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Research article

Parasite fauna of wild ungulates in Kazakhstan: current state and analysis

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Abstract

Background and Aim. Wild ungulates are a vital component of Kazakhstan's biodiversity, encompassing 12 species occupying diverse ecological niches. However, the current structure and epizootiological significance of their parasite fauna remain insufficiently synthesized. This review aims to summarize the contemporary data on parasitic diversity in wild ungulates across Kazakhstan, analyze its host associations, and identify key ecological and epidemiological patterns.

Materials and Methods. A systematic literature search was conducted in Scopus, Web of Science, and RSCI databases, as well as Kazakhstani peer-reviewed journals. Keywords in Kazakh, English, and Russian included the following terms: wild ungulates, parasite diversity, host-parasite relationships, epidemiology, Kazakhstan. The timeframe covered publications from 1989 to 2026, with earlier foundational works included for baseline comparisons. From 120 initially identified sources, 50 peer-reviewed publications were selected after screening.

Results. The parasite fauna exhibits high species richness, with a clear predominance of geohelminths over biohelminths and primary localization in the digestive tract. Dozens of helminth species have been recorded in key hosts, including saiga (*Saiga tatarica*), argali (*Ovis ammon*), maral (*Cervus elaphus sibiricus*), roe deer (*Capreolus pygargus*), Siberian ibex (*Capra sibirica*), and goitered gazelle (*Gazella subgutturosa*). The community structure is complex, showing a significant overlap between host species. Critically, a substantial proportion of parasites are shared between wild and domestic animals, indicating active cross-species transmission in both natural and anthropogenically transformed ecosystems.

Conclusion. The parasitic communities of wild ungulates in Kazakhstan are characterized by structural complexity and extensive faunal exchange with livestock, highlighting significant epidemiological risks. These findings underscore the necessity for continuous epizootiological monitoring and the development of integrated control strategies to mitigate the impact of parasitic infections on both wildlife conservation and livestock health.

Keywords: wild ungulates; parasite fauna; biodiversity; systematic review.

Introduction

Wild ungulates represent a crucial component of the natural and cultural heritage of Kazakhstan, and their conservation is of key importance for maintaining biodiversity and ecosystem stability. The country's natural biocenoses are inhabited by 12 species of ungulates representing various taxonomic groups and ecological niches. In this regard, their comprehensive study, including the analysis of parasite fauna, holds significant scientific importance for understanding the functioning of ecosystems in Asia and adjacent regions.

The territory of Kazakhstan is characterized by pronounced landscape and climatic heterogeneity, ranging from arid deserts and semi-deserts to steppe, forest-steppe, and mountainous ecosystems [1]. Such environmental diversity determines the distribution, migration patterns, and population density of wild ungulates, including key species such as saiga (*Saiga tatarica*), argali (*Ovis ammon*), Siberian ibex (*Capra sibirica*), maral (*Cervus elaphus sibiricus*), roe deer (*Capreolus pygargus*), and goitered gazelle (*Gazella subgutturosa*) [2–4]. These hosts form complex ecological networks and serve as reservoirs for a wide range of parasitic organisms with different life cycles and transmission strategies [5].

Parasites are an integral component of natural ecosystems and play a significant role in regulating host population dynamics, structuring communities, and maintaining ecological balance. At the same time, parasite–host interactions in wild ungulates are of considerable applied importance, as many helminths, protozoa, and arthropod ectoparasites are shared between wild and domestic animals [6]. This overlap facilitates pathogen circulation across wildlife-livestock interfaces, contributing to the emergence and persistence of epizootic and zoonotic diseases. In regions with intensive pastoralism, which is typical for Kazakhstan, such interactions are especially pronounced due to overlapping grazing areas and seasonal movements of animals [7].

Despite the recognized importance of parasite fauna in wild ungulates, available data for Kazakhstan remain fragmented and are often limited to individual host species, specific regions, or particular taxonomic groups of parasites. Earlier studies reported a high diversity of helminths, with a predominance of geohelminths and a primary localization in the gastrointestinal tract. However, recent environmental changes, including climate variability, anthropogenic pressure, and transformation of natural landscapes, may significantly affect parasite diversity, transmission pathways, and host-parasite relationships [8].

