



REVIEW ARTICLE

Gastrointestinal Nematodes of the Saiga Antelope: A Review of Diversity, Epidemiology, Pathophysiology and Conservation Significance

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ABSTRACT

The presence of gastrointestinal nematode (GIN) infections is a constraint of importance yet under-investigated in the current population restoration of the highly endangered saiga antelope (*Saiga tatarica*), a migratory species undergoing several ecological and conservation pressures. The review compiles and critically evaluates the current knowledge on diversity, epidemiology, transmission patterns, pathophysiological effects, diagnostic methods, and conservation implications of GIN infections of *Saiga tatarica* on their geographical distribution. In Kazakhstan, Ukraine and Russia evidence shows that saiga harbor a rich community of helminths with cold-adapted genera, including *Marshallagia*, *Nematodirus* and *Trichostrongylus* with the majority of 38 identified species present in domestic livestock, a strong interface between wildlife and livestock and potential cross-transmission. The epidemiology of the parasites relies heavily on the migration of the saiga, timely calving groups, and ecological factors that promote larval survival even in severe climate conditions of the steppe. Although infections may be subclinical, chronic parasitism can result in immunosuppression, fecundity reduction, and growth retardation, which might increase vulnerability to other disease outbreaks, including pasteurellosis. Diagnostic methodologies like McMaster and Fulleborn do provide useful information but cannot track these nomadic species for which molecular tools like metabarcoding and q-PCR are efficient. Therefore, a comprehensive conservation strategy is required, encompassing anthelmintic treatment in shared grazing areas, saiga health monitoring, and safeguarding migration routes to minimize environmental pollution. This review underscores that managing these parasites is crucial for the saiga's health and are indicators of its ecosystem health.

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INTRODUCTION

The most important and unavoidable components of ecosystem health and biodiversity are parasites, having co-evolved with the passage of time along with their hosts. Instead of being solely harmful, they control the population of hosts, influence the organization of the community, and stimulate evolutionary changes (Neronov *et al.*, 2012; Wang *et al.*, 2025). Nevertheless, when the environment is stressed, nutrition is limited, population density is

increased, or a co-infection occurs, the balance between parasitism and pathogenesis becomes disrupted (Mabbott, 2018; Ezenwa, 2020). The immediate consequences of parasitism are growth retardation, lower fecundity, body deformities, and secondary infections vulnerability (Khanyari *et al.*, 2022). Such chronic and subclinical infections can lead to no direct mortality in threatened wildlife populations but may serve as underlying stress factors that reduce the ability of the population to sustain itself in the long term (Morgan *et al.*, 2006; Cable *et al.*,

2017). Accordingly, the study of the dynamics of parasites has emerged as a key part of contemporary wildlife conservation and conservation medicine.

The saiga antelope (*Saiga tatarica*) is a notable instance of an endangered migratory ungulate. The unique migratory animal with its native habitat in the Eurasian grasslands, the saiga had a historical distribution between the Carpathian Mountains and Mongolia (Neronov *et al.*, 2012; Bizhanova *et al.*, 2025). Survival during lengthy seasonal migrations across extreme continental climates is facilitated by its morphological adaptations, including the characteristic bulbous nose (Chimeddorj *et al.*, 2024a; Chimeddorj *et al.*, 2024b). In late spring, females create huge calving herds and coordinate births within a period of approximately 10 days, and up to 80 percent of births take place in one week (Singh *et al.*, 2010). Although this predator-swamping approach increases the survival of neonates, it also forms temporary high-density groups of immunologically naïve hosts, which may lead to a further expansion of the spread of the pathogen (Begilov *et al.*, 2024). At present, the largest surviving population is supported by Kazakhstan, which is estimated to have around 801,000 individuals as of 2019 (Abybekova *et al.*, 2023; Begilov *et al.*, 2024; Kushaliyev *et al.*, 2024). However, the unchecked poaching since the early 1990s has resulted in a drastic change in population and the classification of the species as Critically Endangered by the International Union for Conservation of Nature (Mallon and Kingswood, 2001; Milner-Gulland and Singh, 2016). The destructive 2015 mass mortality outbreak when more than 200,000 animals succumbed to hemorrhagic septicemia induced by *Pasteurella multocida* also indicated the susceptibility of this species to infectious pressures (Kock *et al.*, 2018; Fereidouni *et al.*, 2019; Robinson *et al.*, 2019).

The gastrointestinal nematodes (GIN) are the most common and the most abundant parasitic group in wild ungulates (Barone *et al.*, 2020; Figueiredo *et al.*, 2020). Helminths, especially Strongyloides nematodes, are a fixed part of the gastrointestinal community of parasites in saiga antelope. As infections are often subclinical, they may result in retarded growth, poor fecundity, and impaired immune response, especially in difficult climatic conditions or under nutritional stress (Mabbott, 2018; Hassan *et al.*, 2023). Notably, the research shows that 35 out of 38 species of helminths reported in saigas are also shared with domestic ruminants (Zvegintsova *et al.*, 2015). Since the saigas cross-laminate the multi-use rangelands occupied by the sheep, goats, cattle, and camels (Moon *et al.*, 2023), this cross-species parasitism fauna is reciprocally transmissible. Besides the fact that such overlap complicates the epidemiology of the situation, it raises socio-ecological tensions, with saigas potentially viewed as reservoirs of livestock parasites (Khanyari *et al.*, 2022; Absatirov *et al.*, 2025). Habitat fragmentation, climate variability, and the shift toward livestock management also affect the free-living larval development and contact rate and change the transmission patterns across the landscape (Zarlenga *et al.*, 2014; Khanyari *et al.*, 2022a).

Although the role of parasitism in the ecology of saiga is now understood, there are still significant knowledge gaps. A significant portion of this base work was published in Russian-language literature and is not well known outside of the country, usually with taxonomic inconsistencies. Most of the historical data were obtained

through cross-sectional surveys and cull-based investigation of 1997 (Morgan *et al.*, 2005) and there was minimal systematic sampling after the legal culls were stopped. Recent non-invasive fecal surveys can be of great interest but vary in methodology and geographical focus, which does not allow making direct spatial and temporal comparisons (Burshakbayeva *et al.*, 2025; Khamchukova *et al.*, 2025). Furthermore, the socio-ecological changes that occurred after the disintegration of the Soviet Union, such as the redistribution of livestock density and veterinary facilities, have also probably changed the patterns of parasite transmission, but these data have not been adequately measured (Konopliankova *et al.*, 2018). This leads to the fact that now there is no single point of integration between historical and modern parasitological data.

The purpose of this review is to synthesize the existing historical and recent data on the diversity, prevalence, epidemiology, and geographical distribution of gastrointestinal nematodes in *Saiga tatarica*. This review aims to summarize existing knowledge about the ecological factors that drive the spread of diseases, find gaps in comprehension of this problem, and offer an evidence-based approach to conservation and disease management practices.

