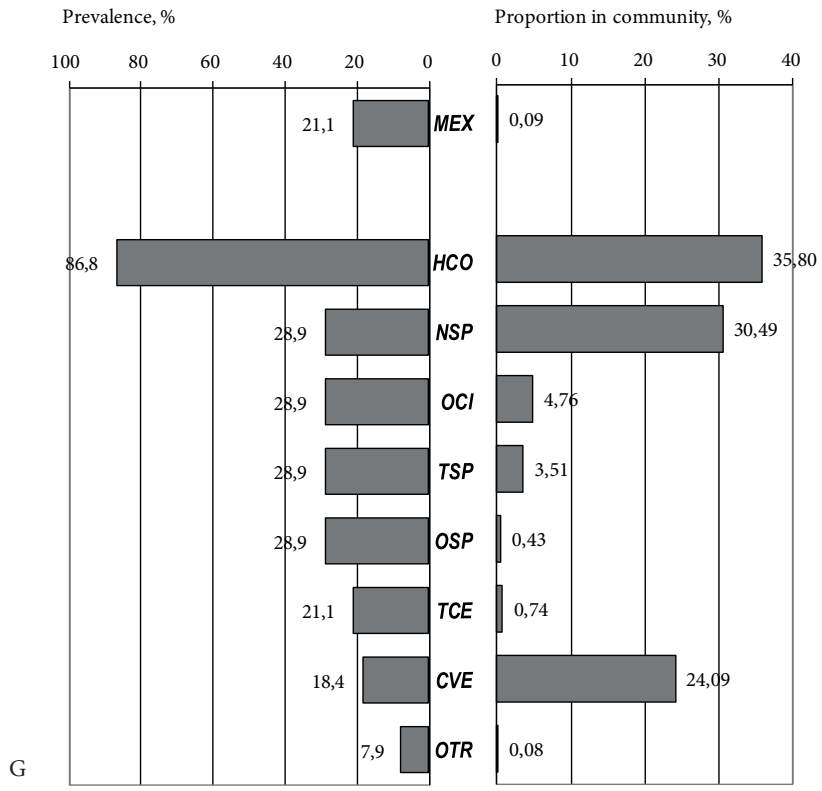

Fig. 2. Structure of the helminth communities in ungulates of the family Bovidae from the Askania-Nova Reserve: A — saiga antelope, B — Barbary sheep, C — European mouflon, D — markhor, E — American bison, F — blackbuck, G — common eland.
Cestodes and trematodes: *MEX — Moniezia expansa; MBE — M. benedeni*; *THY — Taenia hydatigena; TMU — Taenia multiceps; ACE — Avitellina centripunctata*; *FHE — Fasciola hepatica;* Nematodes: *ABO — Aonchotheca bovis; CME — Camelostrongylus mentulatus; CON — Cooperia oncophora; CPE — C. pectinata*; *CZU — C. zurnabada*; *CVE — C. verrucosa; COV — Chabertia ovina; DFI — Dictyocaulus filaria; HCO — Haemonchus contortus; MMA — Marshallagia marshalli; NSP — Nematodirus* sp.; *NAB — N. abnormalis; OOS — Ostertagia ostertagi; OCI — O. circumcincta; OTR — O. trifurcata; OVE — Oesophagostomum venulosum; OSP — Oesophagostomum* sp.; *SLA — Setaria labiatopapillosa; SOV — Skrjabinema ovis; TPR — Trichostrongylus probolurus; TAX — T. axei; TCO — T. colubriformis; TVI — T. vitrinus; TOV — Trichuris ovis; TSK — T. skrjabini; TCE — T. cervicaprae; TSP — Trichostrongylus* sp.

Analysis of the similarity of the parasite faunas in different ungulates

The Bray-Curtis cluster analysis of the species diversity of ungulates revealed that Barbary sheep and markhors had the highest similarity within the parasite faunas; saiga antelopes and European mouflons were similar to them (fig. 4). Exotic ungulates such as gayal, banteng, sitatunga and blue wildebeest had the lowest similarity of their parasite faunas with other ungulates. Two species of Cervidae, fallow deer and sika deer, had severely impoverished parasite communities — only one and three species, respectively, were found in these hosts; thus their parasite faunas were also significantly different from those of other ungulates.

