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Helminths of domestic and wild artiodactyls (Mammalia, Artiodactyla) in Uzbekistan

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The article discusses some features of the helminthofauna of domestic and wild artiodactyls in Uzbekistan, represented by the families Suidae, Cervidae, and Bovidae. The total of 14 species turned out to be hosts to helminths. The prevalence ranged 75.5% to 100.0%. Our research team identified 103 helminth species, belonging to the classes Cestoda (13 species), Trematoda (10), Acanthocephala (1), and Nematoda (79). The highest parasite species diversity was recorded in the domestic animals: 48 species in sheep, 34 in goats, and 40 in cattle. The number of helminth species in wild artiodactyls varied from 13 to 28. Most of the recorded helminths parasitised different parts of the artiodactyls' bodies, causing serious diseases. They were found in almost all organs. The most widespread helminths in the animals studied included the representatives of the class Cestoda – *Moniezia expansa*, *M. benedeni*, *Avitellina centripunctata*, and *Echinococcus granulosus*. From the class Trematoda, these included *Fasciola hepatica*, *F. gigantica*, *Gastrothylax crumenifer*, *Calicophoron erschowi*, *Dicrocoelium dendriticum*, and *Schistosoma turkestanicum*. The class Nematoda in this regard was represented by *Trichocephalus ovis*, *Chabertia ovina*, *Dictyocaulus filaria*, *Metastrongylus elongatus*, *Ostertagia occidentalis*, *Marshallagia marshalli*, *Nematodirus helvetianus*, *Teladorsagia circumcincta*, *Gongylonema pulchrum*, *Parabronema skrjabini*, and *Setaria labiatopapillosa*. Of the total number of helminths species of artiodactyls, a number of species are of interest from the point of view of medical parasitology. According to their life cycle, the helminths can be divided into two groups: homoxenous and heteroxenous. The first one, homoxenous, consists of parasites that do not change hosts throughout their life. According to our materials, this group included nematodes from the genera *Trichocephalus*, *Strongyloides*, *Bunostomum*, *Chabertia*, *Oesophagostomum*, *Trichostrongylus*, *Haemonchus*, *Marshallagia*, *Nematodirus*, *Ostertagia*, *Dictyocaulus*, *Skrjabinema*, *Ascaris,* and *Neoascaris*. The second, he heteroxenous, group was formed by all representatives of the classes Cestoda, Trematoda, and Acanthocephala, and also some Nematoda species. We identified oligochaetes, molluscs, and insects as intermediate hosts. The artiodactyls of Uzbekistan were also determined as intermediate hosts to parasites from the family Taeniidae, class Cestoda. The hosts and their parasites exerted close topical (in relation to biosystems) and trophic relationships, which ensures contacts with components of the parasitic system and contributes to the formation of the helminthofauna and the circulation of parasites in the wild of Uzbekistan.

Keywords: helminthes; fauna; intermediate hosts; artiodactyls; Uzbekistan.

Introduction

Against the background of the rapid ongoing development of economy and culture, along with the growing use of natural resources, animals' habitats are being increasingly transformed, which also affects various aspects of the life of such components of biodiversity as parasitic organisms. Those changes manifest in the parasites' distribution and abundance, as well as their roles and importance in ecosystems. Those circumstances urge researches in the field of parasitology to carry out extensive studies, particularly, regarding the conservation of biological diversity associated with increased productivity and rational use of natural resources, optimisation of human relations with the environment, and also regarding the basic laws of the functioning of parasitic systems in specific groups of animals.

Furthermore, as the anthropogenic impact drives changes in the historical relations among animals, including the established faunal parasitic complexes, studying the formation of the faunal complexes of helminths and forecasting the appearance of foci of the most dangerous helminthiases are crucial from theoretical and practical aspects. Such research regarding artiodactyls in Uzbekistan is necessary to develop measures to prevent the spread of the most harmful parasitic worm diseases in the rangelands by combating pathogens in both the host's organism and the surroundings.

Uzbekistan is endowed with a rich environment and vast territories for the habitation of wild artiodactyls and for breeding domestic animals such as sheep, goats, and cattle. As a major national branch of industry, livestock breeding is one of the priorities in the country's socio-economic development. Agrarian reforms implemented after 1991 have resulted in the formation of a new economic structure, with the reorganisation of outdated forms of management into private farming. Specific measures have been taken to develop livestock breeding and veterinary sectors. A special focus has been placed on improving the species and breed compositions of sheep, goats, and cattle through the import of highly productive animals.

All these major changes in the livestock breeding have in a certain way triggered changes in the helminthology and epizootology of parasitic diseases. Helminthiases continue to cause significant economic damage to livestock farms, and thus, in our opinion, require new, more research-based approaches to prevention and control. Unfortunately, the results of the previous studies on certain helminths of domestic and wild artiodactyls in Uzbekistan (Sultanov et al., 1975; Matchanov et al., 1986) are quite outdated and fragmentary. Moreover, there are a number of artiodactyl species in Uzbekistan that had not been included in helminthological studies earlier.

Artiodactyla, or even-toed ungulates, are the focus of parasitological studies in many parts of Asia, Europe, Africa, America, and Australia. Researchers have made a significant progress in studying the fauna of helminths in certain species. A considerable amount of work in this field has been conducted by the scientists in Transcaucasian and Central Asian countries (Asadov, 1960; Boyev et al., 1962, 1963). Thus, Asadov (1960) examined 34 species of domestic and wild ruminants from the order Artiodactyla and recorded 232 species of parasitic worms, representing the classes Cestoda (20 species), Trematoda (17), Acanthocephala (1), and Nematoda (194). Boyev et al. (1962, 1963) studied 16 species of artiodactyls in Kazakhstan from the families Suidae, Cervidae, and Bovidae, detecting helminth infections in both domestic and wild animals. These authors identified from 15 to 92 species of helminths in each representative of Artiodactyla. The highest helminth species diversity was recorded in domestic artiodactyls – sheep (92 species), goats (60), and cattle (55). The helminthofauna of wild artiodactyls was significantly less diverse and ranged 1 to 36 species.

A number of parasitologists studied the helminthofauna of domestic and wild artiodactyls in Ukraine and Belarus (Trach, 1954, 1959; Treus & Dvoinos, 1985; Bychkova et al., 2017; Zvegintsova et al., 2018), recording helminths from the classes Cestoda, Trematoda, Acanthocephala, and Nematoda. The total numbers of helminth species in artiodactyls accounted for about 90 in Ukraine and more than 50 in Belarus (Bychkova et al., 2017).

The helminthofauna of Artiodactyla has become more actively studied in recent years. Many of the studies have been conducted in various Eurasian countries, where some representatives of Suidae, Cervidae, and Bovidae were examined through dissection. The researchers who have contributed to the studies include Gräfner (1980), Barutzki et al. (1989) and Murnik et al. (2024) in Germany; Genchi et al. (1982) and Fagiolini et al. (2010) in Italy; Ortiz et al. (2001) and Pérez et al. (2008) in Spain; Hertzberg & Kohler (2006) in Switzerland; Drózdz et al. (1989) in Poland; Sharhun & Sharkhun (2004) in Mongolia; Panova et al. (2017) in Russia; Talukdar et al. (2020) and Khurshid et al. (2021) in India; and others. The authors provide valuable information about the fauna of parasitic worms in wild artiodactyls in various Eurasian countries. The recorded helminths representted the parasitic classes Cestoda, Trematoda, and Nematoda. The researchers admit the possibility of cross infection between domestic and wild artiodactyls in the studied territories. Durie (1951) and Andrews (1973) reported about the helminthofauna of ruminants in Australia and New Zealand. Larval forms of Taeniidae from the class Cestoda and mature forms of *Facsiola* sp. and *Paramphistomum* sp. from the class Trematoda were recorded in domestic ruminants. Substantial studies on the helminthofauna of artiodactyls have been performed by the African researchers (Horak, 1981; De Villiers et al., 1985; Boomker et al., 1986, 1989; Krecek et al., 1990; Zieger et al., 1998; Junker et al., 2019; Kamani et al., 2020). In particular, parasitic worms of Artiodactyla in a number of African countries have been studied to the same extent as in Eurasia. The recorded parasites belonged to the classes Cestoda, Trematoda, Acanthocephala, and Nematoda. The predominating worms have been those inhabiting the digestive organs. Researchers in North and South America have also paid great attention to the study of the helminthofauna of Artiodactyla (Boomker et al., 1984, 1989; Corn et al., 1985; Purdy et al., 2012; Sánchez et al., 2012; Oyarzun-Ruiz et al., 2018; Barbosa et al., 2020; Dib et al., 2020; Pinheiro et al., 2023). In particular, Oyarzun-Ruiz et al. (2018) reported the infection of the deer populations (*Pudu puda*) with the nematode *Dictyocaulus eckerti* Skrjabin, 1931 in Chile and Argentina; and other groups of Artiodactyla were found to harbour worms of Cestoda, Trematoda, and Nematoda in Peru (Sánchez et al., 2012), Brazil (Boomker et al., 1984; Barbosa et al., 2020; Dip et al., 2020; Pinheiro et al., 2023), and the USA (Corn et al., 1985; Purdy et al., 2012). Some of the recorded helminth species were common to both domestic and wild artiodactyls.