Diversity and ecological biology of gastrointestinal nematodes in *Saiga tatarica*: The helminth community of saiga population represents a complex of gastrointestinal nematodes with a high degree of diversity, organizing itself ecologically, and with a high level of biological specialization both within the natural region and in the controlled environment (Askania Nova Reserve) (Morgan, 2003; Khanyari *et al.*, 2022a). The diversity of parasites seems to be conditioned by the migration of hosts, high population density, the overlapping of livestock, and severe climatic conditions of seasons, all of which affect the process of exposure and transmission (Morgan *et al.*, 2005). The size of the saiga population can also influence the structure of the parasite community, since a decrease in population might decrease transmission of specialist nematodes, whereas recovery and calving aggregations can increase transmission and re-establishment. The long-range movement of the species across the climatically extreme steppe habitats probably places severe selection pressures on the hardy, cold-, and arid-adapted nematode genera. The same patterns of diversity tendencies in other adapted arid ungulates, including addax, scimitar-horned oryx, and dorcas gazelle, further indicate that this pattern is largely due to shared ecological factors, seasonality, and multi-species grazing (Tariq, 2015; Said *et al.*, 2018; Aissa *et al.*, 2021; Bautista-Garfias *et al.*, 2022).

The digestive tract of the saiga antelope hosts different communities of parasites in the abomasum, small intestine, and large intestine each region has different microhabitats that are selective to different groups of nematodes (Table 1). The major infection site is the abomasum, which harbors the highest number of species (Zhang *et al.*, 2023). Among them, the representatives of the genus *Marshallagia* often prevail in number and severity, and they are specifically adapted to cold and arid conditions of the Central Asian steppe (Muma *et al.*, 2010). The abomasum is also commonly inhabited by *Nematodirus gazellae*, a species that has the capacity to inhabit various parts of the digestive tract

(Agrawal *et al.*, 2024). The other species that belong to this compartment are *Teladorsagia circumcincta*, *Trichostrongylus axei* and *Haemonchus contortus* as each leads to a total increase in the parasite burden despite the moderate intensities of occurrence (Ashrafi *et al.*, 2020; Fentahun, 2020). A second group of nematodes is found in the small intestine, the most widespread of which is *Nematodirus gazellae*, which can become extremely common, with an extensive burden of worms (Aissa *et al.*, 2021). With this type of species, eggs are of large size and very thick shelled making them very tough and thus able to survive until the environment is favorable to allow growth. Another important occupation of the small intestine is *Nematodirus spathiger* and *Nematodirella longissipesculata*. The species like *Chabertia ovina* and *Oesophagostomum venulosum* add more diversity to this area (Polaz, 2022; Macchioni *et al.*, 2023).

Biological parameters of these helminths are in perfect harmony with the environmental limitations and ecological dynamics of the saigas grazing. The gastrointestinal nematodes that infect saigas all have direct life cycles, i.e. no intermediate hosts, which facilitates effective spread through open rangeland (Tariq, 2015; Khanyari *et al.*, 2022b; Khanyari *et al.*, 2024). When eggs are released into the feces of saiga antelope, they immediately start developing under appropriate warmth and moisture conditions until they become third-stage larvae (L3) as shown in Fig. 1 which clearly explains the helminths' life cycle. This phase preserves the cover of the previous molt, which offers security against drying up and temperature changes. These adaptations are also necessary to survive in the highly seasonal environments in which saigas live. Climatic patterns such as warm and moist climatic conditions facilitate transmission, whereas extreme heat or cold retards or halts transmission (Jas *et al.*, 2022; Elwakil, 2023). Nevertheless, most helminth eggs, especially those of *Nematodirus* and *Marshallagia*, are resistant to extended periods of drought or freezing, and thus they can survive on the pasture until conditions are favorable. The most striking biological characteristics of the saiga helminths are the major infections that they obtain in winter, especially the *Marshallagia* species (Morgan *et al.*, 2005).

Pasture ecology also affects the dynamics and diversity of helminths in the saiga group transmission. Shared grazing in a habitat with more than one species of ungulates, e.g. at Askania Nova or in North African reserves of antelopes, can result in a depression in the

number of infective larvae on the pasture (Kock *et al.*, 2016; Katona and Coetsee, 2019).

Life cycles and transmission of saiga gastrointestinal nematodes: All the gastrointestinal nematodes (GIN) that parasitize the saiga antelope have direct, non-migratory life cycles i.e. they do not have an intermediate host and are spread exclusively by eating infected stages that have been deposited in the environment (Morgan *et al.*, 2007). The overall life cycle, which is homologous in all the major *Trichostrongylid* species (e.g., *Marshallagia*, *Nematodirus*, *Trichostrongylus*), may be split into a parasitic phase in the saiga host and a free-living phase on pasture, which is highly sensitive to the environmental conditions. The cycle starts inside the definite host. Male and female adults of the nematodes live in specific microhabitats within the gastrointestinal tract of *Saiga tatarica*, primarily localizing in the abomasum (e.g., *Marshallagia*, *Haemonchus contortus*) or the small intestine (e.g., *Nematodrus gazellae*) (Agrawal *et al.*, 2024). Here, they reproduce, and the females give birth to eggs, which are expelled out of the host in the feces onto the pasture. A major parameter that determines the level of transmission is the rate of egg production (fecundity) (Brown *et al.*, 2022; Morgan *et al.*, 2023). On being released into the environment, the eggs embryonate and become first-stage (L1) and then second-stage (L2) larvae in the fecal pellet.

Although this overall pattern is universal, it can be seen that the given research points to important genus-specific differences when it comes to the free-living stages that determine the peculiar epidemiology of a given parasite. The greatest variations are in the resilience of the eggs and the time of transmission. For instance, the *Nematodirus* species has extremely tough eggs that could endure the freezing temperatures of Kazakh winter on pasture (Akramova *et al.*, 2025).

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Table 1: Distribution, biological importance, and dominance site of major helminth genre found in saiga antelope.

Sr. No.	Species/ genus of helminth	Dominance site of helminths	Prevalence	Ecological note	References
1.	<i>Marshallagia</i>	Abomasum	Elevated intensities in abomasum	This nematode is adapted to cold and dry weather and is the core fauna of grassland ungulates. The infection is mostly acquired in winter seasons because of the adaptation to cold climates	(Morgan, 2003)
2.	<i>Nematodirus gazelles</i>	Small intestine	Highest prevalence in small intestine	Characterized by delayed hatching of eggs because of environment resilience, and is of same importance in Moroccan antelopes	(Aissa <i>et al.</i> , 2021)
3.	<i>Skrjabinema ovis</i>	Large intestine	Ubiquitous	Rapid transmission in the herds occurs by direct ingestion if eggs from contaminated vegetation	(Agrawal <i>et al.</i> , 2024)
4.	<i>Teladorsagia circumcincta</i>	Abomasum	Lower intensity	Contributes to additive parasitic load in host animals.	(Cortés <i>et al.</i> , 2020)
5.	<i>Nematodirus spathiger</i>	Small intestine	Moderate prevalence	An extended incubation period characterizes it before hatching in dry regions	(Goossens <i>et al.</i> , 2003)
6.	<i>Oesophagostomum venulosum</i>	Large intestine	Less frequent	Provides functional diversity to a large gut microbiota	(Zvegintsova <i>et al.</i> , 2018)
7.	<i>Camelostromylus mentulatus</i>	-	Enriches the microbiota community	Common in other antelope also	(Zvegintsova <i>et al.</i> , 2018)

