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Animal and bird diseases – the food chain of the snow leopard in the highlands of the Tian Shan

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Abstract. The snow leopard (*Panthera uncia*) is a rare and vulnerable species that is threatened with extinction and listed in the Red Book of the Kyrgyz Republic. It inhabits the inaccessible high-mountain areas of the Tian Shan, where the ecological balance directly depends on the state of the fauna that makes up its food chain. In recent years, there has been an increase in the number of diseases among wild and domestic animals, which may affect the health of the snow leopard population and the stability of the ecosystem as a whole. The aim of this study was to investigate parasitic diseases in mammals that are part of the snow leopard's food chain, determining their biological characteristics, sources of infection and impact on the epizootic situation in mountainous areas. The study used field observations, helminthological autopsies, microscopic analysis of biomaterial, comparative morphological and descriptive analysis of veterinary research data. As a result, it was established that alveococcosis and muelleriosis are the most epidemiologically significant of the identified parasitic diseases, posing a serious threat to both wild and domestic animals. The causative agent of alveococcosis is the larval stage of the tapeworm *Alveococcus multilocularis*, which affects the liver and causes the formation

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of multiple cystic parasitic nodes capable of infiltrative growth and metastasis. The final hosts of this parasite are carnivorous animals (dogs, cats, wolves, foxes, manuls, etc.), and the intermediate hosts are small wild rodents. It has also been established that the pathogen *Mullerius capillaris* causes lung damage in goats, sheep and wild ruminants, manifested by multiple foci of productive alveolitis and a decrease in the overall resistance of animals. A comprehensive analysis of the biological and ecological characteristics of pathogens allows for assessing their circulation in natural conditions and potential risks to humans. The practical significance of the study lies in the possibility of using the data obtained to develop a system of preventive and diagnostic measures aimed at protecting rare predators and stabilising the epizootic well-being of the high-mountain ecosystems of Kyrgyzstan

Keywords: Siberian ibex; argali; roe deer; alveococcosis; mulleriosis; cysticercosis

Introduction

The conservation of wild fauna and rare animal species in the context of global environmental change is one of the priority tasks of modern biological and veterinary science. In recent decades, against the backdrop of increasing anthropogenic impact, climate change and the degradation of natural ecosystems, there has been a decline in the numbers of many mammals in Kyrgyzstan, including Red Book species. The most vulnerable species include the snow leopard (*Panthera uncia*), Siberian ibex (*Capra sibirica*), argali (*Ovis ammon*) and roe deer (*Capreolus capreolus*), which play an important role in maintaining the biological balance of the Tian Shan Mountain ecosystems. Disruption of food chains, deterioration of the food base and the spread of parasitic diseases among animals in these chains have a significant impact on the epizootic situation and the stability of ecosystems (Esson *et al.*, 2019). In recent years, there has been a trend towards an increase in the number of parasitic diseases in wild animals (Chrétien *et al.*, 2023). Parasitic infestations, including alveococcosis and muelleriosis, are becoming an important factor limiting the growth of ungulate and predator populations in Central Asia. These diseases affect not only internal hosts (rodents and ungulates) but also final hosts – carnivorous animals, including the snow leopard, for which parasite infection can have fatal consequences. According to S. Ostrowski & M. Gilbert (2024), parasitic infections cause complex morphofunctional changes in internal organs, disrupt metabolism, suppress the immune system and reduce the ability of animals to adapt to extreme environmental conditions.

The immune system of vertebrates is a collection of organs, tissues and cells that recognise and destroy foreign agents. The primary organs of immunogenesis – the thymus and bone marrow – are the source of the formation and maturation of lymphocytes, which are responsible for cellular and humoral immunity. Secondary organs – lymph nodes, spleen and lymphoid formations of the mucous membranes – ensure the implementation of immune responses and the formation of immunological memory (Weiskopf *et al.*, 2016). According to G. Schaller (2012), the morphological organisation of the immune system in animals living in high-altitude conditions differs from that of lowland species due to hypoxia, low temperatures and limited food diversity. The adaptive mechanisms of the immune system in wild animals are formed under the influence of natural selection, but constant stress, parasitic load, and environmental factors can cause depletion of immune resources. Research by M. Luo *et al.* (2023) has shown that chronic parasitic diseases lead to changes in the structure of lymphoid organs, in particular thymus atrophy and reduction of the follicular zones of the spleen. Similar changes have been observed in domestic ruminants infected with *Mullerius capillaris* (Shao *et al.*, 2019). In wild species living in the mountains, these processes are more pronounced due to limited access to food and increased physiological stress.

Parasitic diseases such as alveococcosis and mulleriosis have a direct impact on the immune system of animals. The larval stage *of Alveococcus multilocularis* affects the liver, causing the formation of cystic nodules, infiltrative tissue growth, and metastatic spread to the lungs and brain (Shao *et al.*, 2021). These processes are accompanied by a pronounced immune response, activation of macrophages and lymphocytes, which ultimately leads to depletion of the lymphoid organs. The pathogen *Mullerius capillaris* affects the lungs, causing chronic alveolitis and fibrosis, which also leads to changes in the structure of secondary organs of the immune system, especially the lymph nodes. Research by M. Osborne & J. Laird (2022) confirms that prolonged parasitic infections lead to the restructuring of lymphoid tissue, impaired lymphocyte differentiation, and a decrease in the effectiveness of the immune response.