The Global Mammal Parasite Database (GMPD) (Stephens, Pappalardo, Huang et al., 2017) contains analyses of 2,700 literary sources, according to which, wild artiodactyls have been observed to have Trematoda in 211 cases, Cestoda in 257 cases, Nematoda in 2,918 cases, and Acanthocephala in 3 cases. This brief review of the works dedicated to artiodactyl parasites suggests that the helminthofauna of domestic animals (sheep, goats, cattle and pigs) has been studied most fully, but there is still a pressing need for research on the helminthofauna of wild artiodactyls.

The objective of this study was comparing the helminthofaunas of domesticated and wild artiodactyls in different regions of Uzbekistan.

Materials and methods

The research was carried out in the Laboratory of General Parasitology at the Institute of Zoology, Academy of Sciences of the Republic of Uzbekistan, in 2018–2024. The material comprised of the helminths from sheep, goats, and cattle, collected on the livestock farms in Uzbekistan in all seasons of the year. The helminthological material from wild artiodactyls, namely, wild boar and Siberian roe deer, was collected during hunting seasons. Other species, such as Bukhara deer, Siberian ibex, markhor, argali, Severtsov's argali, saiga, urial, and goitered gazella were studied in limited numbers. We dissected the carcasses of animals that had died naturally or been killed by hunters. The volume of the material is illustrated in tables 1 and 2. The rate of infection with helminths was determined by complete and incomplete helminthological dissection of the infected animals and their organs using the method proposed by Skrjabin (1928). We also examined the faeces of wild animals—argali, urial, goitered gazella, deer, Siberian ibex, Siberian roe deer, and markhor—living in the Tashkent Zoo and in the reserves and sanctuaries across Uzbekistan for larvae and adult helminths. During the examination, our research team studied over 400 faecal samples.

Table 1
Species composition and number of individuals of studied artiodactyls in Uzbekistan (2018–2024)

Species		Studied	
Latina	English	number of individuals	sets of individual organs
Bos taurus dom.	Cattle	58	486
Capreolus pygargus (Pallas, 1771)	Siberian roe deer	11	–
Capra hyrcus dom.	Goat	124	333
C. falconeri (Wagner, 1839)	markhor	6	–
C. sibirica (Pallas, 1776)	Siberian ibex	12	–
Cervus hanglu bactrianus (Lydekker, 1900)	Bukhara deer	32	–
Gazella subgutturosa (Güldenstaedt, 1780)	goitered gazella	15	–
Ovis aries dom.	Sheep	149	630
O. ammon (Linnaeus, 1758)	Argali	12	–
Ovis vignei Blyth, 1841	Urial	11	–
O. ssp. Severtzovi, 1914	Severtsov's argali	7	–
Saiga tatarica (Linnaeus, 1766)	Saiga	16	–
Sus scrofa dom.	Pig	65	252
S. scrofa Linnaeus, 1758	wild boar	38	–
Total		567	1,702

To identify the helminths, we used well-known guides and monographs (Ivashkin et al., 1981, 1989; Anderson, 2000; Azimov et al., 2015). The helminths' morphology was studied using temporary and permanent preparations under a J10M0 C-10 stereoscopic microscope (Digital Microscope, China, 2022), a CK 2-TR inverted microscope (Olympus, Germany, 2005), and an NLCD-307B binocular microscope (Motic, Japan, 2020). To identify the range of intermediate hosts of the dominant species and groups of trematodes and nematodes, we collected aquatic and terrestrial molluscs, and insects in the wilderness areas of Uzbekistan. The aquatic molluscs were examined using the hydrobiological method (Jadin, 1952), the terrestrial mollusks were studied using the malocological method (Pazilov & Azimov, 2008), and the insects were analyzed according to the the approach developed by Agrinsky (1962) and Kabilov (1983). In total, in the course of the research, we examined 1,591 individuals of domestic and wild artiodactyls (Suidae, Cervidae, Bovidae), 400 samples of faeces, and more than 10,000 individuals of oligochaetes, crustaceans, aquatic and terrestrial molluscs, and insects.