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Epidemiology and transmission of gastrointestinal nematodes in *Saiga tatarica*: The epidemiology of gastrointestinal nematode (GIN) infection in the endangered saiga antelope is a complicated story that relies on host biology, climatic extremes, and highly intertwined relationships with domestic livestock (Chimeddorj *et al.*, 2024a). It is not merely a basic host-parasite interaction, but a vast ecological event. Migration, climate variability, and communal grazing by domestic animals are key factors that shape infection dynamics. The initial investigations, especially in Kazakhstan and the "Askania Nova" Biosphere Reserve in Ukraine, have demonstrated a stable

and diversified gastrointestinal nematode community (Table 2). Researchers have reported up to 15 helminth species in one survey in Kazakhstan, including abomasal nematodes such as *Marshallagia marshalli*, *M. mongolica* and *Nematodirus gazellae* predominant, in addition to the almost ubiquitous pinworm *Skjabinema ovis* in the large intestine (Morgan, 2003). In Ukraine, a 35-year study recorded 16 species of nematodes, with the community structure changing dramatically, with *Trichostrongylus axei*, *T. probolorus* and *M. marshalli* adults dominating the community (Cafiero *et al.*, 2024).

The dynamics of infection rates and severity among the hosts of the saiga are extremely heterogeneous and significantly depend on the age and sex of the hosts (Fig. 2). Age is perhaps the most influential intrinsic factor, influencing different and contrasting patterns of infection in species of nematodes. As an example, the intensity of *Marshallagia* species shows a beneficial supralinear increase with the age of a host. Burdens are very low in juveniles, but increase consistently, reaching a level in adulthood, which is characteristic of repeated exposure and long-duration survival of these worms, and little protective immunity. Conversely, the epidemiology of *Nematodirus gazellae* is convex and reaches its highest intensity in saigas at the age of 2-3 years and drops in other animals. This trend is a strong indication that an efficient acquired immunity has been generated that will inhibit the further development or reproduction of this parasite. Moreover, fecal egg count (FEC) of *Nematodirus* was determined as the sole predictable measure of worm burden in juveniles only, which supports the idea of immune-mediated control in adults. Such age trends are not even constant among the nematodes. An intriguing dynamic process was noted in the "Askania Nova" population, where the nematode *Camelostrongylus mentulatus* was dominant in the helminth community of calves but less in adults (Phetla *et al.*, 2024).

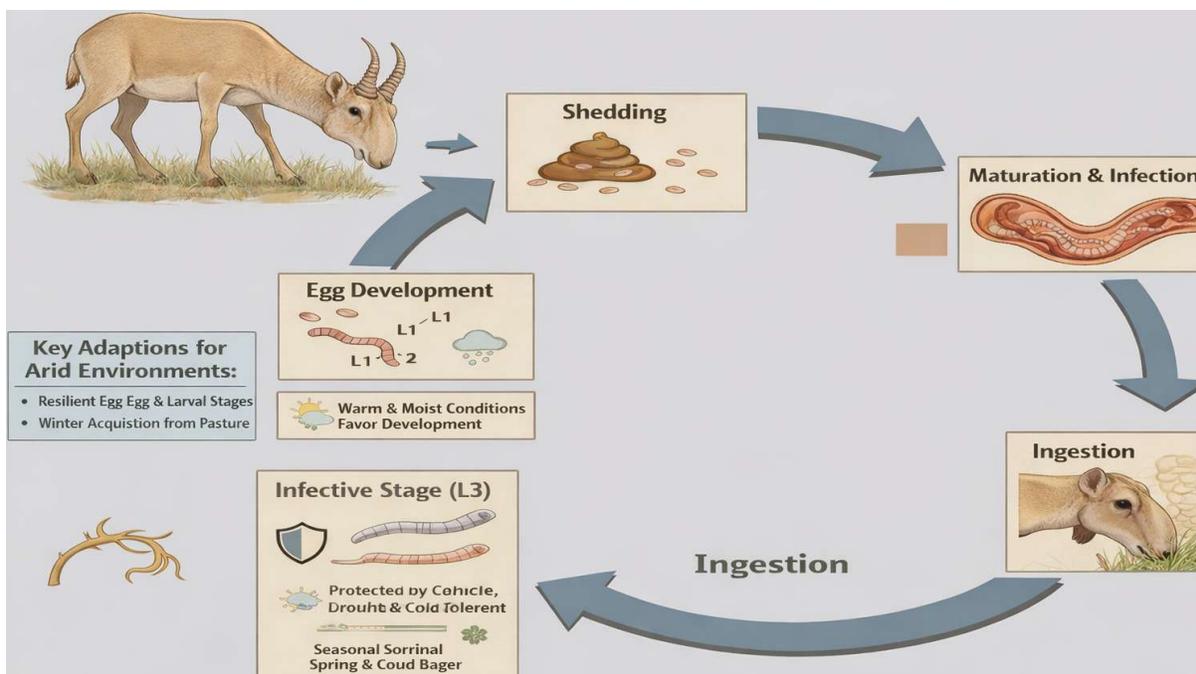


Fig. 1: Life cycle of helminths and their transmission in saiga antelope.

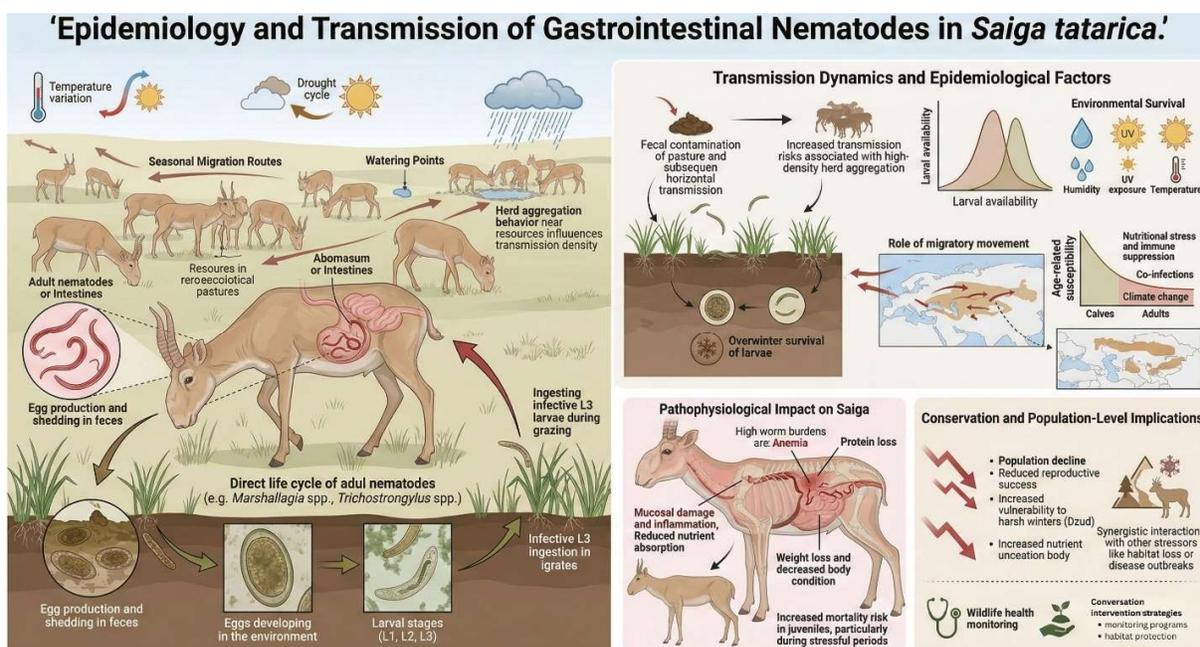


Fig. 2: Epidemiology and transmission of gastrointestinal nematodes in *Saiga tatarica*.