Discussion

In this paper, we analyzed the diversity of parasite species collected from exotic ungulates in the Askania-Nova Reserve during about four decades. Even though some of these data were partially analyzed and published earlier (Treus & Zvegintsova, 1979;

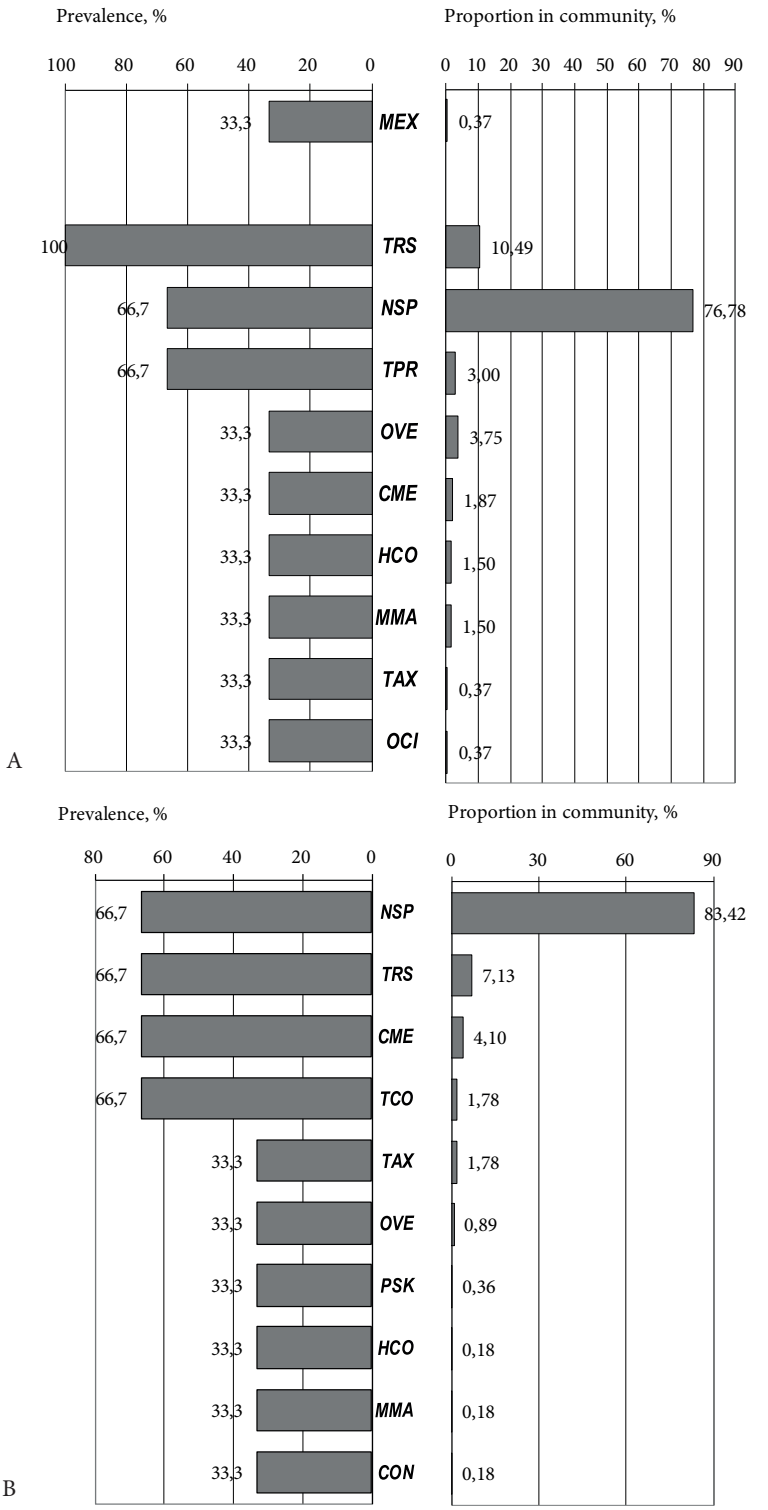

Fig. 3. Structure of the helminth communities of two Camelidae species from the Askania-Nova Biosphere Reserve: A — Guanaco, B — Llama. Cestodes: *MEX — Moniezia expansa;* Nematodes: *CME — Camelostrongylus mentulatus; CON — Cooperia oncophora; HCO — Haemonchus contortus; MMA — Marshallagia marshalli; NSP — Nematodirus* sp.; *OCI — Ostertagia circumcincta; OVE — Oesophagostomum venulosum; PSK — Parabronema skrjabini*; *TPR — Trichostrongylus probolurus; TAX — T. axei; TCO — T. colubriformis; TRS — Trichuris* sp.