Table 2
The place of record and the time of the study of the host animals

Species	Regions								
	Central (2018–2019)			Northeastern (2020–2021)			Northwestern (2022–2024)		
	quantity	time of autopsy	distribution area, records coordinates	quantity	time of autopsy	distribution area, records coordinates	quantity	time of autopsy	distribution area, records coordinates
O. aries dom.	11	10.03–25.03	39°57'15.7"N 64°46'45.4"E	18	20.04–3.05	40°05'11.8"N 67°34'41.5"E	13	21.03–10.04	42°47'11.14"N 59°36'19.45"E
	13	20.05–5.06	40°07'54.9"N 64°50'50.6"E			40°07'20.2"N 67°36'05.8"E			43°4'27.53"N 59°10'52.74"E
	12	15.07–3.08	40°10'53.0"N 64°45'29.5"E			40°08'41.2"N 67°33'59.4"E	10	25.06–11.07	42°42'19.35"N 59°44'22.04"E
			40°03'19.4"N 64°11'46.6"E	14	25.07–5.08	40°09'16.4"N 67°32'23.2"E			42°43'4.97"N 59°42'43.94"E
	14	2.10–25.10	39°39'55.6"N 64°08'46.4"E			40°04'15.8"N 67°29'01.1"E	11	23.10–7.11	42°42'40.58"N 59°41'32.93"E
			39°22'24.0"N 63°56'16.9"E			40°04'46.5"N 67°27'10.6"E			42°41'43.34"N 59°41'19.01"E
	12	26.11–6.12	39°33'03.8"N 63°43'48.3"E	12	28.10–8.11	40°30'22.4"N 67°40'08.5"E	9	20.01–10.02	42°57'59.22"N 59°46'43.01"E
			39°28'36.7"N 64°48'04.0"E			40°59'53.5"N 68°04'00.1"E			43°1'33.26"N 59°48'2.25"E
C. hyrcus dom.	13	5.05–12.05	39°57'15.7"N 64°46'45.4"E	14	20.06–3.07	40°05'11.8"N 67°34'41.5"E	11	26.04–11.05	43°3'13.64"N 59°54'49.62"E
			40°07'54.9"N 64°50'50.6"E			40°04'15.8"N 67°29'01.1"E			43°2'9.69"N 59°59'6.64"E
			40°10'53.0"N 64°45'29.5"E	12	22.10–5.11	40°08'41.2"N 67°33'59.4"E	11	23.08–5.09	43°1'19.36"N 60°19'51.99"E
	11	20.07–6.08	40°03'19.4"N 64°11'46.6"E			40°04'46.5"N 67°27'10.6"E			43°13'30.07"N 59°36'9.20"E
			39°28'36.7"N 64°48'04.0"E	11	16.12–23.12	40°30'22.4"N 67°40'08.5"E	14	25.11–6.12	43°26'42.11"N 59°36'36.59"E
	11	22.10–7.11	39°22'24.0"N 63°56'16.9"E			40°59'53.5"N 68°04'00.1"E			43°4'18.12"N 58°49'12.13"E
			39°33'03.8"N 63°43'48.3"E				16	27.01–12.02	43°0'38.95"N 58°49'10.02"E
									42°47'12.73"N 59°2'20.62"E
									42°37'8.57"N 59°12'16.95"E
									42°26'0.55"N 59°25'12.64"E
B. taurus dom.	5	25.01–7.02	39°28'36.7"N 64°48'04.0"E	3	25.03–8.04	40°05'11.8"N 67°34'41.5"E	4	22.03–9.04	42°47'11.14"N 59°36'19.45"E
	3	27.03–10.04	40°07'54.9"N 64°50'50.6"E	4	21.07–10.08	40°04'15.8"N 67°29'01.1"E			43°4'27.53"N 59°10'52.74"E
	4	22.06–9.07	40°10'53.0"N 64°45'29.5"E	4	29.10–8.11	40°08'41.2"N 67°33'59.4"E			42°42'19.35"N 59°44'22.04"E
	8	21.09–8.10	40°03'19.4"N 64°11'46.6"E			40°04'46.5"N 67°27'10.6"E	3	25.05–9.06	42°43'4.97"N 59°42'43.94"E
			39°39'55.6"N 64°08'46.4"E			40°30'22.4"N 67°40'08.5"E			42°42'40.58"N 59°41'32.93"E
	4	27.11–11.12	39°22'24.0"N 63°56'16.9"E	5	15.12–23.12	40°59'53.5"N 68°04'00.1"E			42°41'43.34"N 59°41'19.01"E
							5	28.11–12.12	43°26'42.11"N 59°36'36.59"E
									43°4'18.12"N 58°49'12.13"E
									43°0'38.95"N 58°49'10.02"E
									42°47'12.73"N 59°2'20.62"E
							6	22.02–5.03	42°37'8.57"N 59°12'16.95"E
									42°26'0.55"N 59°25'12.64"E
S. scrofa dom.	7	25.03–7.04	39°22'40.0"N 63°47'06.4"E	7	20.04–2.05	40°44'50.1"N 67°54'33.3"E	6	25.03–11.04	42°38'13.16"N 59°28'25.45"E
	5	28.06–6.07	39°22'29.8"N 63°45'12.1"E			40°39'34.2"N 68°10'56.6"E	5	21.09–3.10	42°38'4.87"N 59°30'37.35"E
			39°41'14.5"N 64°03'00.0"E	5	26.07–7.08	40°30'15.4"N 68°01'30.4"E			42°38'38.17"N 59°27'32.30"E
	6	22.10–3.11	39°42'32.5"N 64°04'29.3"E			40°31'45.8"N 68°01'09.9"E	6	30.11–12.12	42°38'13.89"N 59°30'25.94"E
			40°07'18.6"N 64°18'30.0"E	7	24.12–7.01	40°18'40.7"N 67°59'04.9"E			42°36'22.50"N 59°33'33.91"E
	5	15.12–25.12	40°06'44.7"N 64°15'35.2"E			40°18'48.9"N 67°52'18.5"E	6	28.02–4.03	42°36'4.88"N 59°35'47.52"E
			40°02'49.6"N 64°50'20.8"E						42°35'48.31"N 59°36'13.75"E
S. scrofa	3	21.10–11.11	40°40'00.4"N 64°30'09.0"E	5	24.11–6.12	40°42'02.3"N 67°38'48.3"E	8	15.10–25.10	42°57'31.88"N 61°31'12.20"E
			40°37'27.4"N 64°35'25.4"E			40°51'42.9"N 67°56'19.8"E			42°31'55.26"N 61°31'25.37"E
			40°26'47.7"N 63°14'07.0"E			40°49'22.9"N 66°55'08.1"E			42°46'07.94"N 61°53'25.81"E
			40°25'21.2"N 63°13'47.1"E			39°42'30.7"N 67°41'55.0"E			42°11'34.68"N 61°31'25.88"E
	5	23.12–7.01	40°22'15.3"N 63°30'50.0"E	9	30.12–11.01	39°41'36.8"N 67°46'09.2"E			43°30'51.19"N 62°07'03.50"E
			39°44'06.2"N 63°36'00.1"E			39°41'33.6"N 67°47'23.7"E	4	25.12–12.01	43°08'47.29"N 61°06'24.81"E
			39°45'16.7"N 63°32'08.2"E			39°41'49.9"N 67°49'33.4"E			42°07'35.20"N 61°28'34.41"E
			39°08'23.0"N 64°09'29.3"E			39°35'50.5"N 68°14'18.1"E			42°38'57.36"N 61°33'15.33"E
						39°35'38.3"N 68°13'45.1"E	4	30.01–9.02	43°37'55.49"N 61°33'15.50"E
						39°36'15.3"N 68°17'11.3"E			42°18'37.13"N 61°33'26.46"E
C. hanglu bactrianus	–	–	–	–	–	–	10	26.04–10.07	42° 0'54.19"N 60°18'46.38"E
									42° 0'14.39"N 60°19'13.86"E
							10	15.09–12.12	41°59'40.42"N 60°19'37.00"E
									41°58'55.83"N 60°20'24.22"E
							12	13.01–27.02	41°58'55.89"N 60°20'57.49"E
									41°59'48.92"N 60°18'53.41"E
C. pigargus	–	–	–	5	30.01–9.02	41°45′19.93″N 70°17′32.14″E	–	–	–
						41°48′49.58″N 70°19′04.26″E			
				4	5.10–18.12	41°49′34.61″N 70°20′22.32″E			
						41°52′25.27″N 70°24′22.98″E			
				2	25.12–12.01	41°53′40.87″N 70°26′42.76″E			
C. sibirica	–	–	–	4	8.10–6.11	41°36′06.72″N 70°07′27.12″E	–	–	–
						41°35′37.31″N 70°07′26.4″E			
				8	15.11–30.12	41°35′46.27″N 70°08′08.88″E			
						41°36′58.73″N 70°07′06.25″E			
						41°37′09.94″N 70°07′58.8″E			
C. falconeri	3	20.04–2.05	40°31′15.96″N 66°37′56.72″E	–	–	–	–	–	–
			40°27′54.84″N 66°41′55.23″E						
	1	26.07–7.08	40°28′06.88″N 66°40′56.08″E						
	2	10.10–30.12	40°28′07.02″N 66°39′39.6″E						
			40°31′37.23″N 66°36′07.76″E						
O. vignei	–	–	–	–	–	–	2	25.03–8.04	42°10'45.57"N 57°39'12.68"E

Species	Regions								
	Central (2018–2019)			Northeastern (2020–2021)			Northwestern (2022–2024)		
	quantity	time of autopsy	distribution area, records coordinates	quantity	time of autopsy	distribution area, records coordinates	quantity	time of autopsy	distribution area, records coordinates
									42°9'35.19"N 57°38'38.85"E
							5	21.07–10.08	42°0'19.83"N 57°2'51.46"E 42°2'41.98"N 57°3'27.34"E 41°22'21.70"N 56°58'47.93"E
							6	5.10–26.12	41°20'37.47"N 56°4'20.13"E 41°22'35.09"N 56°3'7.86"E 41°20'4.89"N 56°5'1.12"E
O. ammon	–	–	–	5	25.03–7.04	40°33′03.94″N 66°44′22.73″E 40°32′49.05″N 66°48′10.08″E	–	–	–
				4	28.06–6.07	40°31′25.56″N 66°48′04.61″E 40°31′36.36″N 66°46′34.47″E			
				2	9.10–30.12	40°30′43.07″N 66°47′17.13″E			
Ovis ssp.	–	–	–	1	25.03–7.04	42°13′45.33″N 71°02′59.03″E	–	–	–
				2	28.06–6.07	42°14′32.47″N 71°05′34.02″E 42°13′03.58″N 70°58′58.72″E			
				4	3.10–29.12	42°12′35.6″N 71°01′53.2″E 42°11′40.98″N 70°56′09.84″E			
S. tatarica	–	–	–	–	–	–	7	20.04–30.12	45° 0'9.82"N 57°34'34.90"E 45° 4'50.98"N 57°42'3.87"E 45°14'4.87"N 57°36'41.29"E 45°17'12.79"N 57°30'38.98"E
							9	5.01–15.02	45°15'13.46"N 57°45'42.41"E 45°8'45.56"N 57°49'44.82"E 45°9'11.52"N 57°52'49.67"E 45°24'11.47"N 58°8'37.84"E
G. subgutturosa	–	–	–	–	–	–	8	4.01–30.08	42°47'47.29"N 57°25'30.69"E 42°54'50.03"N 57°34'58.67"E 42°45'24.77"N 57°16'42.95"E 42°35'06.24"N 59°57'26.58"E 42°30'48.71"N 59°52'10.43"E 42°31'33.9"N 60°07'31.89"E
							7	10.09–26.12	41°58'55.79"N 56°30'45.71"E 44°00'46.62"N 61°16'51.83"E 43°51'52.99"N 61°27'14.87"E 43°48'55.16"N 61°16'01.90"E
Total: 567	168			171			228		

Results

The study found 14 examined species and subspecies of artiodactyls of the fauna of Uzbekistan to be the hosts to helminths. The prevalence ranged 75.5% to 100.0%, with the highest values recorded in the domestic representatives of artiodactyls, in particular, measuring 100.0% in the sheep, 87.5% in the goats, 94.5% in the cattle, and 90.0% in the pigs. The intensity of the infection, depending on the season, ranged from single to hundreds of individuals. In the course of the work ,103 species of helminths were identified, belonging to four classes – Cestoda (13 species), Trematoda (10), Acanthocephala (1), and Nematoda (79, Table 3).