Despite the growing number of publications on parasitology and immunology of domestic animals, the morphological features of the immune system in wild ungulates of Central Asia have been studied extremely poorly. To date, there is no comprehensive data on structural changes in the thymus, spleen, and lymph nodes of Siberian ibex, argali, and roe deer in parasitic diseases. Meanwhile, such information is necessary to assess the biological stability of populations, predict their condition, and develop preventive measures in the system of protection of rare species. The study of the morphology of immune organs in wild fauna has not only scientific but also practical significance. The morphological features identified in the course of research can be used to diagnose invasive diseases, develop criteria for epizootic monitoring, and assess the impact of parasitic load on animal health (Ale, 2007). In addition, the results of such analysis make it possible to clarify the mechanisms of immunogenesis in extreme conditions and determine the body's adaptive capacity to prolonged exposure to pathogens. An important direction in modern research is the interdisciplinary approach, combining data from morphology, histology, parasitology, and immunology. As noted by S. Ashokumar (2023) noted, only a comprehensive study of structural changes in the immune system allows for an adequate assessment of the impact of infectious agents on the body and the development of effective biosecurity measures. In Kyrgyzstan, where wildlife is under constant exposure to climatic and anthropogenic factors, such research is of particular importance.

An analysis of scientific publications shows that the morphology of immune organs is a key indicator of animal health and their ability to adapt to external influences. However, there have been no systematic studies devoted to wild species in Kyrgyzstan to date. The aim of this study was to identify morphological changes in the main, primary and secondary organs of the immune system (thymus, spleen and lymph nodes) in Siberian ibex, argali and roe deer affected by parasitic diseases, and to determine the characteristics of their immune reactivity and adaptive mechanisms in the high-altitude ecosystems of the Tian Shan.

Materials and Methods

The study was conducted in the Kyrgyz Republic from May 2023 to March 2025 and included two main areas: monitoring wild animal populations and pathomorphological study of the organs and tissues of hunted individuals. The objects of the pathomorphological study were wild ungulates: Siberian ibex (*Capra sibirica*), argali (*Ovis ammon*) and roe deer (*Capreolus capreolus*), which are the main components of the snow leopard (*Panthera uncia*) food chain in the high-altitude ecosystems of the Tian Shan. The animals were shot in strict accordance with licence No. 45/2025, issued by the Ministry of Hunting and Fisheries of the Kyrgyz Republic on 10 March 2025, as well as with the Guidelines for Wildlife Research (2022). A total of five individuals were studied, weighing between 35 and 48 kg. The culling was carried out in the Katta-Taldyk district of the Talas region between 12 and 15 March 2025.

Automatic camera traps were used to assess the abundance and spatial distribution of wild animals in the study area. The cameras were installed on 17 May 2023 in the areas of Zindi-Suu, the Chon-Emgek gorge, Zhaia, Koi-Suu in the Chon-Kemin valley, as well as on the Kakshaal-Too ridge at an altitude of 2,500 to 4,500 m above sea level. A total of 13 cameras were installed at various exposures on the slopes. The camera traps were checked between May and September 2023. Immediately after the shooting, a detailed inspection and photographing of the animals was carried out.

Samples of the following organs and tissues were taken from the shot animals for histological examination: liver, lungs, heart, kidneys, spleen, thymus, lymph nodes, thigh and back muscles, skin, and pancreas. The size of the samples taken was 1.0-2.5 cm^3, and the weight of each was 1.2-3.5 g. The material was fixed in 10% neutral formalin to preserve the morphological structure of the tissues. After fixation, the samples were sequentially dehydrated in alcohols of increasing concentration (70%, 80%, 90%, 96%, 100%). Further processing was carried out according to the following scheme: alcohol/chloroform (50:50), chloroform, paraffin/xylene (50:50) at a temperature of 37°C, followed by sequential impregnation with paraffin at 56-57°C (paraffin 1, paraffin 2) and final immersion in pure paraffin to compact the tissues. All stages of processing, storage and preparation of samples were carried out in the laboratory conditions of the Research Laboratory of Zoology of the Kyrgyz National Agrarian University named after K.I. Skryabin in compliance with standard safety and hygiene protocols. The prepared samples were used for subsequent microscopic examination according to standard methodology (Eckert *et al.*, 2001; Huynh *et al.*, 2022). Serial sections 5-7 μm thick were prepared from paraffin blocks using a sliding microtome. The histological preparations were stained with haematoxylin and eosin according to standard methodology. The histological preparations were examined using Biolam LOMO (Russia) and PZO Warszawa (Poland) light microscopes at magnifications of ×40, ×100, ×200 and ×400. Microphotography was performed using a Leica ICC50 HD microscope (Leica Microsystems, Germany) equipped with a built-in high-resolution digital camera. During the pathological autopsy, a visual examination of the internal organs was performed to detect macroscopically visible parasitic lesions. The pathological changes identified were photographed and described morphologically. Parasites were identified based on the morphological characteristics of the larval and sexually mature stages of helminths in histological sections.

The study area is located in the high-mountain zone of the Tian Shan at an altitude of 700 to 4,500 m above sea level. The territory is characterised by mountainous relief with pronounced vertical zonation, including alpine meadows, rocky areas and upland scree. Climatic conditions are characterised by low temperatures, hypoxia and limited food diversity, which determines the specific adaptation mechanisms of the fauna inhabiting this area.