In addition, advances in molecular biology have substantially expanded the possibilities for studying parasite fauna, allowing for more accurate species identification, detection of cryptic taxa, and clarification of phylogenetic relationships. The integration of classical parasitological approaches with molecular-genetic methods provides new insights into the structure and dynamics of parasite communities in wild ungulates and enhances the reliability of epidemiological assessments. While individual aspects of wildlife parasitology in the region have been addressed in specific contexts, a unified, large-scale synthesis has historically been lacking.

This manuscript represents the first comprehensive, multi-host systematic review dedicated exclusively to the parasite fauna of wild ungulates across the entire territory of Kazakhstan. Unlike previously published regional reports or species-specific papers that focused restrictedly on isolated host populations, this study uniquely consolidates fragmented, long-term national data with contemporary global findings.

By evaluating these integrated data through the lens of the global One Health concept and climate-driven ecosystem shifts, this review aims to summarize existing knowledge on the diversity, host associations, and ecological features of parasite fauna in wild ungulates of Kazakhstan. Furthermore, it establishes an unprecedented analytical framework to evaluate potential risks associated with parasitic infections at the wildlife–livestock–human interface, highlight critical research gaps, and outline strategic priorities for future veterinary biosecurity and wildlife conservation in Central Asia.

Materials and Methods

The literature analysis was conducted through a systematic search of the Scopus, Web of Science, and RSCI databases, as well as peer-reviewed journals indexed by the Science and Higher Education Quality Assurance Committee of the Republic of Kazakhstan and relevant inormative sources. To ensure comprehensive regional coverage, specialized monographs and dissertation abstracts were also examined. The search strategy utilized targeted keywords in both Kazakh, English and Russian, including wild ungulates, parasite diversity, host-parasite relationships, epidemiology, Kazakhstan. The chronological scope primarily covered publications from 1989 to 2026, though earlier foundational works were included to establish baseline taxonomic comparisons. A total of 120 sources were initially identified, from which 50 peer-reviewed publications were selected for the final analysis after screening.

Eligibility was strictly controlled through defined inclusion and exclusion criteria. Included studies comprised peer-reviewed research focusing on parasite biodiversity, host-parasite relationships, and epidemiology within Kazakhstan and neighboring territories. Conversely, publications lacking sufficient taxonomic resolution (such as a lack of species-level identification), those with unverified parasitological methodologies, or studies with low relevance to the geographic and ecological scope of the review were excluded. The selected literature was subsequently systematized by parasite taxa, host species, and geographic distribution. Data synthesis involved a qualitative and comparative analysis of infection indices, including prevalence and intensity of infection, alongside morphological data to identify regional epizootic trends and address existing knowledge gaps.

Results

The review is devoted to the study of the parasitic fauna of wild ungulates in Kazakhstan. Among wild caprine bovids in Kazakhstan, representatives of the genera Saiga, Capra, and Ovis are found. The only representative of the genus Saiga is the saiga antelope, alongside which the Siberian ibex (*Capra sibirica*), as well as urial and argali (*Ovis* spp.), inhabit. On the territory of Kazakhstan, three populations of saiga are distinguished – the Ural, Ustyurt, and Betpak-Dala populations, which emphasizes its wide geographical distribution. According to aerial survey data, the saiga antelopes population demonstrates a stable positive trend: in 2023 it exceeded 1.9 million individuals, in 2024 it amounted to 2,833,600 individuals, and in 2025 it reached 3.9–4.1 million individuals [9–11].

The Siberian ibex is distributed in the mountain systems of the Tien Shan, the Zhetysu (Dzungarian) Alatau, and the Southern Altai; its population is estimated at 15 000–20 000 individuals. Among wild sheep, rare and protected forms are of particular importance. The Ustyurt urial is listed in the Red Book of Kazakhstan, as are subspecies of argali (*Ovis ammon ammon, O. ammon nigrimontana, O. ammon collium, O. ammon karelini*), whereas *O. ammon* severtzovi is likely extinct. The Ustyurt mouflon (O. vignei arkal) also inhabits Kazakhstan. The total number of argali is about 19 thousand individuals, with significant populations concentrated in the State National Nature Park "Altyn-Emel" and the "Almaty State Nature Reserve" [12, 13].

The only representative of gazelles is the goitered gazelle (*Gazella subgutturosa*), listed in the Red Book of Kazakhstan. Its population is about 15 thousand individuals, including approximately 5.5 thousand in the State National Nature Park "Altyn-Emel" [14, 15].