Table 3
Species diversity and taxonomy of helminths in the artiodactyls of Uzbekistan

Class	Family	Species	Host	Infection intensity
Cestoda	Anoplocephalidae	*Moniezia expansa* Rudolphi, 1810	*O. aries* dom.	1–19
			O. vignei	1–3
			O. ammon	1–3
			C. hyrcus dom.	1–5
			C. falconeri	1–2
			B. taurus dom.	1–7
			C. pygargus	1–2
			S. tatarica	1–4
		Moniezia benedeni (Moniez, 1879)	*O. aries* dom.	3–15
			O. vignei	1–4
			O. ammon	1–3
			C. hyrcus dom.	1–3
			C. sibirica	1–2
			C. falconeri	1–2
			B. taurus dom.	1–8
			C. hanglu bactrianus	1–2
			C. pygargus	1–2
		Moniezia autumnalia Kuznetsov, 1967	*O. aries* dom.	1–2
			O. vignei	1–3
			O. ammon	1–2
			C. hyrcus dom.	1–2
			B. taurus dom.	1–3
		Moniezia alba (Perroncito, 1879)	*O. aries* dom.	1–2
			C. hyrcus dom.	1–2
	Avitellinidae	*Avitellina centripunctata* (Rivolta, 1874)	*O. aries* dom.	2–24
			C. hyrcus dom.	1–7
			B. taurus dom.	3–19
			C. pygargus	1–2
			S. tatarica	2–5
			G. subgutturosa	1–2
		Thysaniezia giardi (Moniez, 1879)	*O. aries* dom.	1–13
			O. vignei	1–2

Class	Family	Species	Host	Infection intensity
			C. hyrcus dom.	3–4
			B. taurus dom.	3–5
			C. pygargus	1–2
	Taeniidae	*Taenia solium* Linnaeus, 1758*	*S. scrofa*	1–30
		Taenia hydatigena Pallas, 1766*	*Ovis* ssp.	1–2
			O. aries dom.	1–5
			O. vignei	3–5
			O. ammon	3–5
			C. hyrcus dom.	1–2
			B. taurus dom.	3–9
			S. scrofa dom.	1–2
			C. hanglu bactrianus	1–2
			C. pygargus	1–3
			C. sibirica	1–2
			C. falconeri	1–2
			S. tatarica	1–3
			G. subgutturosa	1–3
		Taeniarhynchus saginatus (Goeze, 1782)*	*B. taurus* dom.	1–95
		Multiceps multiceps (Leske, 1780)*	*O. aries* dom.	1
			C. hyrcus dom.	1
			B. taurus dom.	1
		Multiceps gaigeri Hall, 1916*	*C. hyrcus* dom.	1
		Echinococcus granulosus (Batsch, 1786)*	*O. aries* dom.	1–20
			O. vignei	1–5
			O. ammon	1–5
			C. hyrcus dom.	3–9
			B. taurus dom.	5–13
			S. scrofa dom.	2–3
			S. scrofa	1–3
			C. hanglu bactrianus	3–5
			C. pygargus	3–4
			S. tatarica	1–6
			G. subgutturosa	3–5
		Echinococcus multilocularis Leuckart, 1863*	*O. aries* dom.	1–5
			B. taurus dom.	1–3
Trematoda	Fasciolidae	*Fasciola hepatica* Linnaeus, 1758	*O. aries* dom.	1–180
			O. vignei	3–7
			O. ammon	3–10
			C. hyrcus dom.	1–75
			B. taurus dom.	3–250
			S. scrofa dom.	1–7
			C. hanglu bactrianus	3–9
			C. pygargus	1–3
		Fasciola gigantica Cobbold, 1856	*O. aries* dom.	1–280
			C. hyrcus dom.	1–78
			B. taurus dom.	3–296
			S. scrofa dom.	1–5
			S. scrofa	1–3
			C. hanglu bactrianus	1–10
			S. tatarica	1–5
			G. subgutturosa	1–3
	Paramphistomidae	*Paramphistomum ichikawai* Fukui, 1922	*O. aries* dom.	5–160
			B. taurus dom.	3–250
		Calicophoron calicophorum (Fischoeder, 1901)	*O. aries* dom.	3–186
			B. taurus dom.	3–202
		Calicophoron erschowi Davydova, 1959	*O. aries* dom.	3–47
			B. taurus dom.	13–100
		Liorchis scotiae (Willmott, 1950)	*B. taurus* dom.	1–11
	Gastrothylacidae	*Gastrothylax crumenifer* (Creplin, 1847)	*O. aries* dom.	5–288
			C. hyrcus dom.	3–35
			B. taurus dom.	3–356
	Dicrocoeliidae	*Dicrocoelium dendriticum* (Rudolphi, 1819)	*Ovis* ssp.	3–21
			O. aries dom.	9–366
			O. vignei	3–25
			O. ammon	5–45
			B. taurus dom.	5–420
			C. hanglu bactrianus	3–75
			C. pygargus	3–11
			C. hyrcus dom.	3–98
			C. sibirica	3–9
			C. falconeri	1–5
	Echinochasmidae	*Echinochasmus perfoliatus* (Ratz, 1908)	*S. scrofa* dom.	3–17
			S. scrofa	3–13
	Schistosomatidae	*Schistosoma turkestanicum* Skrjabin, 1913	*O. aries* dom.	1–952
			C. hyrcus dom.	3–175
			B. taurus dom.	13–1650
			S. scrofa dom.	1–75
			S. scrofa	1–43
			C. hanglu bactrianus	3–137
			S. tatarica	3–80
			G. subgutturosa	3–62

Class	Family	Species	Host	Infection intensity
Acanthocephala	Oligocanthorhynchidae	*Macracanthorynchus hirudinaceus* (Pallas, 1781)	*S. scrofa* dom.	3–18
			S. scrofa	3–14
Nematoda	Trichocephalidae	*Trichocephalus ovis* Abildgaard, 1795	*Ovis* ssp.	1–3
			O. aries dom.	1–15
			O. ammon	1–3
			C. hyrcus dom.	1–5
			B. taurus dom.	1–19
			S. tatarica	1–5
			G. subgutturosa	1–3
		Trichocephalus suis Schank, 1788	*S. scrofa* dom.	1–9
			S. scrofa	1–7
		Trichocephalus globulosa von Linstow, 1901	*B. taurus* dom.	1–16
		Trichuris skrjabini Baskakov, 1924	*O. aries* dom.	1–13
			O. vignei	2–3
			O. ammon	3–6
			C. hyrcus dom.	1–2
			C. sibirica	1–3
			C. falconeri	1–3
			B. taurus dom.	3–17
			C. hanglu bactrianus	3–13
			C. pygargus	1–3
			S. tatarica	1–3
			G. subgutturosa	1–3
	Capillaridae	*Aonchotheca bovis* (Schneyder, 1906)	*B. taurus* dom.	1–7
	Dioctophaymidae	*Dioctophyme renale* (Goeze, 1782)	*S. scrofa* dom.	1–2
	Strongyloididae	*Strongyloides papillosus* (Wedl, 1856)	*O. aries* dom.	6–152
			B. taurus dom.	3–210
	Ancylostomatidae	*Bunostomum trigonocephalum* (Rudolphi, 1808)	*O. aries* dom.	5–110
			O. vignei	1–3
			O. ammon	2–5
			B. taurus dom.	1–105
			C. pygargus	1–5
			C. hanglu bactrianus	1–3
		Bunostomum phlebotomum (Railliet, 1900)	*Ovis* ssp.	1–2
			O. aries dom.	1–39
			O. vignei	1–2
			O. ammon	1–3
			C. pygargus	1–2
	Chabertidae	*Chabertia ovina* (Fabricius, 1788)	*O. aries* dom.	1–175
			O. vignei	2–3
			O. ammon	2–3
			C. hyrcus dom.	1–17
			B. taurus dom.	3–88
			C. pygargus	1–3
			S. tatarica	1–2
		Oesophagostomum columbianum Curtice, 1890	*O. aries* dom.	3–22
			O. ammon	1–3
			C. hyrcus dom.	1–3
			B. taurus dom.	3–19
		Oesophagostomum venulosum (Rudolphi,1809)	*O. aries* dom.	1–39
			O. vignei	1–2
			C. hyrcus dom.	1–5
			B. taurus dom.	3–45
			C. hanglu bactrianus	1–2
			C. pygargus	1–2
		Oesophagostomum asperum Railliet et Henry, 1909	*B. taurus* dom.	2–11
		Oesophagostomum radiatum Rudolphi, l803	*B. taurus* dom.	5–26
			S. scrofa dom.	3–7
	Dictyocaulidae	*Dictyocaulus filaria* (Rudolphi,1809)	*O. aries* dom.	2–65
			O. vignei	1–2
			O. ammon	1–2
			C. hyrcus dom.	1–11
			B. taurus dom.	2–55
			C. sibirica	1–2
			G. subgutturosa	2–3
		Dictyocaulus vivaparus (Bloch, 1782)	*B. taurus* dom.	3–11
		Dictyocaulus eckerti Skrjabini, 1931	*C. hanglu bactrianus*	1–3
	Protostrongylidae	*Protostrongylus davtiani* Savina, 1940	*O. aries* dom.	2–7
			O. ammon	2–1
			C. sibirica	11–10
			C. falconeri	1–9
		Protostrongylus hobmaieri Schulz, Orloff et Kutass, 1933	*O. aries* dom.	3–17
			O. vignei	1–2
			O. ammon	1–3
			C. hyrcus dom.	1–5
			C. falconeri	1–2
		Protostrongylus raillieti (Schulz, Orloff & Kutass, 1933)	*Ovis* ssp.	1–2
			O. aries dom.	4–52
			O. vignei	2–6
			O. ammon	2–8
			C. hyrcus dom.	3–22