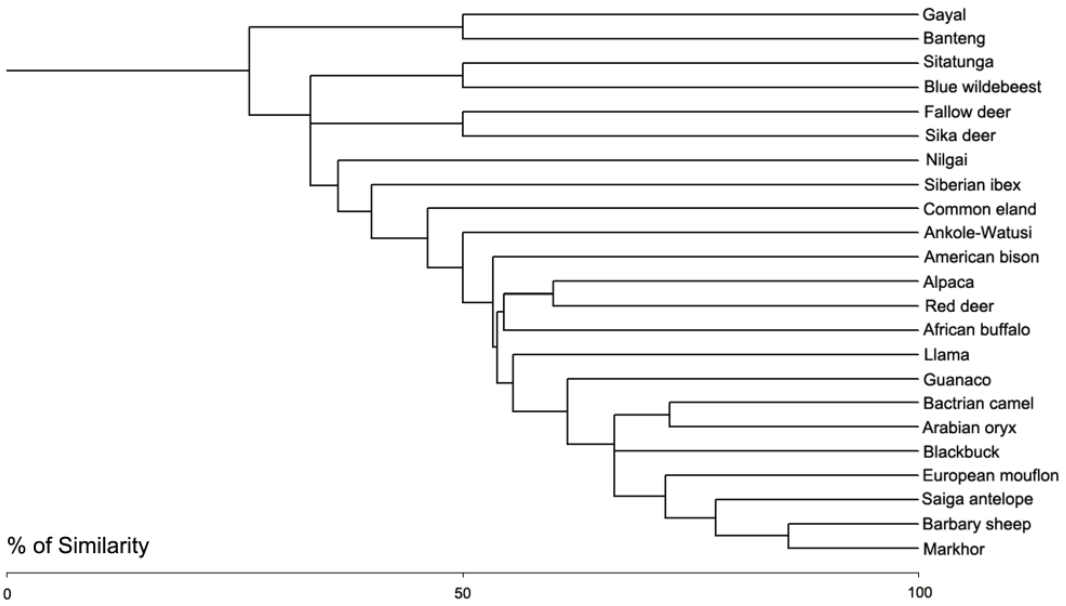

Fig. 4. Bray-Curtis cluster analysis of the species diversity in 23 species of ungulates from the Askania Nova Reserve, Ukraine.

Zvegintsova & Treus, 2007; Zvegintsova, 2008, 2009, 2012, 2013, 2014; Zvegintsova et al., 2015), a complete list of the parasites is published for the first time in the present paper. In 24 species of exotic ungulates kept in the Reserve, 38 species of helminths were found. Most of these species are common for wild and domestic ruminants in Europe, including Ukraine (Shumakovich, 1968; Govorka et al., 1988; Trach, 1986; Kuzmina et al., 2010; Anisimova, 2016).