Results and Discussion

Kyrgyzstan is a mountainous country located within three physical-geographical territories: the Central Asian Plain, the Central Asian Highlands, and the

Central Asian Plateau. The Central Asian Plain is located in the Turan Lowland and is characterised by desert landscapes. Within its boundaries, in the north of Kyrgyzstan, there is the Chui Valley at an altitude of 850-900 m, the Talas Valley at an altitude of 700-800 m, and in the south, the sloping plains of the Fergana Valley stretch at an altitude of 1,000-1,100 m above sea level. The Central Asian Highlands cover most of Kyrgyzstan, which is divided into two large regions: the mountainous area of the Northern and Inner Tian Shan and the Fergana mountainous area. These areas are characterised by mountain ranges with heights of 1,500-5,500 m above sea level. The Central Asian highlands include the southern and south-eastern regions of Kyrgyzstan, namely the Alay Valley in the south-west and the north-east up to the Sary-Jaz River basin. Among these highlands is the mountain-syrty part of Kyrgyzstan, where syrty is a type of highland with a flat relief, mainly used as high-altitude summer pasture. The fauna in these areas is very diverse, including birds such as the alpine chough, golden eagle, capercaillie, mountain turkey or ular, saker falcon, gyrfalcon, vultures, bearded vulture, Himalayan ular, eagles, etc. (Bar, 2021). Mammals include marmots, mountain goats, argali, snow leopards, wolves, foxes, wild boars, brown bears, Turkestan lynxes, and manuls (Table 1).

Table 1. Species diversity of wild animals on the Kakshaal-Too ridge

Name	Name (lat.)	Approximate number
Snow leopard	*Uncia uncia*	1
White-clawed bear (Tian Shan)	*Ursus arktos*	3
Arhar	*Ovis ammon*	145
Mountain goat	*Carpa sibirica*	150
Manul	*Felis manul*	3
Red fox	*Vulpes vulpes*	18
Wolf	*Canis lupus*	7
Badger	*Meles meles*	5
Golden eagle	*Aquila chrysaetus*	2
Bearded vulture	*Gypaetus barbatus*	1
Himalayan ibis	*Tetraogallus himalayensis*	34

Source: compiled by the authors based on reports from the NABU (n.d.) monitoring department for 2024

To count the number of snow leopards, mountain goats, argali, roe deer, wild boars and other mammals in the snow leopard's food chain, camera traps were installed on the mountain slopes of the Turkestan Range, Teskey Ala Too, Central Tian Shan and other locations. The camera traps were installed in the study areas at various exposures on slopes at an altitude of more than 2,500-3,000 metres above sea level. The installation of camera traps began on 17 May 2023, and 13 cameras were installed in the areas of Zindi-Suu, in the Chon-Emgek Gorge, Zhay, Koi-Suu, and the Chon-Kemin Valley, at altitudes of 500-4,500 m above sea level. When checking the camera traps on 26 May 2023 in the Zindi-Suu area at an altitude of 3,175 m above sea level, the presence of a snow leopard was recorded. This graceful, beautiful animal has a smoky grey coat with dark rings. Its fur is thick and fluffy, and it is more commonly found at the edge of the permanent snow line, descending to the coniferous forest belt in winter, as confirmed by camera traps (Tetzloff & Schwartz, 2024). In the second half of September 2023, an expedition was conducted to the Ak-Sai Valley in the At-Bashinsky District in collaboration with employees of NABU (The Nature and Biodiversity Conservation Union) Kyrgyzstan. During the expedition, camera traps previously installed on the Kakshaal-Too ridge were removed. The images captured snow leopards, ibexes, argali sheep, wolves, martens, foxes and other species of fauna. Figure 1 shows the species diversity of wild animals recorded on the Kakshaal-Too ridge in 2024. The data reflects the approximate number of individuals of each species identified during field observations by NABU's (n.d.) monitoring department. The graph clearly shows the abundance of the most common species, including argali, mountain ibex and rare predators such as snow leopards and golden eagles. The most numerous among the observed species are the mountain goat (150 individuals) and the argali (145 individuals). Moderate numbers were recorded for the Himalayan ibex (34 individuals) and the red fox (18 individuals). Other species, such as the wolf (7 individuals), badger (5 individuals), manul and white-toothed Tian Shan bear (3 individuals each), golden eagle (2 individuals), bearded vulture and snow leopard (1 individual each), are much less common. The data show a clear predominance of large ungulates in the ecosystem of the ridge. During the study, observations were made and the locations of wild animals on the Kakshaal-Too ridge were recorded. Figure 2 shows the locations of the animals, reflecting their spatial distribution in the study area.

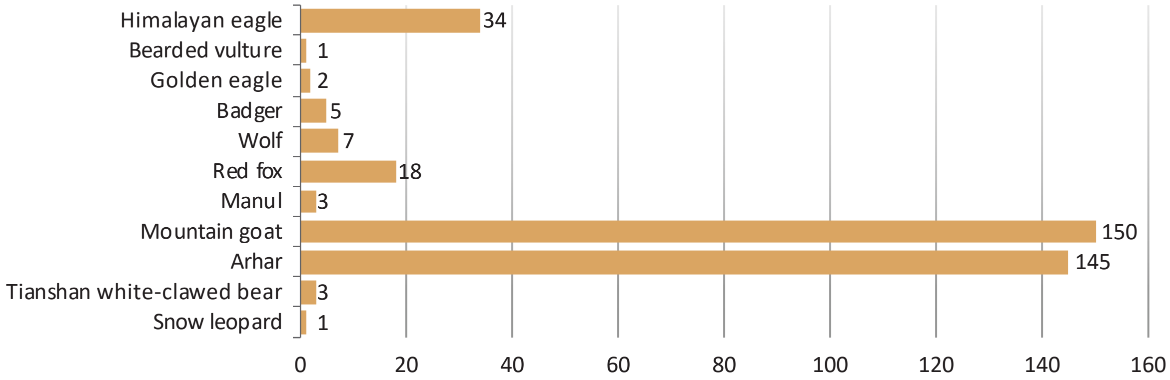


Figure 1. Species diversity of wild animals on the Kakshaal-Too ridge
Source: compiled by the authors based on reports from the NABU (n.d.) monitoring department for 2024