The family Cervidae is represented by three genera – *Cervus, Capreolus,* and *Alces*. The red deer (*Cervus elaphus*), including the Altai maral (*C. elaphus sibiricus*), is widely distributed in mountainous regions, whereas the Bukhara deer (*C. elaphus bactrianus*) is a rare species (about 1140 individuals). The total number of red deer is about 13 thousand individuals [14, 16]. The Siberian roe deer (*Capreolus pygargus*) reaches about 100 thousand individuals and is distributed throughout the country.

Among perissodactyls, the Turkmenian kulan (*Equus hemionus kulan*) is noted, with a population of about 4.1 thousand individuals, as well as Przewalski's horse, maintained under reintroduction conditions [14].

Thus, the diversity of hosts [17] creates the prerequisites for the formation of complex parasitic systems.

Correspondingly, the parasite fauna of wild ungulates is characterized by high species richness and a complex structure. According to studies by *K.K. Baitursinov* [18, 19], conducted in 1983–2007, various species of wild animals were examined using the method of complete helminthological dissection. A wide distribution of nematodes of the family Trichostrongylidae, including the genera *Trichostrongylus, Ostertagiella, Nematodirus, Marshallagia,* and *Nematodirella,* was established.

Studies conducted in the West Kazakhstan region (Ural population) revealed that saiga antelopes are infested with a range of helminth species. Coproscopic examinations identified four helminth species: *Oesophagostomum venulosum, Trichuris skrjabini, Nematodirus gazellae,* and *Moniezia expansa,* as well as oocysts of the protozoan *Eimeria elegans / E. manafovae.* In addition to these findings, other studies in the same region have reported four additional nematode species belonging to four different genera: *Ostertagia ostertagi* (intensity: 18.2 worms per host), *Cooperia onchophora (*17.3), *N. spathiger* (35.2), and *Trichostrongylus axei* (12.8). These intensity values indicate a moderate to high level of infection in this population compared with other regions of Kazakhstan [20–23].

An analysis of climatic, natural, and anthropogenic factors affecting seasonal patterns of helminth infestation has shown that environmental conditions play a crucial role in the survival and transmission of helminth larvae. The main source of helminth infestation in saiga populations is watering sites, where larvae accumulate and remain viable under favourable conditions. Therefore, the creation of additional, ecologically safe watering points and the greening of surrounding areas are recommended as practical measures to reduce infection rates and improve the health status of wild ungulate populations. As a result of contacts between wild and domestic animals, pathogen exchange and helminth circulation among different animal species can occur in the West Kazakhstan region. Consequently, it can be hypothesized that saiga antelopes of the Ural population may contribute to the maintenance of helminth foci in the region, but direct evidence of parasite transmission from saigas to livestock under natural conditions is not yet available. Further molecular epidemiological studies are needed to confirm the directionality of cross-species transmission [24–26].

Regarding to domestic scientists works in 2014–2017 of the total number of parasite species recorded across all wild ungulate hosts in Kazakhstan (73 species), the distribution by host species was as follows: in saiga antelope – 34 species (46.6%); in argali – 28 species (38.6%); in maral – 17 species (21.9%); in roe deer – 14 species (17.8%); in wild boar, Siberian ibex, and kulan – 10 species each (13.7% each); in Ustyurt urial – 9 species (12.3%); in moose – 6 species (8.2%); and in goitered gazelle – 4 species (5.5%). Among all recorded parasite species, 30 (41.1%) belong to biohelminths and 43 (58.9%) to geohelminths. Most parasite species are localized in the digestive tract. Studies of maral (2015–2017) revealed 11 parasite species, including *M. expansa, O. venulosum, Capillaria bovis, T. skrjabini, Bunostomum phlebotomum, N. spatiger, Haemonchus contortus, Strongylata* sp., as well as *E. robusta, E. gallivalerioi,* and *E. cervi*. The prevalence of infection ranged from 33.17 to 100% [27–34].

According to data by *A. Smagulova* et al. [35], a wide spectrum of gastrointestinal parasites was identified in wild ungulates, including *Dama dama, O. ammon collium, Cervus elaphus, C. pygargus, Alces alces, O. ammon, Saiga tatarica, Bos mutus,* and *O. gmelina*; these included strongylid-type eggs, *Eimeria, Trichuris, Nematodirus, Capillaria,* and *Dicrocoelium lanceolatum*. The highest prevalence of infection was noted in *D. dama* (66.6%), whereas *S. tatarica* recorded the highest mean intensity of infection; meanwhile, *A. alces, O. ammon,* and *C. pygargus* were characterized by a relatively low prevalence (less than 15%) and moderate intensity of infection (approximately 4–5 helminths per infected host).