Pathophysiology and clinical impacts:

The major pathophysiological outcomes of such nematode infections are the localization and feeding of the parasites in the gastrointestinal tract of saiga antelope (Mohsin *et al.*, 2024). Comparatively, *Marshallagia marshalli*, *Camelostrongylus mentulatus* and *Haemonchus contortus* may cause serious damage to the abomasum of saiga antelope (Mayo *et al.*, 2013; Tehrani *et al.*, 2023). Researchers recently found that *Camelostrongylus mentulatus* causes abomasitis with symptoms that are similar to those of ostertagiosis, such as diarrhea, emaciation, and possible collapse in young ones (Zhou *et al.*, 2023; Chetan Kumar, 2023). Likewise, the extremely pathogenic blood-sucking species *Haemonchus contortus* can lead to anemia, hypoproteinemia, and edema. While not a major issue in saiga populations, it can still affect saiga antelopes given their similar species traits (Khanyari *et al.*, 2022a; Kandil *et al.*, 2025). The genera such as *Nematodirus* (e.g., *N. spathiger*, *N. gazellae*) can damage the intestinal mucosa in the small intestine due to the migration of larvae (Saidi *et al.*, 2020). Although usually subclinical in adults, this may cause dehydration syndromes in the more vulnerable young animals because of poor nutrient uptake and loss (Fig. 3). These parasites cause inflammatory reactions, including mucosal thickening and cell infiltration, which do not only decrease the efficiency of the digestive system but also require massive use of metabolic energy by the host to service the immune system and repair cell damage (McRae *et al.*, 2015). This persistent immune activation may cause hosts to dysregulated inflammatory reactions, such as cytokine storm syndromes (including hemophagocytic lymphohistiocytosis (HLH)) which have been reported to be serious complications to immune challenges in other mammalian hosts (Zhang *et al.*, 2023).

Clinical significance of these parasitic infections is very context-dependent, and it depends on host species, age, population density, and environmental conditions. The

most important observation that came out of the studies is that although there is a wide range of nematodes found that parasitise these antelopes, the observed levels are mostly tolerable or subclinical. In the Souss-Massa National Park, the number of antelopes is constant despite infections, and in the "Askania Nova" Biosphere Reserve, even without anthelmintics the helminths did not cause the death directly (Panayotova-Pencheva, 2024). Mathematical models of saiga antelopes reveal that the threat of pathogen maintenance and spread, including that of Foot and Mouth Disease Virus (FMDV), is extremely susceptible to the size of a host population and the entrance of pathogens. Equally, in the case of nematodes such as *Marshallagia*, models predicted that certain seasonal migrations may aid the process of livestock-wildlife and vice versa transmission (Rose *et al.*, 2014; Khanyari *et al.*, 2021).

The research persistently indicates extensive host range for most gastrointestinal nematodes present in antelopes, and most of them can infect domestic cattle, goats, and sheep. This gives a two-way transmission risk, which has significant implications. In threatened species such as the addax, scimitar-horned oryx and saiga antelope, there is a risk of population extinction due to the introduction of new or high-intensity parasites by sympatric livestock, especially where small, isolated groups or reintroductions are involved and inbreeding can make them susceptible (Saidi *et al.*, 2020; Ellis *et al.*, 2025).

Diagnosis of gastrointestinal nematodes in saiga antelope and current research gaps:

To recognize and identify the fauna of gastrointestinal parasites found in saiga antelopes, there is a need for diagnostic techniques for studying the nomadic species of parasites in the vast steppes (Abdybekova *et al.*, 2023). These methods range from simple post-mortem procedures to emerging tools and field adapted protocols, all of which are extensively used in the studies provided (Kock *et al.*, 2018).

Table 2: Prevalence of gastrointestinal nematodes found in saiga antelope through research studies

Sr. No.	Location of study	Study period	Sample size/ Sample method	Technique used for diagnosis	Nematode species identified	Prevalence	Mean intensity	Primary location of parasite	Ecological notes	Reference
1.	Betpak-Dala, Kazakhstan	1997	The sample size for this study was 133 saiga antelope	McMaster chamber used for the counting of fecal eggs; other includes necropsy, abomasum and intestine washings	<i>Skjabinia ovis</i> , <i>Nematodirus gazellae</i> , <i>M. mongolica</i> , <i>Marshallagia marshali</i>	<i>M. mongolica</i> ; 54% adults, <i>M. marshali</i> ; 70% adult, and <i>N. gazellae</i> ; 61% adult stages were found	<i>M. marshi</i> 213 worms in adult stages, <i>N. gazellae</i> 875 worms in juvenile stages, and <i>S. ovis</i> 400-732 worms	<i>Marshallagia</i> , <i>Nematodirus</i> and <i>Skrjabinema</i> are found in abomasum, small intestine and large intestine respectively	No adverse effects on body were observed, have potential of cross transmission	(Morgan et al., 2005)
2.	Askania-Nova	35 years (1979–2013)	252 fecal samples and 31 necropsies	Necropsy, coprology	19 species with highest intensities of <i>camelostongylus mentulatus</i> , <i>Marshallagia marshali</i> , <i>Trichostrongylus axei</i> , <i>T. colubriformis</i> , <i>T. probolurus</i> , <i>Haemonchus contortus</i> , <i>Nematodirus</i> spp., <i>Trichuris ovis</i> .	100% nematode infections	<i>C. mentulatus</i> responsible for 80% of the burden of nematode infection with 207 adults	<i>Marshallagia</i> and <i>Haemonchus</i> in abomasum, <i>Trichostrongylus</i> and <i>Nematodirus</i> in small intestine, <i>Trichuris</i> and <i>Skrjabinema</i> in large intestine	Parasites may not be responsible for mortality but are vulnerable to calves	(Zvegintsova et al., 2015)
3.	Ural, Kazakhstan	Data from 2019 field and climate modelling in 2000 to 2020 climate	79 fecal pools from saiga antelope and 76 fecal pool samples from livestock	GLOWOR M-FL transmission model, Mini-FLOTAC	Strongyle-typed nematodes	Data based -	-	Parasites are found in majority part of GIT as pasture infectivity mainly from the shared grassland's livestock animal	Cross transmission from livestock animals	(Khan yari et al., 2022a)
4.	Betpak-Dala, Kazakhstan	2016	32 fecal samples only	Coprology	<i>Haemonchus contortus</i> , <i>Nematodirus</i> spp, <i>Marshallagia marshali</i>	<i>H. contortus</i> with 75%, <i>Nematodirus</i> with 34% and <i>Marshallagia</i> with 31% prevalence	No sufficient mean because of low overall intensities	Abomasum with <i>Marshallagia</i> and <i>Haemonchus</i> while small intestine with <i>Nematodirus</i>	Poor forage with low burden of parasite can cause immunosuppression	(Haines, 2016)
5.	Betapak-Dala, Kazakhstan	1989 climate model	Model only	Transmission model of saiga antelope with sheep	<i>Haemonchus contortus</i> , <i>Nematodirus</i> spp, <i>Marshallagia marshali</i>	As study was model based so not measured	The prevalence depends upon the seasons	<i>Marshallagia</i> and <i>Haemonchus</i> in abomasum while <i>Nematodirus</i> in small intestine	The transmission of the parasite is due to the amplification from sheep while the parasitic dynamic is influenced by migration and climate changes	(Morgan et al., 2007)
6.	North and Central Kazakhstan through multi-species survey	2023-2024	126 fecal samples were collected from saiga antelope	Microscopy, Fullebron flotation	Strongyle eggs, <i>Emeria</i> , <i>Trichuris</i> , and <i>Nematodirus</i>	15.9% prevalence	Mean intensity of eggs is 14.1	Found in the generalized location of the gastrointestinal tract of the saiga antelope	The parasite burden is modern as compared to other livestock animals	(Smagulova et al., 2025)