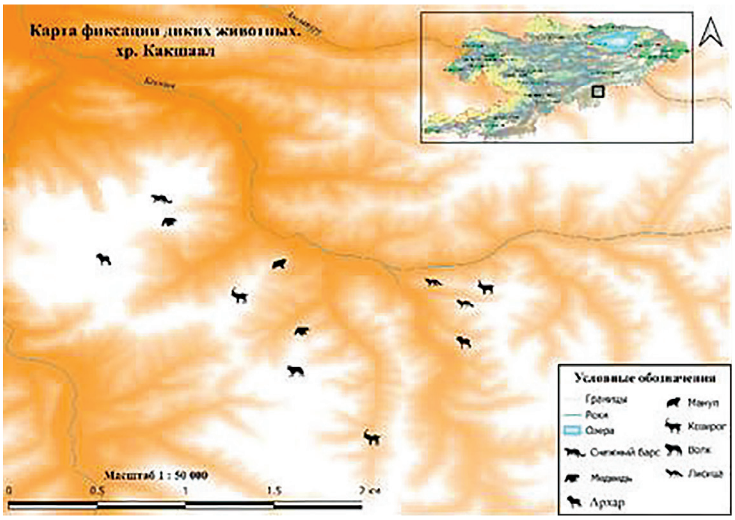


Figure 2. Points where wild animals were recorded on the Kakshaal-Too ridge
Source: compiled by the authors

The cartographic diagram in Figure 2 shows the location of the points where wild animals were recorded (detected) in the Kakshaal-Too ridge area. The map is drawn to a scale of 1:50,000. The scale bar in the figure allows the distances on the ground to be estimated. For clarity, the map includes symbols representing: the boundaries of the study area; rivers and lakes (hydrography); the animals observed – snow leopards and argali (mountain sheep); and the routes along which the observations were presumably made. The distribution of animal symbols on the map allows for a visual assessment of the areas of concentration and spatial distribution of key fauna species – snow leopards and argali – within the Kakshaal-Too ridge.

The snow leopard (Fig. 3) is one of the rare and endangered species of animals. Body length: 100-130 cm; tail length: 80-100 cm; height at the withers: 60 cm; weight: 37-55 kg (males), 35-42 kg (females); lifespan: ≈11 years, up to 21 years in captivity; number of offspring: 2-3 kittens; lifestyle: solitary predator; diet: medium-sized ungulates (ibex, argali, roe deer, wild boar, etc.), small mammals (marmots), and birds (ulars, etc.); habitat: high-altitude steppes and rocky terrain from 600 to 5,800 m above sea level; population: total number approximately 4,000-6,400 individuals. As noted by J. Khatiwada *et al.* (2007), the total area of the historically established range of the snow leopard is about 2.2 million square kilometres, which is less than 2% of the total land area. This territory is located in the highlands and inaccessible areas of the world – the Himalayas, Tibet, Karakoram, Hindu Kush, Pamir, Pamir-Alai, Tian Shan, Altai and Sayan.

One of the prey species of the snow leopard is the Siberian ibex or mountain goat (Fig. 4), which inhabits steep mountain slopes with abundant rocks and scree at an altitude of 2,500-4,000 metres above sea level. Ibex graze on alpine meadows, hiding from danger in the rocks, and descend to lower slopes with less snow in winter (Justa & Lyngdoh, 2023). They live in small herds of 10-30 individuals, with adult males forming separate groups of up to 10 individuals and spending most of the year in the most inaccessible places, separate from the females. On summer days, mountain goats graze in the morning and evening hours, and during the hot part of the day, they spend time under the shelter of rocks on windy mountain ridges. Depending on the locality and weather conditions, the mating season for Siberian goats is in November or December and lasts 10 days or more. The gestation period is 170-180 days, with females giving birth to one or two kids in late May or June. Their lifespan in the wild is 15-20 years.

Figure 3. Snow leopard (*Panthera uncia*)
Source: authors' photo

Figure 4. Siberian ibex (*Capra sibirica*)
Source: authors' photo

One of the diseases diagnosed among Siberian ibex is larval alveococcosis of the liver. Larval or cystic alveococcosis is a naturally occurring focal disease of animals and humans caused by the cestode *Alveococcus multibocularis*. The sexually mature (tapeworm) stage of the alveococcus parasitises in the intestines of carnivores (foxes, dogs, wolves, jackals, etc.). According to J. Janecka *et al*. (2020), the larval form is more commonly found in the liver and other internal organs of animals and humans. The macroscopic larval form is a multi-chambered cyst consisting of a large number of small bubbles (alveoli) tightly packed together, containing fluid and the parasite's scolex (Bobdey *et al*., 2023). The alveococcus bubble consists of a cuticular and germinative layer and hydatid fluid. The cuticular or protective layer is represented by hyaline, and the germinative layer is the source of the formation of excretory capsules with scolexes and a cuticular membrane. Alveococcus cysts develop primarily in the liver and then in other organs of the abdominal cavity. Exogenous growth of the lavrocyst (cyst) occurs through budding. The budded cysts penetrate the intercellular spaces and infiltrate the surrounding tissue. According to R. Pramod *et al*. (2021), the cells of the organ parenchyma are compressed, undergo dystrophy, atrophy and are gradually replaced by alveocytes. Alveococcal cysts metastasise to the lymph nodes, retroperitoneal tissue, lungs and brain. As the parasitic node grows, necrosis occurs in its centre due to insufficient blood circulation, and a capsule forms, which fills with a clear or cloudy fluid. The peripheral part of the node consists of actively multiplying parasite vesicles. The cavity of the vesicles contains a small amount of viscous fluid. When cut open, the parasitic node has a cellular structure with a cavity of decay in the centre. The larval form is represented by a conglomerate of small vesicles (parasitic node) connected by connective tissue and is characterised by exogenous reproduction and infiltrative growth (Ullah *et al*., 2020).