Twenty-seven species found in our study are monoxenous — they have direct life cycles and do not require any intermediate hosts (Boev et al., 1963; Shumakovich, 1968; Olsen, 1986). This greatly facilitates their circulation in the ecosystem within the Reserve. As for the heteroxenous helminths with complex life cycles, we found trematodes from the genera *Paramphistomum* and *Fasciola*, cestodes from the genera *Avitellina*, *Moniezia*, and larval forms (cysts) of *Taenia hydatigena*, *Taenia multiceps* and *Echinococcus granulosus*, as well as two nematode species from the genera *Parabronema* and *Setaria*. For the trematodes, fresh-water snails of the genera *Bulinus, Planorbis, Physa, Stagnicola* and *Pseudosuccinea* are the intermediate hosts (Horak, 1971; Olsen, 1986); these snails are widely distributed throughout the territory of Europe, including Ukraine. Despite there were no special studies on the snail diversity in the Askania-Nova Reserve, we suppose these snails inhabit local natural ecosystems and can be included in life-cycles of these trematodes. Moreover, many digenean trematodes can parasitize their ruminant hosts for years (Boev et al., 1963; Skrjabin & Petrov, 1964), and, it is probable, that specimens found in our study could have been transported into the Askania-Nova Reserve together with their hosts and persisted in them throughout their whole life.

Six species of cestodes found in our study parasitize wild and domestic ungulates in Europe, including Ukraine (Shumakovich, 1968; Govorka et al., 1988; Shimalov & Shimalov, 2003; Demiaszkiewicz, 2005; Kuzmina et al., 2010; Anisimova, 2016). These parasites could have been brought into the Askania-Nova with their hosts from nature, as well as they could be transmitted to them locally. The main definitive hosts for cestodes of the genera *Echinococcus* and *Taenia* are wild and domestic carnivores

including wolves, foxes, jackals and domestic dogs (Skrjabin & Petrov, 1964). In the Askania-Nova, the infection of ungulates with cestode larval stages is probably connected with their contacts with foxes and domestic dogs. The level of infection was low — single cysts of *E. granulosus* and *Taenia* spp. were found in less than 10% of the animals; thus the cestodes hardly pose a significant threat to the ungulate health in the Reserve.

Twenty-nine nematode species were found in the gastrointestinal tract and respiratory system of the ungulates. Eleven species: *Ca. mentulatus, C. oncophora, H. contortus, M. marshalli, Nematodirus* sp., *O. circumcincta, Oe. venulosum*, *T. axei, T. colubriformis, T. probolurus* and *Tr. ovis* dominated the parasite communities (figs 2 and 3). All these species, except for *Ca. mentulatus,* are common parasites of ruminants in Ukraine (Skryabin & Petrov, 1964; Shumakovich, 1968; Trach, 1986; Safiulin, 1997; Kuzmina et al., 2010). These species were reported in the ungulates in natural habitats: in Barbary sheep (Mayo et al., 2013), saigas (Morgan et al., 2005), mouflons (Jansen, 1976; Balicka-Ramisz et al., 2017), camels and blackbucks (Farooq et al., 2012; Thornton et al., 1973), llamas (Cheney & Allen, 1989; Richard & Bishop, 1991; Abdouslam et al., 2003), and in various ruminants in Europe (Govorka et al., 1988; Shimalov & Shimalov, 2003; Demiaszkiewicz, 2005; Rehbein & Visser, 2007; Borkovcova et al., 2013; Rehbein et al., 2014; Pilarczyk et al., 2015; Anisimova, 2016).

Setaria labiatopapillosa and *P. skrjabini* found in the Askania-Nova Reserve are heteroxenous nematodes with complex life cycles. Both species have wide specificity to their hosts; they were recorded in various domestic ruminants and camelids in Europe and Asia (Kaufmann, 1996). More specialized parasites such as *S. cervicapra*, a parasite of antelopes in Asia (Singh & Pande, 1963), were not found in the Askania-Nova Reserve. We suppose that absence of suitable insect vectors prevent the transmission of this nematode under climatic conditions of southern Ukraine.