Class	Family	Species	Host	Infection intensity
			C. sibirica	3–5
		Protostrongylus rufescens (Leuckart, 1865)	*O. aries* dom.	3–44
			O. vignei	1–3
			O. ammon	1–3
			C. hyrcus dom.	1–6
			C. sibirica	1–3
		Protostrongylus skrjabini (Boev, 1936)	*O. aries* dom.	1–10
			O. vignei	1–3
			O. ammon	1–2
			C. hyrcus dom.	1–3
		Protostrongylus caprae Zdzitowiecki et Boev, 1971	*O. aries* dom.	1–9
			C. hyrcus dom.	1–13
			C. falconeri	1–9
		Spiculocaulus leuckarti Schulz, Orloff et Kutass, 1933	*O. aries* dom.	3–7
			O. vignei	1–3
			O. ammon	1–3
			C. hyrcus dom.	1–2
			C. sibirica	1–2
			C. falconeri	1–2
		Spiculocaulus kwongi (Wu et Liu, 1943)	*Ovis* ssp.	1–3
			O. aries dom.	1–3
			C. hyrcus dom.	1–2
			C. falconeri	1–2
		Spiculocaulus austriacus (Gebauer, 1932)	*C. hyrcus* dom.	1–5
			C. sibirica	1–2
			C. falconeri	1–2
		Muellerius capillaris (Müller, 1889)	*O. aries* dom.	1–5
			O. vignei	1–2
			O. ammon	1–3
			C. hyrcus dom.	1–3
			C. sibirica	1–2
		Cystocaulus ocreatus (Railliet et Henry, 1907)	*O. aries* dom.	3–35
			O. vignei	1–3
			O. ammon	2–6
			C. hyrcus dom.	2–8
			C. sibirica	1–5
			C. falconeri	1–3
		Neostrongylus linearis (Marotel, 1913)	*O. aries* dom.	1–4
			C. hyrcus dom.	1–2
			C. sibirica	1–2
	Metastrongylidae	*Metastrongylus elongatus* (Dujardin, 1845)	*S. scrofa* dom.	3–10
			S. scrofa	3–7
		Metastrongylus pudentotectus Wostokow, 1905	*S. scrofa* dom.	1–13
			S. scrofa	3–10
		Metastrongylus salmi Gedoelst, 1923	*S. scrofa* dom.	2–9
			S. scrofa	3–9
	Trichostrongylidae	*Trichostrongylus axei* (Cobbold., 1879)	*O. aries* dom.	3–107
			O. vignei	1–10
			O. ammon	1–7
			C. hyrcus dom.	3–54
			B. taurus dom.	1–109
		Trichostrongylus capricola Ransom, 1907	*O. aries* dom.	2–25
			O. vignei	2–3
			C. hyrcus dom.	2–30
			C. pygargus	3–5
			C. falconeri	3–5
		Trichostrongylus colubriformis (Giles, 1892)	*O. aries* dom.	1–80
			O. vignei	1–3
			O. ammon	1–3
			C. hyrcus dom.	1–13
			B. taurus dom.	1–43
		Trichostrongylus probolurus (Railliet, 1896)	*O. aries* dom.	1–52
			O. vignei	1–2
			O. ammon	1–2
			C. hyrcus dom.	1–6
			C. pygargus	1–2
		Trichostrongylus skrjabini Kalantarian, 1928	*O. aries* dom.	3–16
			O. vignei	1–3
			O. ammon	1–5
			C. hyrcus dom.	3–5
		Trichostrongylus vitrinus Looss, 1905	*O. aries* dom.	1–13
			O. vignei	1–7
			O. ammon	1–5
			B. taurus dom.	3–33
			C. pygargus	1–9
		Camelostrongylus mentulatus (Railliet et Henry, 1909)	*O. aries* dom.	1–5
			C. hyrcus dom.	1–2
			S. tatarica	1–11
		Ostertagia occidentalis Ransom, 1907	*O. aries* dom.	1–23
			O. vignei	3–4
			O. ammon	1–3

Class	Family	Species	Host	Infection intensity
			C. hyrcus dom.	3–5
			B. taurus dom.	3–13
			C. pygargus	1–2
			C. falconeri	1–2
		Ostertagia belockani (Assadov, 1954)	*O. aries* dom.	1–5
		Ostertagia ostertagi (Stiles, 1892)	*O. aries* dom.	1–280
			O. vignei	3–7
			O. ammon	3–9
			C. hyrcus dom.	3–27
			B. taurus dom.	3–180
			C. sibirica	3–5
		Orloffia orloffi (Sankin, 1930)	*O. aries* dom.	3–5
		Haemonchus contortus (Rudolphi, 1803)	*O. aries* dom.	1–352
			O. vignei	1–5
			O. ammon	3–8
			C. hyrcus dom.	1–47
			B. taurus dom.	3–158
			C. hanglu bactrianus	1–17
			S. tatarica	3–11
		Haemonchus placei (Place, 1893)	*O. aries* dom.	3–78
			O. vignei	1–2
			O. ammon	3–5
			C. hyrcus dom.	1–9
			B. taurus dom.	3–156
			C. pygargus	1–3
			S. tatarica	1–3
			G. subgutturosa	1–3
		Marshallagia marshalli (Ransom, 1907)	*Ovis* ssp.	1–5
			O. aries dom.	5–550
			O. vignei	3–5
			O. ammon	1–9
			C. hyrcus dom.	3–150
			B. taurus dom.	3–675
			C. pygargus	3–5
			S. tatarica	3–15
			G. subgutturosa	1–25
		Marshallagia mongolica Schumakovitsch, 1938	*O. aries* dom.	1–66
			O. vignei	3–6
			O. ammon	3–6
			C. hyrcus dom.	3–5
			C. sibirica	1–3
			C. falconeri	1–4
			B. taurus dom.	3–5
			G. subgutturosa	1–8
		Marshallagia dentispicularis Asadov, 1954	*O. aries* dom.	1–13
			C. hyrcus dom.	2–5
		Marshallagia uzbekistanica Azimov et Dadaev, 2001	*O. aries* dom.	3–7
			C. hyrcus dom.	1–3
		Nematodirus abnormalis May, 1920	*O. aries* dom.	1–45
			O. vignei	1–3
			O. ammon	1–5
			C. hyrcus dom.	1–10
			B. taurus dom.	3–35
			C. sibirica	5–7
			S. tatarica	1–8
		Nematodirus archari Sokolova, 1948	*O. aries* dom.	3–5
			O. vignei	1–2
			O. ammon	1–3
			C. hyrcus dom.	1–3
			C. sibirica	1–2
			C. falconeri	1–2
		Nematodirus dogieli Sokolova, 1948	*O. aries* dom.	1–8
			O. vignei	1–2
			O. ammon	1–3
			C. hyrcus dom.	1–2
			G. subgutturosa	1–2
		Nematodirus helvetianus May, 1920	*O. aries* dom.	1–55
			O. vignei	3–45
			O. ammon	3–6
			C. hyrcus dom.	1–15
			B. taurus dom.	3–45
		Nematodirus filicollis (Rudolphi, 1802)	*O. aries* dom.	3–9
			C. hyrcus dom.	1–11
		Nematodirus oiratianus Raewskaja, 1929	*O. aries* dom.	1–108
			O. vignei	2–3
			O. ammon	3–6
			C. hyrcus dom.	1–8
			C. sibirica	1–3
			C. falconeri	2–3
			B. taurus dom.	5–110
			C. hanglu bactrianus	3–15