Among 36 examined wild ungulates, infection was identified in 3 animals: *Taenia multiceps* was found in 2 out of 25 roe deer (*C. pygargus*) with cysts localized in the femoral muscle, and *Taenia hydatigena* was identified in 1 out of 9 moose (*A. alces*) with cysts localized in the liver. Both of the 2 examined red deer were free from cysticercosis [36].

In four out of seven moose examined in the Akmola and Kostanay regions, third-stage larvae of Cephenemyia ulrichii were discovered [37].

In the studies of *F.D. Akramova* et al. [38], the presence of 26 helminth species was established in wild ungulates. Similar infection rates have been identified in Northwestern Uzbekistan [39–42]. In the biogeocenoses of Karakalpakstan, the artiodactyl fauna is represented by five wild ungulate species: *Sus scrofa nigripes* (wild boar), *C. elaphus bactrianus* (Bukhara deer), *G. subgutturosa* (goitered gazelle), *S. tatarica* (saiga antelope), and *O. orientalis* arcal (arkal sheep). A total of 26 helminth species were identified in these hosts, belonging to the classes Cestoda (6 species), Trematoda (2 species), and Nematoda (18 species). The species composition varied by host: wild boar harbored 14 helminth species, Bukhara deer – 11, saiga antelope – 13, and goitered gazelle – 14. Common parasites shared among these ungulate species included representatives of the genera *Taenia, Echinococcus, Fasciola, Schistosoma, Gongylonema,* and *Setaria*. Based on their life cycles, the identified helminths can be divided into two ecological groups: monoxenous (direct life cycle, without intermediate hosts) and heteroxenous (requiring one or more intermediate hosts). Monoxenous species included representatives of the families Trichosephalidae (3 species), Trichostrongylidae (2 species), Dictyocaulidae (2 species), Syphaciidae (1 species), and Ascarididae (1 species). Heteroxenous development, involving obligatory intermediate hosts, was characteristic of 18 species, including 6 cestodes, 2 trematodes, and 10 nematodes. The high proportion of heteroxenous species emphasizes the importance of intermediate host communities in maintaining parasite transmission in this arid region [43].

Studies conducted in the Caucasus revealed a high prevalence of mixed protostrongylid infections in wild and domestic ruminants, with roe deer and tur showing the highest helminth diversity and infection rates due to extensive migration and frequent contact with livestock pastures. The dominant lung nematodes included *Protostrongylus hobmaeri, P. kochi,* and *Muellerius capillaris*, particularly in tur populations. Infection intensity and prevalence were influenced by season, altitude, host ecology, and mollusk abundance. Wild ungulates occupying mountain pastures shared numerous helminth species with sheep and goats, suggesting active parasite exchange between wildlife and domestic animals across the Caucasus region [44, 45].

Discussion

Detailed summaries by species are of particular importance [26]. In the goitered gazelle, 21 species of helminths have been registered, including F*asciola hepatica, Avitellina centripunctata, Multiceps multiceps (larvae), Taenia hydatigena (larvae), Taenia sp., Haemonchus longistipes, Marshallagia* *marshalli, Nematodirella gazelli, Nematodirus dogieli, N. gazellae, N. mauritanicus, N. oiratianus, N. spathiger, Ostertagiella circumcincta, O.occidentalis, Parabronema skrjabini, Setaria labiato-papillosa, Skrjabinema ovis, Skrjabinodera saiga, Trichuris skrjabini, Trichuris sp.,* and *Trichinella spiralis.*

Taxon-specific distribution, geographic localization, and diagnostic methods of major parasites identified in wild ungulates of Kazakhstan