Restricted data on the species diversity of the parasites of exotic ungulates (artiodactyls) in nature are available in literature. Most of the studies were carried out by coprological methods examining the animals from zoos and nature reserves where dissection of animals for parasitological studies was impossible (Epe et al., 2001; Farooq et al., 2012; Vadlejch et al., 2015; Mir et al., 2016; Sengar et al., 2017). Therefore, we were not able to collect enough data to perform reliable comparative analysis of the parasite diversity of ungulates kept in the Askania-Nova Reserve and under natural conditions. However, we could observe that in nature the parasite communities of some exotic ungulates are represented by small number of specific species. For example, the common elands from the national parks in Africa harbored only 2–5 specific species of nematodes (Sachs & Sachs, 1968; Zieger et al., 1998; Boomker et al., 2000); while, in Askania-Nova, the common elands were infected with nine species mostly typical for domestic ruminants, except of their specific nematodes, *C. verrucosa* and *T. cervicaprae* (table 2). The blackbucks examined under natural conditions in Pakistan also harbored only two helminth species (Farooq et al., 2012); while 10 species were detected in Askania-Nova. At the same time, the parasite community of the blue wildebeests was extremely impoverished, only a couple of *H. contortus* were found; while up to 17 helminth species were registered in the blue wildebeests in Africa (Horak et al., 1983). The same pattern was observed in exotic ungulates from several zoos where their parasite communities are impoverished and supplemented with species from domestic ruminants (Jansen & van den Broek, 1963; Lim et al., 2008; Panayotova-Pencheva, 2013; Mir et al., 2016; Kvapil et al., 2017).

In this study, we observed dramatic alteration within the parasite community structure in most of the ungulates kept in the Askania-Nova Reserve. The main "core" of the communities was presented by 1–3 dominant non-specific species that were found in most of the animals; these species composed more than half, and sometimes even more than

80% of the total parasite number. All of these dominant species (*T. colubriformis, T. axei, T. probolurus, O. circumcincta, M. marshalli, C. oncophora, H. contortus, Nematodirus* sp., etc.) are common in domestic ruminants in southern Ukraine (Trach, 1986; Ivashkin et al., 1989). We believe that, except of peculiarities of the natural and climatic conditions of the steppe natural zone of the southern Ukraine, this depletion in the parasite fauna was associated with effective quarantine measures and parasite control programs conducted in the Reserve for decades.

In our study, the highest species diversity was observed in parasite communities of Bovidae, 36 helminth species were found. This is related to larger number of examined bovids (126 animals of 16 species) comparing to Cervidae and Camelidae, as well as to their habitate conditions. Except for a small number of exotic species such as sitatunga, blue wildebeest, banteng or Arabian oryx which are traditionally kept in the Askania-Nova Zoo individually or in small groups, most Bovidae are kept in large steppe enclosures together with other ungulates. Such habitat conditions facilitate the exchange of parasites among different host species and maintenance of high parasite biodiversity.

Among the Bovidae, the highest number of host individuals were examined in common elands (38 animals) and saiga antelopes (31 animals). Common elands were introduced to the Askania-Nova first in 1892 (Treus, 1968; Zvegintsova & Treus, 2007). Generally, these antelope had lost most of their specific African parasite species, except for two nematodes: *C. verrucosa* and *Tr. cervicaprae*, and then became infected with the parasite fauna typical for domestic ruminants in the Askania Nova (Zvegintsova & Treus, 2007). Saiga antelopes were imported to Ukraine several times; the last large group of saigas was brought to the Askania-Nova in 1979 from Kazakhstan. Therefore, despite that most of their specific parasites disappeared, the species composition of saiga's parasites in the Reserve is still similar to that in saigas from Kazakhstan (Zvegintsova et al., 2015).

Similar patterns are observed for other species of ruminants including European mouflons, Barbary sheep and markhors. These ungulates are in semi-free populations which have been kept in the Reserve for about 50–70 years. Despite the high species richness (17–18 species) of parasites in these ungulates, all of these species are typical of domestic ruminants (Boev et al., 1963; Shumakovich, 1968; Trach, 1986). Similar alterations in the parasite faunas were observed in these ungulates in different countries (Allen et al., 1956; Boev et al., 1963; Jansen, 1976; Mayo et al., 2013; Bartczak & Okulewicz, 2014; Rana et al., 2015; Balicka-Ramisz et al., 2017). In regard to exotic Bovidae from tropical or warm areas, a conspicuous depletion of parasite fauna (down to 1–3 species) was observed in the Askania-Nova Reserve. We assume that most of their specific helminths could not survive under dry and cold climatic conditions of the steppe zone of Ukraine. At the same time, physiological and biological specificity of these exotic ungulates does not allow them to acquire infection from other ungulates kept in the Reserve.