Alveococcus is a biohelminth that develops by changing hosts. Its definitive hosts are carnivores: wolves, foxes, cats; and its intermediate hosts are wild rodents of the *Cricetidae family* (Vishnu *et al*., 2024). A study by A. Lypska *et al*. (2023) also showed that rodents in natural populations can be carriers of multiple parasitic infections, including blood-borne zoonotic pathogens, which increases their epizootological significance in the circulation of pathogens between wild and domestic animals. The final host becomes infected by eating infected liver containing formed alveococcus vesicles with scolexes (Figs. 5, 6). Wild animals and humans suffer from natural focal diseases, with humans becoming infected during skinning, when eggs stuck to the fur get onto their hands and are carried into the mouth. Another route of human infection with is through the consumption of wild berries and herbs contaminated with the excrement of infected carnivorous animals.

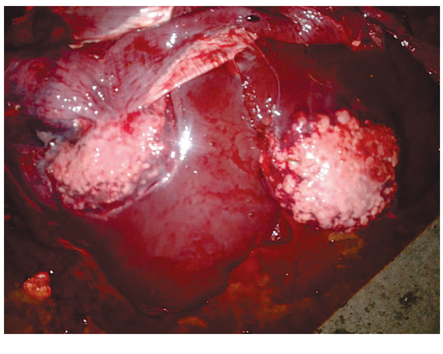


Figure 5. Alveococcosis, macro picture
Source: authors' photo

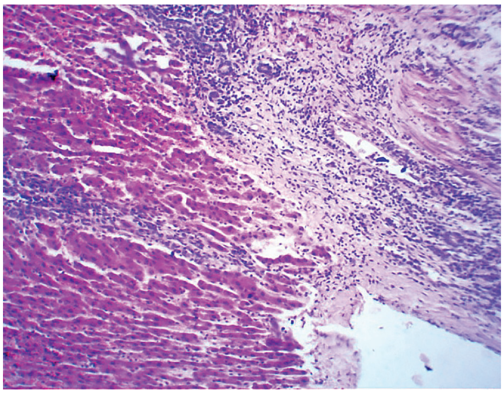
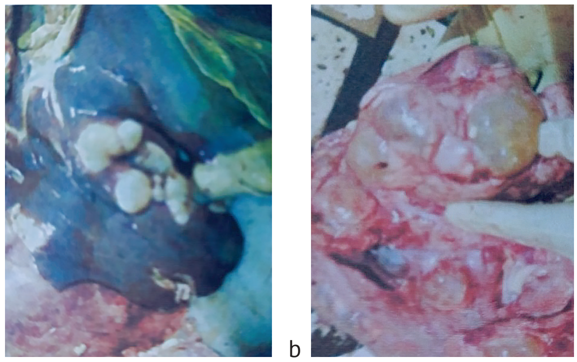


Figure 6. Alveococcosis, micrograph
Note: haematoxylin and eosin, 9×10
Source: authors' photo



a b

Figure 8. Larval echinococcosis in cattle
Note: the liver (a) and lungs (b) are affected by typical echinococcal cysts
Source: authors' photo

Another object in the snow leopard's food chain is the roe deer, a small, graceful deer with a relatively short body (Fig. 7). Its ears are long and pointed, and its tail is short and does not protrude from its fur. Its coat is single-coloured, bright red in summer and dull greyish in winter. Its body length is 150 cm, and it weighs up to 60 kg. Roe deer mate in August, and gestation lasts 4-4.5 months, resulting in 1-3 fawns.

Figure 7. Roe deer (*Capreolus capreolus*)
Source: authors' photo

Roe deer suffer from echinococcosis, which is carried by carnivores. Echinococcal cysts are round in shape and are most often found on the surface and in the thickness of the liver and lungs. Depending on the stage of the disease, the number of echinococcal cysts in the liver varied. The cysts are represented by a capsule containing a transparent fluid with a slightly yellowish tint (Fig. 8). The final stages of larval echinococcosis were accompanied by almost total organ damage, as indicated in the work of M. Bashari *et al.* (2018). The wall of the cyst consists of the following layers: the outer adventitial layer and the inner germinative layer.

Among roe deer, the lung disease mulleriosis was diagnosed (Fig. 9). Mulleriosis in animals, caused by *Mullerius capillaries*, belongs to the *Protostrongylidae* family and affects wild ruminants (Habib *et al.*, 2014). These are small, thin, separately hollow nematodes, almost indistinguishable to the naked eye against the background of the lungs. The lung tissues are involved in the pathological process, which is a pathological picture of chronic productive alveolitis. The affected areas of the lung have clear boundaries macroscopically and are coloured yellowish-grey. During invasion, numerous foci are scattered in various areas of the lungs, but mainly in the posterior lobes.