In the last decades, gastrointestinal nematodes of saiga were mainly investigated with the help of partial helminthological research, including systemic dissection of gastrointestinal organs (abomasum, small and large intestine) and examination of extra-intestinal organs in the presence of larval parasites (Mederos *et al.*, 2012). The method was also used under controlled conditions in the Askania Nova Biosphere Reserve. Its use in free-ranging feral populations of saiga, however, is seriously limited by migratory behavior, remote locations and practical limitations of field necropsy during official culling of the species in Kazakhstan, such as limited

access to water, chemicals, and transport infrastructure. The simplified field necropsy protocols were created to address these issues, in which the washed gut is sieved, and a standardized aliquot is stored to be analyzed in the laboratory later and used to estimate the total burden of worms (Knoll *et al.*, 2021). Such methods are based on opportunistic sampling and culled material, although proven to be reliable due to resource-limited conditions, which restrict longitudinal monitoring and population-level inferences. In turn, this makes it challenging to monitor live, nomadic saiga in any non-invasive manner, which identifies a significant diagnostic gap in the

accurate evaluation of the parasite prevalence, intensity, and dynamics of migratory fauna.

Coprological methods are the most used non-invasive approaches for monitoring and measuring parasite load in living animals. The Fulleborn flotation and the McMaster egg counting technique are the two principal techniques that were recorded in the saiga studies. Fulleborn is a semi-quantitative and qualitative method of flotation (Zhang *et al.*, 2023). This technique is ideal for identifying the occurrence of most nematode eggs. Instead, the McMaster technique is a quantitative procedure which aims to determine the number of eggs per gram (EPG) of fecal matter.

Although traditional practices have been able to offer substantial grounding, the future of saiga parasitology is set to be revolutionized by the application of molecular diagnostics, which is already in its infancy stages but has proven to be viable within the area. PCR is already in application, such as the screening of ticks gathered from saigas to detect the presence of blood-borne parasites such as *Theileria* and *Babesia*. The usage of the same technology in the diagnosis of GIN would be a milestone towards the right direction. Such methods as quantitative PCR (qPCR) may enable the highly sensitive and species-specific detection of nematodes in fecal samples, circumventing the difficulty of morphologically separating the eggs of the different trichostrongylid species (Hedley, 2022). The existing non-invasive diagnostic techniques to determine the presence of nematode infection in saiga are not supported by the standard protocols, which restrict our knowledge of the molecular epidemiology and exclude the possibility of longitudinal detection of a single parasite infection in a population. To resolve these essential gaps, it would be possible to use metabarcoding (a form of deep-amplicon sequencing) to describe the full gastrointestinal nematode community based on a single fecal sample. This would provide a viewpoint on biodiversity and infection never seen before without lethal sampling (Davey *et al.*,

2021). The recent reports on the allergenome genome-wide characterization of the house dust mite named *Blomia tropicalis* are a successful example of advanced molecular approaches, which have shown that integrated genomics and bioinformatics are powerful to deconstruct host-reactive proteins.

Conservation implications and integrated management of gastrointestinal nematodes in *Saiga tatarica*: The conservation consequences of gastrointestinal nematode (GIN) infections in the critically endangered saiga antelope lie in the fact that these infections cause chronic, sub-clinical stress that may undermine the fitness of the individual and the population (Khanyari *et al.*, 2022a). Direct mortality is not the major threat, but the synergetic effect of parasitism in combination with other threats (Jamil *et al.*, 2022; Mohsin *et al.*, 2024). High GIN loads lead to low body condition, low growth rates in juveniles and low fecundity in adults because of the redirection of energy towards the immune response (Morgan, 2003). More importantly, this parasitic burden may cause immunosuppression, which is predicted to have been one of the major causative conditions of the catastrophic mass fatality events, including the 2015 outbreak of pasteurellosis (Sweeny *et al.*, 2021). Such secondary bacterial infections are further complicated by the development of antimicrobial resistance globally; recent clinical trials have shown that even well-characterized Gram-negative bacterial infections such as those caused by *Pasteurella* species are difficult to treat, some being even resistant to last-line antibiotics.

A comprehensive, coordinated management plan should therefore be able to deal with this parasite-near stress by focusing on the wildlife-livestock disease interface. The main element here is the strategic use of anthelmintic treatments in domestic sheep and cattle, especially in strategic spaces and times of overlap identified as an outcome of modeling, like the southern