Host Species	Parasite Taxonomic Group	Representative Parasite Species / Genera	Geographic / Regional Distribution	Primary Diagnostic Methods
Saiga antelope (*Saiga tatarica*)	Nematoda, Cestoda, Protozoa	*Nematodirus gazellae, Oesophagostomum venulosum, Trichuris skrjabini, Moniezia expansa, Ostertagia ostertagi, Eimeria elegans*	West Kazakhstan (Ural population), Betpak-Dala, Ustyurt ecosystems	Coproscopy, complete helminthological dissection, Molecular (PCR)
Argali (*Ovis ammon*)	Nematoda, Cestoda, Trematoda	*Fasciola hepatica, Dicrocoelium lanceatum, Marshallagia marshalli, Protostrongylus hobmaieri, Echinococcus granulosus (larvae)*	Tien Shan, Zhetysu Alatau, National Park “Altyn-Emel”	Complete helminthological dissection, morphological identification
Altai maral (*Cervus elaphus sibiricus*)	Nematoda, Cestoda, Protozoa	*Moniezia expansa, Capillaria bovis, Haemonchus contortus, Eimeria robusta, Eimeria cervi*	East Kazakhstan region, mountainous zones	Coproscopic profiling, post-mortem diagnostics
Siberian roe deer (*Capreolus pygargus*)	Nematoda, Cestoda, Trematoda	*Dicrocoelium lanceatum, Capreocaulus capreoli, Dictyocaulus eckerti, Taenia multiceps (larvae)*	Widespread throughout Northern, Central, and Eastern Kazakhstan	Morphological analysis, Molecular tissue screening (PCR)
Siberian ibex (*Capra sibirica*)	Nematoda, Cestoda, Trematoda	*Cystocaulus vsevolodovi, Neostrongylus zvetkovi, Protostrongylus kochi, Spiculocaulus austriacus*	High-altitude systems of Tien Shan and Altai mountains	Complete helminthological dissection, larvoscopy
Goitered gazelle (*Gazella subgutturosa*)	Nematoda, Cestoda, Trematoda	*Haemonchus longistipes, Nematodirella gazelli, Parabronema skrjabini, Skrjabinodera saiga*	Arid deserts, National Park “Altyn-Emel”	Coproscopy, historical baseline dissections
Moose (*Alces alces*)	Nematoda, Cestoda, Diptera (Arthropoda)	*Taenia hydatigena (larvae), Cephenemyia ulrichii (larvae)*	Northern Kazakhstan (Akmola and Kostanay regions)	Morphological diagnostic keys, Molecular barcoding (COI *gene*)

Overall, in the argali, 47 species of helminths were identified, including *Fasciola hepatica, Dicrocoelium lanceatum, Taenia hydatigena* (larvae), *Multiceps multiceps* (larvae), *Moniezia benedeni, M. alba, Parabronema skrjabini, Skrjabinema ovis, Chabertia ovina, Trichostrongylus colubriformis, T. probolurus, Ostertagia ostertagi, O. occidentalis, O. circumcincta, O. orloffi, O. trifida, O. trifurcata, Marshallagia marshalli, M. mongolica, M. schumakovitschi, Haemonchus contortus, N. abnormalis, N. archari, N. dogieli, N. oiratianus, N. spathiger, Dictyocaulus filaria, Protostrongylus hobmaieri, P. skrjabini, P. davtiani, P. raillieti, Spiculocaulus leuckarti, Cystocaulus ocreatus, Trichuris ovis, T. skrjabini, Capillaria sp., Setaria labiato-papillosa, N. gazellae, Nematodirella gazelli, N. longissimespiculata, Taenia ovis* (larvae), *Echinococcus granulosus* (larvae), *Ostertagiella davtiani*, and *Muellerius capillaris.*

In the Siberian roe deer, 22 species were identified, including *Dicrocoelium lanceatum, Moniezia expansa, Taenia cervi* (larvae), *T. hydatigena* (larvae), *Capreocaulus capreoli, Chabertia ovina, Dictyocaulus eckerti, Haemonchus contortus, Marshallagia marshalli, N. filicollis, N. oiratianus, N. spathiger, Ostertagiella circumcincta, O. occidentalis, O. trifurcata, Parabronema skrjabini, Setaria capreola, Spiculocaulus austriacus, Trichuris skrjabini, Trichostrongylus colubriformis, T. probolurus,* and *T. vitrinus.*

In the Siberian ibex, 28 species were registered, including *Dicrocoelium lanceatum, Moniezia benedeni, Multiceps multiceps* (larvae), *M. skrjabini* (larvae), *Taenia hydatigena* (larvae), *Cystocaulus vsevolodovi, Marshallagia marshalli, M. mongolica, M. schumakovitschi, Nematodirus abnormalis, N. dogieli, N. filicollis, N. oiratianus, N. spathiger, N. sugatini, Neostrongylus zvetkovi, Ostertagia ostertagi, Ostertagiella circumcincta, O. occidentalis, Protostrongylus davtiani, P. dikmansi, P. kochi, P. raillieti, Skrjabinema ovis, Spiculocaulus austriacus, S. leuckarti, S. orloffi,* and *Trichuris skrjabini.*

In saiga antelopes, 49 helminth species have been recorded, of which 16 are common to all populations, including *Taenia hydatigena* (larvae), *Avitellina centripunctata, Skrjabinema ovis, Ostertagiella occidentalis, Marshallagia marshalli, M. mongolica, Trichuris skrjabini, as well as additionally Echinococcus granulosus* (larvae), *Protostrongylus skrjabini, Trichostrongylus axei, T. probolurus, Haemonchus contortus, N. abnormalis, N. gazellae, N. mauritanicus* and *Nematodirella longissimespiculata.*

In natural biocenoses adjacent to areas of developed livestock breeding, active exchange of parasites between wild and domestic animals is observed.