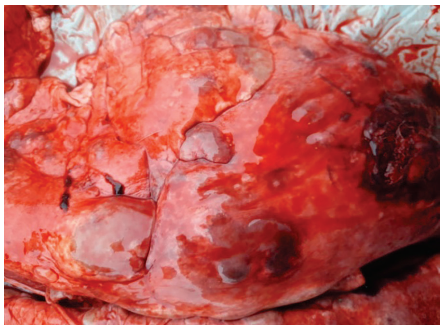


Figure 9. Macroscopic picture of muelleriosis
Source: authors' photo

At the same time, alveolar epithelial cells divide and multiply by amitotic and mitotic division. The process may begin with exudative phenomena, with the filling of the alveolar lumens with serous exudate. In such areas, the interalveolar septa are thin, and later they thicken noticeably due to lymphoid-histiocytic infiltration. Lymphoid cells, neutrophilic leukocytes, and histiocytes are mixed with desquamated epithelial cells in the alveolar lumens. Parasites that have reached sexual maturity, located in the bronchial branches or in the alveolar tissues, are localised in their lumens, where they lay eggs in the alveolar lumens and alveolar passages. Sexually mature parasites are found in areas bordering healthy tissue in the lumens of the alveoli or outside the foci of consolidation, among normal tissue (Fig. 10). Freshly laid eggs have unsegmented fine-grained cytoplasm and one large light nucleus. Subsequently, all stages of development can be seen in the sections, from the beginning of fragmentation into blastomeres to the formation of a finished larva inside the egg shell. In the areas where the eggs are located, the alveolar tissue, especially the alveolar septa, thins, becomes thread-like, disappears, and cavities of various sizes may form as a result of the fusion of adjacent alveoli filled with eggs or larvae.

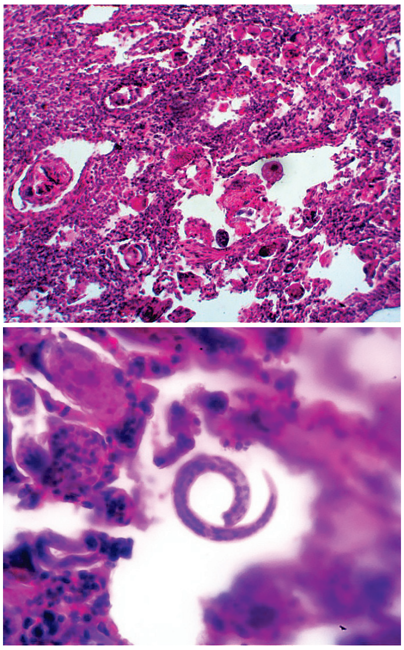


Figure 10. Paraffin section of the lungs – muellerian invasion in a roe deer
Note: staining – haematoxylin and eosin, ×90
Source: authors' photo

The pathological process involves the small bronchial branches, where catarrhal bronchitis initially develops. The bronchial lumens contain mucus, desquamated epithelial cells, and leukocytes. The number of goblet cells in the epithelial lining of the mucous membrane increases. Changes are observed in the walls of the small bronchi in the form of thickening. The epithelial layer of the mucous membrane hyperplasiates and papillary protrusions form in the lumen of the bronchi, where the base of the mucous membrane is infiltrated by lymphoid-histiocytic elements, later fibroblasts. The lumens of the bronchi become slit-like, and the layers of peribronchial tissue gradually expand and become infiltrated with cellular elements, mainly lymphoid cells. The lumens of the alveoli are filled with the bodies of sexually mature parasites, and the epithelial lining is compressed and atrophied. The pulmonary pleura and interlobular connective tissue septa are involved in the pathological process. They thicken and undergo severe sclerotic changes. In other areas of the lung parenchyma, proliferative changes develop, leading to thickening of the interalveolar septa due to cell proliferation consisting of lymphoid and histiocytic elements. Later, fibroblasts, collagen fibres and a small number of plasma cells appear. In the affected areas, the thickening of the alveolar septa is due to the growth of thick smooth muscle bundles, while the alveolar lumens narrow or disappear completely, and areas replaced by collagen and smooth muscle cells appear.

Another object of the snow leopard's food chain is the mountain sheep (*Ovis ammon*) – a very beautiful, slender animal, light in build, with long legs and a high head (Fig. 11). Its horns are beautifully curved, sometimes very large. The colouring of the sides and back is solid yellow or brown-grey in various shades. Mountain sheep are 120-130 cm tall at the withers and weigh 200-220 kg. These animals prefer vast open spaces with gently rolling terrain and gentle mountain slopes. In summer, adult males form separate herds and keep away from females. Gestation lasts 155-170 days, and from April to May, females give birth to 1 or 2 lambs.

Figure 11. Argali (*Ovis ammon*)
Source: authors' photo

During the pathological autopsy of a mountain sheep that had been culled for sanitary reasons, pathological changes were found on the serous membranes. A translucent oval-shaped bubble on a thin stalk was found under the peritoneum. The bubble was filled with a clear fluid in which a floating scolex was visible. This bubble is a thin-necked cysticercosis, which is the outer serous membrane of the host and the scolex's own membrane (Fig. 12). The snow leopard, eating such animals, becomes the definitive host, where a tapeworm begins to develop in its intestines, which has a head with suckers, a neck and a body. The body or tapeworm reaches 1.5-5 m and as the segments mature, they fall off, are excreted with faeces, contaminate the soil, grass and water, and the parasite's eggs are swallowed with the food of herbivorous animals. The causative agent is the cystic stage of the cestode *Taenia hydatigena*, which lives in the small intestine of carnivores (wolves, jackals). The sexually mature parasite reaches a length of 2 m, its scolex has 4 suckers and is armed with 32-44 hooks arranged in two rows. The thin-necked cysticercus is a bubble filled with a colourless liquid, oval in shape, up to the size of a goose egg, hanging down like a bubble. When the shell is cut open, the parasite, which has a long thin neck, a tail bubble and a scolex, is easily squeezed out of the bubble.