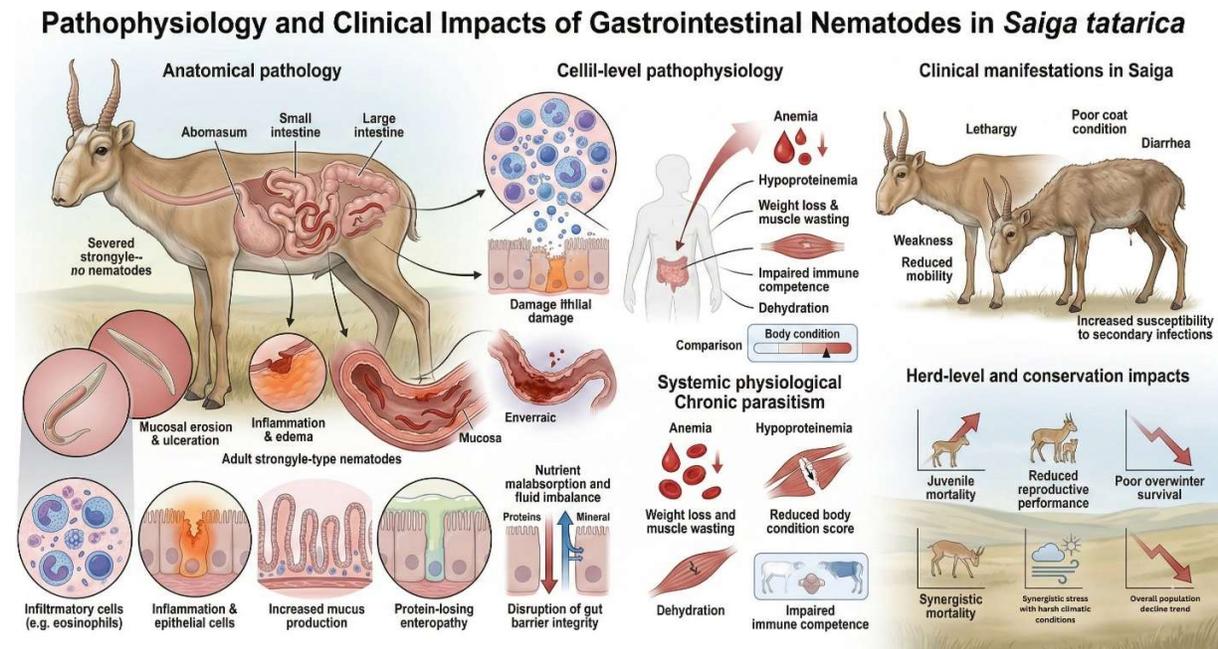


Fig. 3: Pathophysiology and clinical impacts of gastrointestinal nematodes in *Saiga tatarica*.

autumn/winter ranges where saigas are most likely to be infested with most of its *Marshallagia* (Khanyari *et al.*, 2022a; Saeed and Alsayeqh, 2023). Other studies have indicated that botanical compounds have potential as a control measure against other parasitic infections such as *Trypanosoma cruzi*, which could lead to exploring if other plant-based methods can be applied to gastrointestinal nematodes in livestock and wildlife (Abbas *et al.*, 2025).

Finally, the control of nematode infection is not only a veterinary problem but an important part of a holistic conservation policy (Kock *et al.*, 2018). Conversation can help in reducing the major, un-noticed decline in saiga's population by combining specific targeted programs that aim to improve health through monitoring both livestock and saiga populations.

Conclusions: Overall, this review has shown that gastrointestinal nematodes (GINs) compose a heterotrophic and ecologically stable community of parasites in saiga antelope characterized by cold-adapted genera like *Marshallagia* and *Nematodirus*, as an indicator of long-term host-parasite co-evolution in the steppe ecosystem. Their spread is mainly dictated by direct life cycles, seasonal climatic conditions, migratory patterns, timed calving, and massive overlap with grazing livestock systems, which form predictable epidemiological hotspots, especially among the young. Despite the mostly subclinical infections, there is supportive evidence of cumulative impact, including immunomodulation, decreased growth, and decreased fecundity, which indicates a chronic and population-wide burden to fitness, which could increase exposure to other disease outbreaks and environmental stress. One of the primary conservation issues is that parasite overlap between saigas and domestic livestock is high, which means that cross-transmission at grazing interface points is easy and the management of the disease in mixed-use rangelands is complicated.

Nevertheless, there are still major gaps in the knowledge such as a lack of molecular epidemiological data, longitudinal and standardized surveillance studies, as well as the insufficiency of the quantification of the long-term effects of parasitism on the dynamics and resilience of the saiga population. According to the existing evidence, systematic non-invasive parasite surveillance, systematic surveillance of the areas of calving and migration, and strategic anthelmintic treatment of livestock in high-contact areas are the aspects that should be considered as immediate management priorities. Long-term longitudinal investigations, use of molecular techniques like metabarcoding and qPCR, and combined transmission modeling studies should be prioritized in future research to enhance the idea of livestock-wildlife parasite transmission across changing climatic and socio-ecological environments. Overall, GIN monitoring needs to be included in a conservation medicine framework to inform management and allow to restore the saiga and its steppe habitats sustainably.

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REFERENCES

- Abbas RZ, Abbas A, Raza MA, *et al.*, 2019. In vitro anticoccidial activity of *Trachyspermum ammi* (Ajwain) extract on oocysts of *Eimeria* species of Chicken. *Advances in Life Sciences* 7(1):44-47.
- Abbas RZ, Qureshi MA and Saeed Z, 2025. Botanical compounds: A promising control strategy against *Trypanosoma cruzi*. *Boletín Latinoamericano y del Caribe de plantas medicinales y aromáticas* 24(3):308-327.
- Abdybekova AM, Zhaksylykova AA, Kushaliyev KZ, *et al.*, 2023. A survey of the parasites of Ural saiga antelopes and Turkmenian kulans of Kazakhstan. *International Journal for Parasitology: Parasites and Wildlife* 21:232-236.
- Absatirov G, Smagulov D, Bozymov K, *et al.*, 2025. Risks to the growth, conservation and management of the Ural saiga population. *Diversity* 17(9):595.
- Agrawal V, Swami M, Jaiswal AK, *et al.*, 2024. *Parasites of Gastrointestinal System, Parasitic Diseases of Goats*. Bentham Science Publishers. pp:26-61.
- Aissa S, Rachida M, Fatima H, *et al.*, 2021. Gastrointestinal nematode infections in antelopes from Morocco: A coprological survey. *Acta Veterinaria* 71(1):47-60.
- Akramova F, Shakarbaev U, Mirzayeva A, *et al.*, 2025. Helminths of domestic and wild artiodactyls (Mammalia, Artiodactyla) in Uzbekistan. *Biosystems Diversity* 33(1):e2514-e2514.
- Ashrafi K, Sharifdini M, Heidari Z, *et al.*, 2020. Zoonotic transmission of *Teladorsagia circumcincta* and *Trichostrongylus* species in Guilan province, northern Iran: molecular and morphological characterizations. *BMC Infectious Diseases* 20(1):28.
- Barone CD, Wit J, Hoberg EP, *et al.*, 2020. Wild ruminants as reservoirs of domestic livestock gastrointestinal nematodes. *Veterinary Parasitology* 279:109041.
- Bautista-Garfias CR, Castañeda-Ramírez GS, Estrada-Reyes ZM, *et al.*, 2022. A review of the impact of climate change on the epidemiology of gastrointestinal nematode infections in small ruminants and wildlife in tropical conditions. *Pathogens* 11(2):148.
- Begilov T, Grachev Y and Eszhanov B, 2024. A study into the current state of *Saiga tatarica* L. populations with the use of retrospective data. *Acta Scientiarum. Animal Sciences* 46:e68717.
- Bizhanova N, Grachev A, Rametov N, *et al.*, 2025. Railway and Road Infrastructure in Saiga Antelope Range in Kazakhstan. *Diversity* 17(6):431.
- Brown TL, Airds PM, Porter S, *et al.*, 2022. Understanding the role of wild ruminants in anthelmintic resistance in livestock. *Biology Letters* 18(5).
- Burshakbayeva LM, Narbayev S, Arynova RA, *et al.*, 2025. Using innovative technological methods for monitoring and accounting of rare and endangered species of wild animals in Kazakhstan. *Caspian Journal of Environmental Sciences* 23(2):327-333.
- Cable J, Barber I, Boag B, *et al.*, 2017. Global change, parasite transmission and disease control: lessons from ecology. *Philosophical Transactions of the Royal Society. Biological Sciences* 372(1719):20160088.
- Cafiero SA, Rossi C, Cenni L, *et al.*, 2024. The *Echinococcus multilocularis* cycle: first detection of intermediate host in a highly endemic region of Northeastern Italy. *Annals of Parasitology* 70:105-106.
- Chetan Kumar GK, 2023. *Parasitic Diseases of Goats. Principles of Goat Disease and Prevention*. Wiley-Blackwell, United States of America pp:63-77.
- Chimeddorj B, Bayartogtokh B, Mallon D, *et al.*, 2024a. Ecology and Conservation of the Endangered Mongolian Saiga (*Saiga tatarica mongolica*). *Mongolian Journal of Biological Sciences* 22:1.
- Chimeddorj B, Buuveibaatar B, Galsandorj N, *et al.*, 2024b. From isolation to integration: assessing habitat connectivity of the endangered saiga antelope in Mongolia. *Mammalian Biology* 104(3):221-229.