A commonality of helminth fauna has been noted between saiga antelopes and sheep, argalis and sheep, ibexes and sheep, goitered gazelles and small ruminants, and kulans and horses. Among coccidia, representatives of the genus *Eimeria* are widely distributed, including *E. robusta, E. gallivalerioi,* and *E. cervi,* which are detected in various species of ungulates with high infection intensity [47, 48].

The overlap of parasite fauna between wild and domestic ungulates translates into specific risks. Trichostrongylidae nematodes, prevalent in saiga and argali [18–22], can reduce weight gain and milk production in sympatric livestock. *Fasciola hepatica* and *Dicrocoelium lanceatum,* documented in argali and goitered gazelle [26, 35, 38], cause liver condemnation and economic losses. From a public health perspective, *E. granulosus* (hydatid cysts) in saiga and argali [38, 46] poses a zoonotic risk via infected dogs, while Trichinella spiralis in goitered gazelle [26] threatens consumers of undercooked game meat. These findings suggest that wildlife parasitology should be integrated into national veterinary surveillance, particularly at wildlife–livestock interfaces. Despite the substantial amount of accumulated data, modern studies remain limited. This is due to the labor-intensive nature of helminthological research, difficulties in accessing habitats, and restrictions on sampling protected species.

Conclusion

The conducted analysis of literature data on the parasite fauna of wild ungulates in Kazakhstan demonstrates that it is characterized by high species richness, a complex structure, and a significant degree of overlap with parasites of domestic animals. This review summarizes information on 12 host species inhabiting various landscape and climatic zones, ranging from deserts to mountain ecosystems. The most parasitologically studied species proved to be the saiga antelope (*S. tatarica*), argali (*O. ammon*), maral (*C. elaphus sibiricus*), roe deer (*C. pygargus*), Siberian ibex (*C. sibirica*), and goitered gazelle (*G. subgutturosa*).

It has been established that geohelminths predominate in the parasite fauna (58.9%) over biohelminths (41.1%), with the gastrointestinal tract being the primary site of parasite localization. The widest spectrum of helminth species was recorded in the saiga antelope (49 species) and argali (47 species), reflecting both the ecological characteristics of these hosts and their higher level of study. A high degree of helminth fauna commonality between wild and domestic ruminants has been revealed, indicating the formation of a unified parasitic system driven by shared use of pastures and watering sites, as well as the ongoing reduction of natural wildlife habitats.

At the same time, the available data suggest a possible decline in parasite species diversity in the natural biocenoses of Kazakhstan, although direct long-term comparative studies are lacking. This potential trend may be related to anthropogenic ecosystem transformation, climate change, and host population fragmentation, but the current evidence remains circumstantial. Further targeted monitoring is required to confirm whether species richness is genuinely decreasing or whether apparent differences reflect uneven sampling effort over time [49].

Consequently, the conservation of wild ungulate biodiversity in Kazakhstan is impossible without regular monitoring of their parasite fauna [50]. Priority directions for future research should include: (1) systematic surveys of all key host species across all major populations using standardized protocols; (2) integration of classical and molecular genetic diagnostic methods; (3) assessment of climate change and anthropogenic pressure impacts on parasite community structure; and (4) development of predictive models for epizootic risks at the wildlife–livestock–human interface. Addressing these tasks will not only expand fundamental knowledge on the functioning of natural foci but also provide a scientifically sound basis for conservation strategies of vulnerable species and for the control of parasitic diseases in a changing environment.

Authors' Contributions

EK, AZh: Conceptualized and designed the study, conducted a comprehensive literature search, analyzed the gathered data and drafted the manuscript. EA, AA: Conducted the final revision and proofreading of the manuscript. All authors have read, reviewed, and approved the final manuscript.

Statement on Competing Interests

The authors declare that they have no conflicts of interest.

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