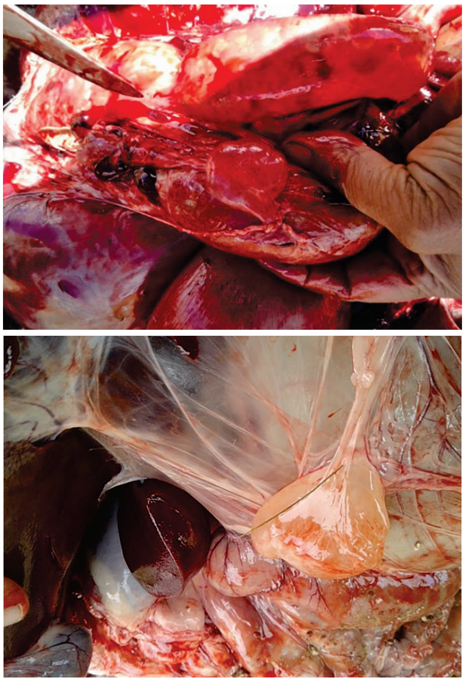


Figure 12. Thin-necked cysticercosis, macro picture
Source: authors' photo

The morphofunctional state of the thymus is expressed by its lobular structure and specific mass. Each lobe of the thymus is represented by cortical and medullary substance in different proportions in different lobules. The lobules are in different morphofunctional states. In the subcapsular zone, blast transformation and thymoblast proliferation are observed, and in most lobules of the thymus, the boundary between the cortical and medullary substances is blurred. In some lobules, small and large Gassall's cells with calcifications are found in the medullary layer (Fig. 13). Clusters of labrocytes, lymphocytes, and macrophages are observed, as well as products of cell breakdown. Blood vessels are hyperemic. Lymphoid cells in mitosis are found in the cortical substance and sporadically in the medullary substance.

The morphofunctional state of a lymph node is the cortical zone or cluster of lymphatic follicles, or the B-dependent zone and paracortical zone, or the T-dependent zone and medulla. The histological picture showed that the structure of the lymphatic follicle centres of the lymph nodes was destroyed, with a large accumulation of blood and haemorrhages. Hyperplasia of the B-dependent zone was noted (Fig. 14).

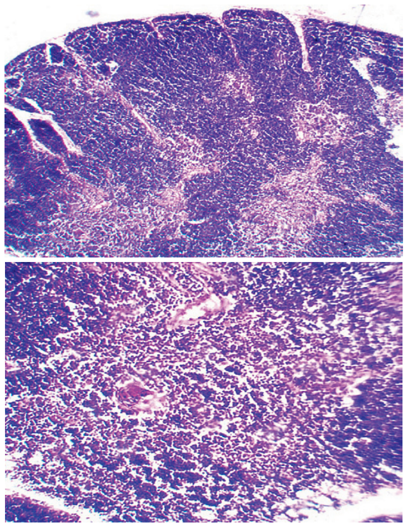


Figure 13. Thymus gland
of a roe deer with Müllerian invasion
Note: staining – haematoxylin and eosin, ×90
Source: authors' photo

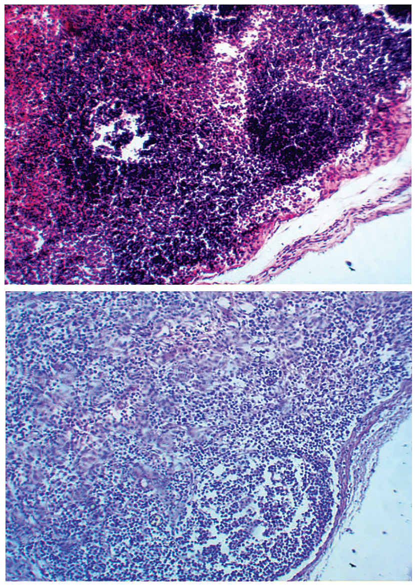


Figure 14. Paraffin section of a lymph node
Note: staining – haematoxylin and eosin, ×90
Source: authors' photo

The spleen is similar in structure to the histological structure of other animal species, where a distinction is made between white and red pulp. In roe deer, in this case, it stands out in the form of lymphonodules, the B-dependent zone, while the T-dependent zone is poorly developed and is detected near the central vessels. The red pulp is abundantly injected with blood, and hyperplasia of B-dependent zones is observed in the white pulp. The red pulp of the spleen is represented by a large number of erythrocytes, T- and B-lymphocytes, and macrophages. Cells in mitosis are found. Macrophages are located in large numbers around the white pulp and in smaller numbers in the red pulp and sinuses. Apoptosis occurs in both the white and red pulp of the spleen (Fig. 15a). In the white pulp of the spleen, T- and B-dependent zones are distinguished, where T-dependent zones of the white pulp are represented by T-lymphocytes. The central artery of the lymphoid follicles is located eccentrically. Lymphoid formations with light centres have clearly defined centres of lymphoid follicles. The mantle zone is clearly distinguished by the dense arrangement of B and T lymphocytes, plasma cells, and macrophages. Lymphoid follicles without light centres are distinguished by the loose arrangement of B lymphocytes, and the zones are not distinguished. Mitosis of blast cells is rare (Fig. 15b).