The Camelidae are usually kept in small groups separately from other ungulates. Most of the camelids were imported to the Askania-Nova in the 1950s: guanaco in 1957, llamas in 1958, and alpaca in 1959. Only one group of Bactrian camels is kept in the zoo since 1931 (Zvegintzova, 2015). Obviously, during this time, the diversity of their parasites has declined compared to that in Bactrian camels in natural habitats (Boev et al., 1963; Cheney & Allen, 1989; Rickard & Bishop, 1991; Abdouslam et al., 2003; Tajik et al., 2011; Taylor et al., 2016; Sazmand & Joachim, 2017). Only one nematode species, *Ca. mentulatus*, introduced to Askania-Nova with camels is successfully transmitted among several ungulates (table 2).

The lowest species diversity of parasites was registered in Cervidae — from one to six species were found per host species; while high species diversity has been traditionally

observed in cervids under natural conditions (Vengust & Bidovec, 2003; Santin-Duran et al., 2004; Rehbein & Visser, 2007; Kuzmina et al., 2010; Borkovcova et al., 2013; Rehbein et al., 2014; Pilarczyk et al., 2015). In the Askania-Nova Reserve, the deer are traditionally kept in large steppe enclosures together with other ruminants, such as saigas and various bovids. However, massive infection with parasites from other ruminants was not observed in the deer. In our study, single specimens of nematode species typical for ruminants (*C. oncophora, Oe. venulosum, Nematodirus* sp., *T. axei, Tr. ovis*) were found. We believe that this decline in the parasite numbers may be related to physiological and biological characteristics of the deer, which inhibited their infection with parasites from other ruminants, as well as the dry and hot summers in southern Ukraine. These factors would decrease survival and transmission of the larval stages of most of their specific parasites.

We also found that a highly pathogenic abomasum nematode *Ashwortius sidemi* which had been introduced into Europe with sika deer from Asia and Far East was not detected in any cervids or other ungulates in Askania-Nova. Currently, *A. sidemi* has spread widely among wild ungulates in European countries: Slovakia, Czechia, Poland, France, etc. (Ferté et al., 2000, Dródż et al., 2000; Demiaszkiewicz et al., 2009; Kowal et al., 2012). In Ukraine, this nematode was documented in sika deer and red deer in several regions (Dvojnos & Pogrebniak, 1977; Kuzmina et al., 2010). According to our results, the parasite community of the Far East sika deer in Askania-Nova is extremely impoverished — only trematodes, larval forms of cestodes and one species of nematodes, *Oe. venulosum*, were found in this host. We consider that except of effective quarantine measures performed in the Reserve, dry and hot climatic conditions prevented the distribution of *A. sidemi*.

Comparison of the parasite faunas in different ungulate species in the Askania-Nova Biosphere Reserve revealed that the highest species diversity was observed in ungulates (Barbary sheep, markhor, European mouflon and saiga antelope) characterized by biology and ecology similar to those in domestic goats and sheep (fig. 4). These ungulates harbored the highest number of helminth species typical for small domestic ruminants in southern Ukraine. The parasite fauna observed in exotic ungulates from Africa or Southeast Asia, such as gayal, banteng, sitatunga and blue wildebeest, was the most dissimilar to that in other ungulates.

Thus, the results of this study indicated significant changes in the parasite faunas of the exotic ungulates kept in the Askania-Nova Biosphere Reserve. It was found that specialized parasites mostly disappeared from the communities; instead, the communities were enriched with local species typical of domestic ruminants in southern Ukraine. The same example of depletion and destruction of the parasite communities was observed in various species of Equidae kept in the Reserve (Dvojnos et al., 1990; Dvojnos & Kharchenko, 1994; Kuzmina et al., 2007, 2009, 2013). Only a few cases of successful introduction of exotic nematode species, namely *Ca. mentulatus, C. verrucosa* and *Tr. cervicaprae* were observed in the present study. However, effective quarantine measures and deworming programs performed in the Reserve resulted in progressive impoverishment of the species diversity and disruption of the parasite community structure in exotic ungulates kept in the Askania-Nova.

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