Class	Family	Species	Host	Infection intensity
			C. pygargus	3–5
		Nematodirus spathiger (Railliet, 1896) Railliet & Henry, 1909	*O. aries* dom.	3–96
			O. vignei	1–3
			O. ammon	3–5
			C. hyrcus dom.	1–13
			B. taurus dom.	3–59
			C. pygargus	1–3
			G. subgutturosa	3–5
		Nematodirella longispiculata Yorke & Maplestone, 1926	*O. aries* dom.	1–9
			G. subgutturosa	1–9
		Nematodirella gazelli (Sokolova, 1948)	*S. tatarica*	3–6
			G. subgutturosa	2–5
		Teladorsagia trifurcata (Ransom, 1907)	*O. aries* dom.	1–14
			O. ammon	1–3
			B. taurus dom.	1–3
		Teladorsagia circumcincta (Stadelman, 1894)	*O. aries* dom.	3–8
			O. vignei	3–5
			O. ammon	1–7
			C. hyrcus dom.	1–5
			C. sibirica	1–3
			C. falconeri	1–2
			B. taurus dom.	3–10
		Teladorsagia grigoriani Drozdz, 1965	*O. aries* dom.	1–3
	Syphaciidae	*Skrjabinema ovis* (Skrjabin, 1915)	*O. aries* dom.	2–38
			S. tatarica	3–5
			G. subgutturosa	1–5
		Skrjabinema caprae Schad, 1959	*C. hyrcus* dom.	1–7
	Ascarididae	*Ascaris suum* Goeze, 1782	*S. scrofa* dom.	1–39
			S. scrofa	1–11
		Neoascaris vitulorum (Goeze, 1782)	*B. taurus* dom.	1–11
	Gnatastomatidae	*Gnatastoma hispidum* Fedchenko, 1872	*S. scrofa* dom.	1–3
			S. scrofa	1–3
	Physocephalidae	*Physocephalus sexalatus* (Molin, 1860)	*S. scrofa* dom.	3–9
			S. scrofa	1–5
	Thelaziidae	*Ascarops strongylina* (Rudolphi, 1819)	*S. scrofa* dom.	1–13
			S. scrofa	1–12
	Gongylonematidae	*Gongylonema pulchrum* Molin 1857	*Ovis* ssp.	1–2
			O. aries dom.	1–3
			O. vignei	1–2
			O. ammon	1–3
			C. hyrcus dom.	1–2
			C. falconeri	1–2
			B. taurus dom.	1–3
			S. scrofa dom.	1–2
			S. scrofa	1–2
			C. hanglu bactrianus	1–2
			C. pygargus	1–2
			S. tatarica	1–2
			G. subgutturosa	1–2
	Habronematidae	*Parabronema skrjabini* Rossawska, 1924	*O. aries* dom.	3–475
			C. hyrcus dom.	1–105
			B. taurus dom.	3–566
			C. hanglu bactrianus	3–25
			C. pygargus	1–5
			G. subgutturosa	3–15
	Onchocercidae	*Onchocerca gutturosa* Neumann, 1910	*B. taurus* dom.	1–3
		Onchocerca lienalis (Stiles, 1892)	*B. taurus* dom.	3–5
		Setaria labiatopapillosa (Alessandrini, 1838)	*Ovis* ssp.	1–2
			O. aries dom.	1–18
			C. hyrcus dom.	1–9
			B. taurus dom.	1–22
			C. hanglu bactrianus	1–3
			C. pygargus	1–2
			C. sibirica	1–2
			S. tatarica	1–2
			G. subgutturosa	1–2
		Setaria bernardi Railliet et Henry, 1911	*S. scrofa* dom.	1–5
			S. scrofa	1–5
		Skrjabinodera saiga Gnedina et Vsevolodov, 1947	*O. aries* dom.	1–3
			O. vignei	1–2
			S. tatarica	1–3
		Stephanofilaria stilesi Chitwood, 1934	*B. taurus* dom.	20–150
		Stephanofilaria assamensis Pande, 1936	*B. taurus* dom.	15–105

Note. * – larval stages of cestodes.

Of the total number of helminth species, nematodes exhibited the absolute dominance, accounting for 79 species, which constitutes 76.7%. The second most common worms were cestodes (13 species), which were followed by trematodes (10 species). According to the helminths' distribution across the host families, the largest species diversity of the parasites was recorded in Bovidae, comprising 89 species, or 87.2%. The lists of helminths recorded in every species of Artiodactyla are givenin Table 3. The presented materials demonstrate that the species diversity of helminths in artiodactyls in Uzbekistan is quite specific and varies widely depending on the host group. Domestic animals were parasitised by a diverse helminthofauna, with the average number of 34.5 species of helminths. The average number of helminth species recorded in the wild animals was 18.3. The fact that the highest helminth diversity among the different families of artiodactyls was noted in Bovidae is to a large degree associated with the diversity of the helminthofauna of domestic animals – sheep, goats, and cattle. The higher species diversity in domesticated artiodactyls was a general tendency (Table 4).

Table 4
Natural prevalence of infection with helminths in the artiodactyls of Uzbekistan

Host	Prevalence, %	Number of species				
		total	Cestoda	Trematoda	Acanthocephala	Nematoda
Suidae						
Sus scrofa dom.	70.7	18	3	4	1	10
Sus scrofa Linnaeus, 1758	90.0	18	3	4	1	10
Cervidae						
Capreolus pygargus (Pallas, 1771)	54.5	16	4	1	–	11
Cervus hanglu bactrianus (Lydekker, 1900)	71.8	16	4	3	–	8
Bovidae						
Bos taurus dom.	99.5	40	8	7	–	25
Capra falconeri (Wagner, 1839)*	–*	17	4	1	–	12
Capra hyrcus dom.	87.5	34	7	5	–	22
Capra sibirica (Pallas, 1776)	58.3	25	4	1	–	20
Gazella subgutturosa (Güldenstaedt, 1780)	80.0	17	5	2	–	10
Ovis ammon (Linnaeus, 1758)	83.3	28	4	2	–	22
Ovis aries dom.	100.0	48	9	5	–	34
Ovis vignei Blyth, 1841	81.8	17	4	–	–	13
Ovis ssp. Severtzovi, 1914*	–*	17	4	1	–	12
Saiga tatarica (Linnaeus, 1766)	63.0	13	5	2	–	6

Note: * – prevalence is unknown due to the small number of dissected individuals.

By comparing various groups of artiodactyls in Uzbekistan, we determined a significant similarity in the compositions of helminth species of Cervidae and Bovidae, which is, probably, associated with the similar ecology and habitats. The majority of the helminth species were common to both groups, indicating the interchange of helminths between wild and domestic animals. Nevertheless, Suidae (wild and domestic pigs) contained a specific helminthofauna. In this group, wild boars showed a higher parasite species diversity (18). Qualitatively, the helminthofauna of the pigs differed significantly from the other groups of artiodactyls. Of the 28 species of helminths detected in pigs, 13 were found to be specific to this group, likely due to their feeding habits and environmental conditions. The identified helminths parasitised different parts of the host's body. They were detected in almost all the organs and systems, potentially causing serious diseases in the animals.

By their life cycle, the helminths can be divided into two groups.

1. Homoxenous forms of nematodes, the life cycle of which does not involve an intermediate host. According to our research, this group includes species from the genera *Trichocephalus*, *Strongyloides*, *Bunostomum*, *Chabertia*, *Oesophagostomum*, *Trichostrongylus*, *Grosspiculagia*, *Hacmonchus*, *Marshallagia*, *Nematodirus*, *Ostertagia*, *Teladorsagla*, *Dictyocaulus*, *Skrjabinema,* and *Ascaris*. These forms of nematodes develop according to the following pattern. Female parasites lay eggs in the lumens of the digestive or respiratory systems. The eggs containing embryos at the stage of several blastomeres are released into the external environment with faeces. In a favourable environment, the embryo in the egg turns into a first-stage larva, which leaves the egg after the first moult and becomes infectious to ruminant hosts. Representatives of the genera *Marshallagia*, *Nematodirus*, *Dictyocaulus,* and *Skrjabinema* show some deviations from this pattern. First and second stage larvae from the genus *Marshallagia* develop in the egg, and the second-stage larva is released into the external environment to become infectious in 8–9 days after the release. Unlike *Marshallagia*, larvae of *Nematodirus* are infectious already upon the emergence from the eggs, where they undergo two moults. The female *Skrjabinema ovis* lays eggs with larvae that are already infectious. Representatives of the genus *Dictyocaulus* lay eggs in the lumen of the bronchi and trachea. In the digestive tract, the larvae hatch from the eggs and are excreted with faeces into the external environment, where they reach the infectious stage after 5–8 days. The infectious larvae or eggs enter the organisms of the artiodactyls together with food (grass) and water.

2. Heteroxenous forms of helminths, the life cycle of which involves a change of hosts. According to our research, this life cycle applies to all representatives of the classes Cestoda, Trematoda, and Acanthocephala, and to most species of Nematoda parasitising artiodactyls in Uzbekistan. The life cycles of heteroxenous groups of helminths are quite complex. Based on the results of our research and the well-known literary data, we can describe those cycles using helminths of domestic artiodactyls in Uzbekistan as examples (Table 5).