- Cortés A, Wills J, Su X, et al., 2020. Infection with the sheep gastrointestinal nematode *Teladorsagia circumcincta* increases luminal pathobionts. *Microbiome* 8(1):60.
- Davey ML, Utaaker KS and Fossoy F, 2021. Characterizing parasitic nematode faunas in faeces and soil using DNA metabarcoding. *Parasites & Vectors* 14(1):422.
- Ellis L, Yu JH, Mertes K, et al., 2025. Disease Risks for Restoring Endangered Sahelo-Saharan Antelope: A Literature Review. *EcoHealth* 22(3):439-463.
- Elwakil R, 2023. Impact of Climate Change on the Liver and GIT Parasitic Diseases, Impact of Climate Change on Health in Africa: A Focus on Liver and Gastrointestinal Tract. Springer pp:119-152.
- Ezenwa VO, 2020. Co-infection and nutrition: integrating ecological and epidemiological perspectives, Nutrition and infectious diseases: Shifting the clinical paradigm. Springer pp:411-428.
- Fentahun T, 2020. Systematic review on gastrointestinal helminths of domestic ruminants in Ethiopia. *Online Journal of Animal and Feed Research* 10(5): 216-230.
- Fereidouni S, Freimanis GL, Orynbayev M, et al., 2019. Mass die-off of saiga antelopes, Kazakhstan, 2015. *Emerging Infectious Diseases* 25(6):1169.
- Figueiredo AM, Valente AM, Fonseca C, et al., 2020. Endoparasite diversity of the main wild ungulates in Portugal. *Wildlife Biology* 2020(1):1-7.
- Goossens E, Verduyck J, Dorny P, et al., 2003. Gastro-intestinal parasitism in antelopes, gazelles and Giraffidae: prevalence and epidemiology in a zoo collection. *CABI (conference proceedings)* 2003: 1.
- Haines J, 2016. Nutrition-Parasite Interaction in Female Calving Saiga Antelopes (Saiga tatarica): Implications for the 2015 Die-Off. Master's thesis. University of Bristol. United Kingdom.
- Hassan FU, Liu C, Mehboob M, et al., 2023. Potential of dietary hemp and cannabinoids to modulate immune response to enhance health and performance in animals: opportunities and challenges. *Frontiers in Immunology* 14:285052.
- Hedley N, 2022. Development of novel methods for preparing and analysing gastrointestinal nematodes in livestock. Doctoral dissertation, Swinburne University of Technology: 216.
- Jamil M, Aleem MT, Shaikat A, et al., 2022. Medicinal plants as an alternative to control poultry parasitic diseases. *Life* 12(3):449.
- Jas R, Hembram A, Das S, et al., 2022. Impact of climate change on the free-living larval stages and epidemiological pattern of gastrointestinal nematodes in livestock. *Indian Journal of Animal Health* 61(2):83-94.
- Kandil O, Hany M, Elsawy BSM, et al., 2025. A Review: *Haemonchus contortus* Infection in Sheep: Anemia, Epidemiology, and Advances in Diagnosis. *Egyptian Journal of Veterinary Sciences* 2025:1-15.
- Katona K and Coetsee C, 2019. Impacts of browsing and grazing ungulates on faunal biodiversity, The ecology of browsing and grazing II. Springer. pp:277-300
- Khamchukova A, Duysebayeva T, Jamal MA, et al., 2025. Current states of bridge construction materials for wildlife crossings in linear infrastructure for saiga conservation: A review. *ES Energy and Environment* 30:1974.
- Khanyari M, Milner-Gulland EJ, Oyanedel R, et al., 2022. Investigating parasite dynamics of migratory ungulates for sustaining healthy populations: Application to critically-endangered saiga antelopes *Saiga tatarica*. *Biological Conservation* 266:109465.
- Khanyari M, Oyanedel R, Khara A, et al., 2024. Predicting and reducing potential parasite infection between migratory livestock and resident Asiatic ibex of Pin valley, India. *Journal of Biosciences* 49(2):50.
- Khanyari M, Robinson S, Morgan ER, et al., 2022b. Identifying relationships between multi-scale social-ecological factors to explore ungulate health in a western Kazakhstan rangeland. *People and Nature* 4(2):382-399.
- Khanyari M, Suryawanshi KR, Milner-Gulland EJ, et al., 2021. Predicting parasite dynamics in mixed-use trans-Himalayan pastures to underpin Management of Cross-Transmission between Livestock and Bharal. *Frontiers in Veterinary Science* 8:714241.
- Knoll S, Dessi G, Tamponi C, et al., 2021. Practical guide for microscopic identification of infectious gastrointestinal nematode larvae in sheep from Sardinia, Italy, backed by molecular analysis. *Parasites & Vectors* 14(1):505.
- Kock R, Chardonnet P and Risley C, 2016. Antelope Diseases—the Good, the Bad and the Ugly. *Antelope Conservation: From Diagnosis to Action*. Wiley Online Library pp:108-136.
- Kock RA, Orynbayev M, Robinson S, et al., 2018. Saigas on the brink: Multidisciplinary analysis of the factors influencing mass mortality events. *Science Advances* 4(1):ea02314.
- Konoplianikova Y, Karpukhina N, Filippova K, et al., 2018. Practical Geography and XXI Century Challenges. International Geographical Union Thematic Conference dedicated to the Centennial of the Institute of Geography of the Russian Academy of Sciences, 4-6 June 2018, Moscow. Conference Book. Part 2.—Moscow: Institute of Geography, Russian Academy of Sciences pp:358 p.
- Kushaliyev K, Shamshidin A, Kozhayeva A, et al., 2024. Creation of nurseries and veterinary preventive measures for saigas of Betpakdala and Ural populations in Kazakhstan. *Scientific Horizons* 27(1):41-53.
- Mabbott NA, 2018. The influence of parasite infections on host immunity to co-infection with other pathogens. *Frontiers in Immunology* 9:2579.
- Macchioni F, Vallone F, Lenzi C, et al., 2023. Helminth fauna in roe deer (*Capreolus capreolus* Linnaeus, 1758) in the province of Grosseto (central Italy). *Helminthologia* 60(2):134.
- Mallon DP and Kingswood SC, 2001. Regional action plan for antelope conservation. *Antelopes Part 4: North Africa, The Middle East and Asia. Global Survey and Regional Action Plans 2001*:231-244.
- Mayo E, Ortiz J, Martínez-Carrasco C, et al., 2013. First description of gastrointestinal nematodes of Barbary sheep (*Ammotragus lervia*): the case of *Camelostomylus mentulatus* as a paradigm of phylogenetic and specific relationship between the parasite and its ancient host. *Veterinary Research Communications* 37(3):209-215.
- McRae KM, Stear MJ, Good B, et al., 2015. The host immune response to gastrointestinal nematode infection in sheep. *Parasite Immunology* 37(12):605-613.
- Mederos A, Waddell L, Sánchez J, et al., 2012. A systematic review-meta-analysis of primary research investigating the effect of selected alternative treatments on gastrointestinal nematodes in sheep under field conditions. *Preventive Veterinary Medicine* 104(1-2):1-14.
- Mohsin M, Aleem MT, Goraya MU, et al., 2024. Natural products and pseudo-natural products against veterinary disease-causing microorganisms. *Frontiers in Veterinary Science* 11:1429587.
- Moon D, 2023. Saiga antelopes (*Saiga tatarica*) in the environmental history of the Qazaq steppe and desert, Environmental humanities in central Asia. Routledge. pp:107-128
- Morgan E, 2003. The dynamics of parasite transmission between the Saiga antelope and domestic livestock in Kazakhstan. University of Warwick.
- Morgan ER, Medley GF, Torgerson PR, et al., 2007. Parasite transmission in a migratory multiple host system. *Ecological Modelling* 2007 (3-4):511-520.
- Morgan ER, Segonds-Pichon A, Ferte H, et al., 2023. Anthelmintic treatment and the stability of parasite distribution in ruminants. *Animals* 13(11):1882.
- Morgan ER, Shaikenov B, Torgerson PR, et al., 2005. Helminths of saiga antelope in Kazakhstan: implications for conservation and livestock production. *The Journal of Wildlife Diseases* 41(1):149-162.
- Muma JB, Phiri AM, Chota A, et al., 2010. Helminth parasites of the Kafue lechwe antelope (*Kobus lechwe kafuensis*): a potential source of infection to domestic animals in the Kafue wetlands of Zambia. *Journal of Helminthology* 85: 20-27.
- Neronov VM, Lushchekina AA, Karimova TY, et al., 2012. Population dynamics of a key steppe species in a changing world: the critically endangered saiga antelope, Eurasian steppes. *Ecological problems and livelihoods in a changing world*. Springer pp:335-356.
- Panayotova-Pencheva MS, 2024. Control of helminth infections in captive herbivores: An overview of experience. *Journal of Zoological and Botanical Gardens* 5(4):641-667.
- Phetla V, Chaisi M and Malatji MR, 2024. Epidemiology and diversity of gastrointestinal tract helminths of wild ruminants in sub-Saharan Africa: a review. *Journal of Helminthology* 98:e45.
- Polaz SV, 2022. Helminths of wild ungulates living in different regions of Belarus. *Russian Journal of Parasitology* 16(1):33-49.
- Robinson S, Milner-Gulland EJ, Grachev Y, et al., 2019. Opportunistic bacteria and mass mortality in ungulates: lessons from an extreme event. *Ecosphere* 10(6):e02671.
- Rose H, Hoar B, Kutz SJ, et al., 2014. Exploiting parallels between livestock and wildlife: predicting the impact of climate change on gastrointestinal nematodes in ruminants. *International Journal for Parasitology: Parasites and Wildlife* 3(2):209-219.
- Saeed Z and Alsayeqh AF, 2023. Evaluation of anthelmintic, hematological, and serum biochemical effects of herbal dewormer on the cattle. *Slovenian Veterinary Research* 60 (25-Suppl):353-362.