Biology of cestodes. All representatives of the Cestoda class are heteroxenous parasites, infecting more than one kind of host. Life cycles vary quite distinctly across species and may exemplify different types. The main difference between these cycles is that some cestodes use invertebrates as their intermediate hosts, while others use vertebrates, including artiodactyls. The first type relates to representatives of the families Anoplocephalidae and Avitellinidae. The ribbon-like forms of cestodes inhabit the small intestine. Mature segments with numerous eggs detach from the strobilae. These segments are mechanically destroyed in the rectum or after leaving the body with faeces. By that time they are already infectious to their intermediate hosts – oribatid mites and springtails (*A. centripunctata*), in which larval stages develop with the formation of cysticercoids. Cysticercoids from the genera *Moniezia* and *Avitellina* do not actively leave their intermediate hosts. The cestodes' life cycle continues inside ruminants, when the latter ingest the cysticercoids with oribatid mites. The ribbon-like forms of cestodes develop in the small intestine. The second type of life cycle is typical of cestodes from the family Taeniidae, which has been studied quite fully across the world.

Table 5
Intermediate hosts of helminths of artiodactyls in Uzbekistan

Host	Examined, individuals	Infected, %	Infection of intermediate hosts with larval stages of helminths, %			
			Cestoda	Trematoda	Acanthocephala	Nematoda
Oligochaeta	1.052	3.1	–	–	–	3.1
Aquatic molluscs	2.228	28.4	–	28.4	–	–
Terrestrial molluscs	2.840	16.6	–	2.6	–	14.0
Insects	2.300	4.6	–	0.3	0.3	4.0
Artiodactyls	1.591	42.0	42.0	–	–	–

Table 5 shows that a wide range of intermediate hosts – oligochaetes, gastropods (aquatic and terrestrial) and insects – can participate in the life cycles of helminths of artiodactyls in Uzbekistan. The oligochaetes turned out to be intermediate hosts to nematodes from the family Metastrongylidae parasitising domestic and wild pigs. The aquatic gastropods were intermediate hosts to trematodes from the families Fasciolidae, Echinochasmidae, Paramphistomatidae, and Schistosomatidae; and the terrestrial molluscs were intermediate hosts to Dicrocoeliidae and Protostrongylidae. The insects in our study were second intermediate hosts to trematodes (Dicrocoeliidae) and were also involved in the life cycles of nematodes from the families Gangylonematidae, Habronematidae, and Onchocercidae. The artiodactyls in our research also acted as intermediate hosts to the tapeworms *T. hydatigena*, *T. saginatus*, *T. solium*, *M. multiceps*, *M. gaigeri*, *E. granulosus,* and *A. multilocularis*. The definitive host of the cestodes *T. saginatus* and *T. solium* is human. Domestic and wild carnivores are definitive hosts to *T. hydatigena*, *M. multiceps*, *M. gaigeri*, *E. granulosus,* and *A. multilocularis*.

As is known, the main factors determining helminthofaunas and helminths' abundance include the evolutionarily established parasite-host connections, which function on the basis of trophic and topical relationships. Several species of nematodes from the genus *Metastrongylus* and one representative of Acanthocephala (*M. hirudinaceus*) parasitise pigs trophically, when the latter ingest their intermediate (reservoir) hosts as food. However, the overwhelming majority of helminth species infect their hosts topically. Our research identified five species of larval stages of cestodes – *T. hydatigena*, *M. multiceps*, *E. granulosus*, *T. saginatus,* and *T. solium* – parasitising artiodactyls in Uzbekistan. To the first three species, all the studied artiodactyls are intermediate hosts. Cattle is an intermediate host to the cestode *T. saginatus*. The larval stages of *T. solium* develop in the body of domestic and wild pigs. Ungulates become infected with Taeniidae by ingesting their eggs through food, usually found in pastures and other areas where the animals congregate.

Cysticerci of some of the abovementioned cestodes require special attention, in particular, beef tapeworm *T. saginatus* and pork tapeworm *T. solium*, which in the mature stage (ribbon-like) parasitise the small intestine of human, their definitive host. Infection with these worms, teniarynchosis, is recorded in many countries of the world, including Uzbekistan, where it is especially common in people in the northwest (Khorezm Region and Republic of Karakalpakstan). The strobilae of these parasites can grow to great lengths: beef tapeworm commonly reaches 10 m and pork tapeworm can reach a length of 8 m. Both species can remain in their host for extended periods, potentially up to 20 years. Cattle and pigs are infected perorally by ingesting the oncospheres (eggs) from infected humans. The larval forms of the cestode develop in the muscular and connective tissues of cattle and pigs, where they turn into oval larvocysts – cysticerci. People become infected by ingesting meat and meat products that have not been properly treated by heat.

Biology of trematodes. The trematodes found in our research developed with the participation of intermediate hosts – aquatic or terrestrial molluscs. We determined that intermediate hosts to trematodes from the families Fasciolidae, Echinochasmidae, Paramphistomidae, Gastrothylacidae, and Schistosomatidae are aquatic molluscs from the families Lymnaeidae and Planorbidae, in which larval stages develop (sporocysts and redia). Mature cercariae leave the body of molluscs in water. Cercariae of Fasciolidae, Paramphistomidae, and Gastrothylacidae soon encyst on aqueous substrates and turn into adolescariae. Animals become infected by eating grass with adolescaria. Cercariae of *S. turkestanicum* actively penetrate into the body of the definitive hosts through the skin. Fish is also involved in the life cycle of *E. perfoliatus* as a secondary host. Pigs become infected by eating fish with metacercariae. The life cycle of *D. dendriticum* develops in a totally different way. The larval stages of this parasite are harboured by two types of intermediate hosts – terrestrial molluscs and ants. Animals become infected with *D. dendriticum* in pastures, where they ingest ants infected with metacercariae of this helminth together with grass.

Biology of nematodes. According to our research, the ways in which the infectious elements of nematodes (eggs and larvae) enter the body of the definitive host vary. The host (sheep or cattle) ingests the infectious elements (eggs or larvae) of helminths together with food or water. This group of parasites includes most of Nematoda species (about 50). The infectious larvae of some nematodes are absorbed by the definitive host when it feeds on an intermediate one. This strategy is used by the larvae of the nematodes *S. labiatopapillosa*, *P. skrjabibi,* and *S. saiga*. Nematodes from the family Protostrongylidae use terrestrial molluscs as intermediate hosts. Sheep become infected with Protostrongylidae when ingesting intermediate hosts with grass. Metastrongylidae infect pigs when the latter eat earthworms, the parasites' intermediate hosts. In Uzbekistan, artiodactyls are definitive hosts of most parasites and intermediate hosts to 6 species – *T. hydatigena*, *T. saginatus*, *T. solim*, *M. multiceps*, *M. gaigeri*, *E. granulosus,* and *E. multilacularis*. The study of the biology of helminths parasitising wild Artiodactyla suggests various pathways of transmission, depending on the type of the biocoenotic relationships among the components of the parasitic system. It is quite understandable that in most cases the worms parasitise their vertebrate hosts topically, and only several species of pigs become infected trophically (Suidae, Table 6).

Table 6
Ways used by helminths to infest their artiodactyl hosts in Uzbekistan

Ways of infecting host	Host									
	Suidae				Cervidae			Bovidae		
	Number of helminth species									
	Cestoda	Trematoda	Acanthocephala	Nematoda	Cestoda	Trematoda	Nematoda	Cestoda	Trematoda	Nematoda
1. Trophic:										
1.1. Eating animals – food objects	–	1	1	7	–	–	–	–	–	–
2. Topical:										
2.1. Ingestion of eggs or larvae with food and water	3	2	–	3	2	2	6	6	8	42
2.2. Accidental ingestion of soil with grass in a rangeland	–	–	–	–	2	–	–	6	–	–
2.3. Ingestion of terrestrial molluscs with grass	–	–	–	–	–	–	–	–	–	13
2.4. Active penetration of larvae through the skin	–	1	–	–	–	1	–	–	1	3
2.5. Transmission of eggs and larvae by insect bites	–	–	–	1	–	–	2	–	–	7

As noted above, 8.7% of helminth species penetrate into their hosts trophically, which is typical of parasites of pigs, Suidae. Table 6 demonstrates that the helminthofauna of artiodactyls in Uzbekistan is strongly dominated by parasites that have topical relationships with their hosts (91.2% of the total number of helminth species), affecting Cervidae and Bovidae. Those parasites included all representatives of the Cestoda and almost all Trematoda, except for two species – *E. perfoliatus* and *S. turkestanicum*. The metacercariae of *E. perfoliatus* enter the body of the definitive host (Suidae) with fish, while the cercariae of *S. turkestanicum* actively penetrate deer and bovids through the skin. Therefore, our research highlights that the topical relationships play a huge role in the infection of various artiodactyls with parasites in the wilderness of Uzbekistan.