- Said Y, Gharbi M, Mhadhbi M, et al., 2018. Molecular identification of parasitic nematodes (Nematoda: Strongylida) in feces of wild ruminants from Tunisia. *Parasitology* 145(7):901-911.
- Saidi A, Mimouni R, Hamadi F, et al., 2020. Cross-sectional study of Eimeria spp. infection in three antelope species (*Addax nasomaculatus*, *Gazella dorcas* and *Oryx dammah*) maintained in the Souss-Massa National Park (Morocco). *Nature Conservation Research (S2)*:77-82.
- Saidi A, Mimouni R, Hamadi F, et al., 2020. Some larval morphological characteristics of *Camelostrongylus mentulatus* and *Nematodirus spathiger*. *Ukrainian Journal of Veterinary and Agricultural Sciences* 3(2):7-11.
- Singh NJ, Grachev IA, Bekenov AB, et al., 2010. Saiga antelope calving site selection is increasingly driven by human disturbance. *Biological Conservation* 143(7):1770-1779.
- Smagulova A, Uakhit R, Lider L, et al., 2025. The main helminths and protozoa of the digestive tract of domestic and wild ungulates in northern and central Kazakhstan. *Herald of Science of S Seifullin Kazakh Agro Technical Research University: Veterinary Sciences* 3 11:43-51.
- Sweeny AR, Albery GF, Becker DJ, et al., 2021. Synzootics. *Journal of Animal Ecology* 2021:1-11.
- Tariq KA, 2015. A review of the epidemiology and control of gastrointestinal nematode infections of small ruminants. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences* 85(2):693-703.
- Tehrani MH, Shemshadi B, Shayan P, et al., 2023. Prevalence of abomasum nematode infection in sheep from North of Iran. *Journal of the Hellenic Veterinary Medical Society* 74(4):6361-6368.
- Wang L, Huang G, Li G, et al., 2025. Updating conservation metagenomics on the gut microbiome of threatened mammals. *Iscience* 28(7).
- Zarlenga DS, Hoberg E, Rosenthal B et al., 2014. Anthropogenics: human influence on global and genetic homogenization of parasite populations. *Journal of Parasitology* 100(6):756-772.
- Zhang HQ, Cao BZ, Cao QT, et al., 2023. An analysis of reported cases of hemophagocytic lymphohistiocytosis (HLH) after COVID-19 vaccination. *Human Vaccines & Immunotherapeutics* 19(2):2263229.
- Zhang W, Ralston J, Sun W, et al., 2023. Quantitative evaluation of collector flotation performance I: The creation of a flotation index based on mineral recovery. *Separation and Purification Technology* 327:124919.
- Zvegintsova NS, Kharchenko VA and Kuzmina TA, 2018. Helminths of exotic even-toed ungulates (Artiodactyla) in the Askania-Nova biosphere reserve, Ukraine. *Zoodiversity* 52(6):471-494.
- Zvegintsova NS, Treus MY and Kuzmina TA, 2015. Helminths of saiga antelope (*Saiga tatarica* L.) in the "Askania Nova" biosphere reserve, Ukraine. *Helminthologia* 52(3):219-228.