The examined animals showed a very high infection rate. The number of helminth species recorded in one host individual ranged 7 to 18. The intensity of infection with individual species of the parasites ranged single to several hundred individuals. The following diseases can be regarded as epizootologically significant helminthiasis (sheep, goats and cattle): monesiosis, avitellinosis, echinococcosis, coenurosis, cysticercosis, fascioliasis, schistosomiasis, gastrotilaxosis, paramphistomatidosis, dicrocoeliasis, trichuriasis, chabertiasis, marshallagiosis, nematodirosis, hemonchosis, dictyoculosis, protostrongylidosis, parabronemosis, and setariasis. The abovementioned helminthiases, in most cases, occur as mixed infections and cause serious diseases in animals on livestock farms in Uzbekistan, with enzootic outbreaks causing mortality among animals, especially young ones. A number of species, pathogens of helminthiases, are also of high epidemiological importance. These include *F. hepatica*, *F. gigantica*, *S. turkestanicum*, *E. granulosus*, *M. multiseps*, *T. saginatus*, and *T. solium*, which in certain stages can parasitise humans.

To control helminthiases of animals (sheep, goats, and cattle), grazed in pastures in Uzbekistan, preventive deworming should be carried out twice a year in late April and in late September-early October. The prophylaxis should be performed using broad-spectrum anthelmintics, such as praziquantel, ivermectin, and fenbendazole or their combinations, which are available for veterinary purposes.

Discussion

We have discussed the species diversity of the helminthofauna of artiodactyls in modern Uzbekistan. However, it is essential to take a retrospective look at those who have laid the groundwork. The famous traveller and naturalist A. P. Fedchenko was the one who launched the study of helminths and helminthiasis of ungulates in Uzbekistan more than 155 years ago. The materials he collected on the helminthofauna of domestic and wild artiodactyls had been sent to foreign researchers – Dr. G. Krabbe (Denmark) and Dr. O. Linstow (Germany). In their works, Krabbe (1879) and Linstow (1886) provided the first information about helminths (cestodes, trematodes, and nematodes) of animals, including artiodactyls in Uzbekistan.

The systematic study of helminths of vertebrates, including artiodactyls in Uzbekistan, was launched by Academician K. I. Skrjabin. While working in Kazakhstan, he collected materials on the helminthofauna of some artiodactyl species from the northern regions of Uzbekistan. In his master's thesis *On the Characteristics of the Helminthofauna of Domestic Animals in Turkestan* (Skrjabin, 1916), he mentioned 16 species of helminths of sheep in Uzbekistan. In subsequent years, when Central Asia was already a part of the USSR, K. I. Skrjabin launched a series of expeditions featuring A. M. Petrov, E. S. Shakhovtseva (1926), and V. S. Yershov (1933) to study the helminthofauna of animals. The results of the expeditions were reflected in a series of works by these authors, who discussed the species composition of helminths parasitising sheep and cattle in Uzbekistan. The discovered helminths were classified as belonging to the classes Cestoda (4 species), Trematoda (2), and Nematoda (20).

The most comprehensive studies on helminths of artiodactyls in Uzbekistan – mainly sheep, goats, cattle, and wild animals (Suidae, Cervidae, Bovidae) – were conducted in 1960–1975 by a number of researchers – zoologists, parasitologists, and helminthologists. The results of the studies were summarised in the monograph *Helminths of Domestic Mammals in Uzbekistan* (Tashkent, Fan, 1975) by M. A. Sultanov et al. The book presents the faunal complexes of helminths of domestic artiodactyls and carnivores. According to the authors, the helminthofauna of domestic artiodactyls is represented by the classes Cestoda, Trematoda, Acanthocephala, and Nematoda. The total numbers of recorded helminth species accounted for 85 in sheep, 48 in goats, and 25 in pigs (Sultanov et al., 1975). The research conducted between 1970 to 2024 was mainly focused on the life cycles, ecology, parasite-host relations, diagnosis, and control of epizootologically significant species and groups of helminths of artiodactyls. There were also studies dedicated to the helminthofauna of wild artiodactyls in Uzbekistan (Koshchanov, 1972; Azimov, 1986; Dadaev, 1997; Saparov, 2016).

The biology and ecology of trematodes – *F. gigantica*, *G. crumenifer*, *C. calicophorum*, *D. dendriticum,* and *S. turkestanicum* – were also studied quite comprehensively (Azimov et al., 2015; Salimov et al., 2016). Significant results were obtained from the studies on the genera *Protostrongylus*, *Spiculocaulus*, *Muellerius*, *Cystocaulus*, *Stephanofilaria*, *Setaria,* and *Onchocerca* (Azimov et al., 2015; Saparov, 2016).

Nevertheless, the helminthofauna of artiodactyls in Uzbekistan has not been studied equally across different groups. The best studied is the helminthofauna of domestic artiodactyls, such as sheep, goats, cattle, and pigs. By contrast, wild artiodactyls have received only a limited helminthological research. Notable examples include Dadaev (1997) and Turemuratov (2022), who examined various species from the families Suidae, Cervidae, and Bovidae, in which they identified from 17 (wild boar) to 50 (argali) species of helminths from three classes – Cestoda, Trematoda, and Nematoda.

Research on the diversity of helminths has been conducted all around the globe. In Australia, Durie (1951) noted the infection of ruminants with Paramphistomidae from the class Trematoda. In New Zeland, Andrews (1973) determined the helminth infections of red deer and domestic ruminants. In a number of African countries, specialists conducted comprehensive research into the helminthofauna of Artiodactyla (Horak, 1981; Boomker et al., 1986; Junker et al., 2019; Kamani et al., 2020), having noted the infection of sheep, cattle, and impala with gastrointestinal parasites, most of which were helminths from the genera *Moniezia*, *Trichostrongylus*, *Cooperia*, *Haemonchus*, *Dictyocaulus*, *Taenia,* and other. As with the helminthofauna of wild artiodactyls in Africa, a number of papers (Horak, 1978; Horak et al., 1983; De Villiers et al., 1985; Boomker et al., 1989; Zieger et al., 1998) discussed infections with helminths from the classes Cestoda, Trematoda, and Nematoda. Admittedly, nematodes were represented by a much higher number of species (18) compared with cestodes (4) and trematodes (2). Especially notable was the discovery of a number of species of parasitic worms in the greater kudu (*Tragelaphus strepsiceros*) in the Kruger National Park in South Africa (Broomker et al., 1989). Extensive research on the infection of wild artiodactyls with helminths has been also performed by parasitologists in the Americas. Thus, Oyarzún-Ruiz et al. (2018) reported the infection of *Pudu pudu* Molin, 1782 with the nematode *Dictyocaulus eckerti* Skrjabin, 1931 in parts of South America, including Chile and Argentina. This nematode was previously identified in deer in Europe, New Zealand, and North America. The studies in Peru, Brazil, Colombia, Texas, and Canada (Boomker et al., 1984; Corn at al., 1985; Cheney & Allen, 1989; Sànchez et al., 2012; Gomez-Puerta et al., 2016; Oyarzún-Ruiz et al., 2018; Barbosa et al., 2020; Pinheiro et al., 2023) demonstrated the common occurrence of parasitic worms in wild artiodactyls. Our study of the helminthofaunas of both domestic and wild artiodactyls revealed significant similarities, yet there were observed some differences associated with a complex of environmental and anthropogenic factors. Currently, these factors still continue to have effect. For example, species such as *P. skrjabini*, *S. labiatopapillosa*, and *S. saiga* from the order Spirurida displayed a tendency towards broad distribution in the regions of Uzbekistan. All of the artiodactyls were infected with numerous species of parasitic worms all across the various geographical zones.

The presented materials clearly indicate that the faunistic complexes of helminths of Artiodactyla, particularly wild animals, have been studied very unevenly. The best-studied are helminthofaunas in Asia and Europe, where more than 300 species have been identified, belonging to the classes Cestoda, Trematoda, Nematoda, and Acanthocephala, with nematodes dominating. In comparison, the helminthofauna of wild artiodactyls in Africa and America has been studied to a lower extent. Nevertheless, the helminthofauna of these regions is quite specific, probably, due to the ecological and geographical characteristics and the peculiar fauna of artiodactyl hosts. Our research is important for understanding the modern helminthofauna of artiodactyls in Uzbekistan and its control. The discovered parasites pose a threat to ungulates, affecting their health and reducing productivity. Some helminth species are also dangerous to humans, and certain geographical areas require systematic monitoring.

Conclusion

By comparing the species diversity of parasites in different species of artiodactyls, it is clear that the variations do not lie in different susceptibility to helminths but rather in environmental and geographical factors. The most important factors are specific conditions in habitats, most importantly, the available food, and the species composition of other animals acting as intermediate hosts for parasites. There is no doubt that the studied helminths are quite well adapted to ungulates, both wild and domestic, as their hosts. This contributes to the exchange of parasites between these categories of hosts in the biogeocenoses of Uzbekistan. All this necessitates systematic monitoring of the helminthological situation and the implementation of complex measures to prevent helminthiasis of the studied animals.

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