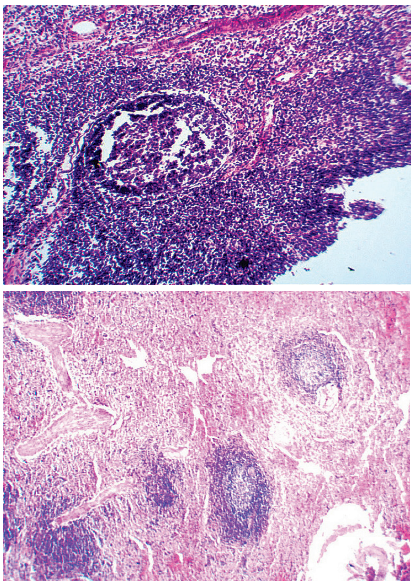

a
b

Figure 15. Paraffin section of the spleen
Note: staining – haematoxylin and eosin, ×90
Source: authors' photo

Analysis of data on the morphology and functional state of the organ allows for concluding that the condition of the white pulp of the spleen corresponds to a state of relative rest and moderate functioning. A large number of red blood cells in the organ is evidence of the highest degree of depositing function. Larvae, entering the roe deer's intestines with food and water, penetrate the submucosal layer of the intestines and, together with the chyme, enter the lymph, reach the large thoracic duct and, with the lymph, penetrate the blood of the small circle of blood circulation and, through the walls of the capillaries, enter the small bronchi, provoking bronchopneumonia. Histological sections stained with haematoxylin and eosin reveal eggs, larvae and sexually mature forms of the pathogens, which are localised in the small bronchi, alveolar passages and alveoli. Focal, diffuse lymphoid, histiocytic, and plasma cell infiltrates are observed in the bronchial walls and peribronchially.

The described morphological structural changes in the primary and secondary organs of immunogenesis in wild cloven-hoofed animals (Siberian ibex, argali, and roe deer) in invasive diseases (alveococcosis, muelleriosis, and cysticercosis) revealed functional tension in the above-mentioned organs of the immune system. This manifested itself in the form of cellular infiltrates, where the number of plasma cells, clusters of macrophages, small lymphocytes, neutrophilocytes, and fibroblasts increased, and where the effectiveness of immunity depended on the coordinated interaction of cellular and humoral immunity (Vishnu *et al.*, 2024). The morphological picture was revealed by the depletion of light centres in the secondary organs of immunogenesis, which indicated a sharp decline not only in the body's immune reactivity, but also in other vital processes. A deficient state arose in the thymus, characterised by morphological changes in secondary organs of immunogenesis in the form of increased proliferation in the B-dependent zone, which is associated with the endocrine system and central nervous system controlling the homeostasis of the animal organism.

In conclusion, it should be noted that anthropogenic factors such as an increase in livestock numbers and degradation of grazing lands, as well as climate change, have a negative impact on the snow leopard's food supply and habitat. M. Bashari *et al.* (2018) emphasised that direct and indirect human impact on the snow leopard's range and food supply is changing the snow leopard's lifestyle. This is also evidenced by a number of examples from the Kyrgyz Republic. In 2020 alone, there were three recorded incidents involving snow leopards descending from the highlands to populated areas. In January 2020, the Department for Biodiversity Conservation and Specially Protected Natural Areas reported the discovery of a snow leopard in the village of Kok-Oy (600-800 m above sea level) in the Talas region. Employees of the Bars Group travelled to the site together with a veterinarian. At the examination site, NABU veterinarian B. Azhybekov assessed the predator's health as critical. After discussing the issue with representatives of state authorities, it was decided to transport the snow leopard to the NABU office in Bishkek. An X-ray of the snow leopard showed that the animal had been shot in the head. A council of veterinarians decided to perform emergency surgery. At present, the leopard's life is not in danger, and it is recovering.

Second example: on 10 January 2020, information was received from a hunting expert in the Zhumgal district of the Naryn region about the discovery of a snow leopard in a shepherd's barn in one of the winter areas (1,800-2,000 metres above sea level). The "Bars Group" immediately left for the Zhugals district of the Naryn region. Upon arrival in the Zhugaly district, the hunting expert showed the snow leopard and drew up a transfer report. After these activities, the snow leopard was taken to the NABU office in Bishkek, where, in agreement with the state authorities, it was decided to deliver the snow leopard to the NABU rehabilitation centre.

Third example: in May 2020, a snow leopard was brought to the rehabilitation centre from the village of Emgek Talaa in the Naryn region (Teskey Torpu, 1,700-1,800 m above sea level). It was brought by the director of the "Ysyq-Köl" biosphere territory, T. Asykulov. The snow leopard was in serious condition and unable to move. Upon examination, it was found that its right eye was damaged and there was a wound on its front paw. The snow leopard brought from the Naryn region was examined by a veterinarian, who noted that the animal was in a state of stress and prescribed the necessary treatment. The snow leopard was given the nickname Tenteq and sent to the NABU rehabilitation centre. The rescued snow leopards caused a public outcry. In the same year, a gamekeeper from the Kara-Buurinsky district of the Talas region reported that he was keeping an argali lamb in his barn. After notifying government officials in advance, the commission decided on the future fate of the red-listed animal. These examples show that anthropogenic factors are severely disrupting the snow leopard's habitat, which is closely linked to climate change. The preservation of the snow leopard population is influenced not only by anthropogenic factors in the habitat, but also by diseases of wild animals, not only of an infectious and invasive nature, but also, in this case, alveococcosis, muelleriosis, cysticercosis and other parasitic diseases.

Conclusions

Studies of wild ungulates – Siberian ibex, roe deer and argali, which constitute the food base of the snow leopard in the highlands of Kyrgyzstan – have revealed a significant prevalence of invasive diseases. Pathological and parasitological studies diagnosed helminthiasis such as alveococcosis, echinococcosis, muelleriosis, and cysticercosis. The most significant result is a detailed description of the specific immunomorphological response of the organs of immunogenesis to these invasions. Characteristic changes were observed in the primary organs (thymus) and secondary organs (spleen, lymph nodes) of infected animals: hyperplasia of lymphoid tissue, an increase in the number and size of germinative centres in lymphoid follicles, and significant plasmacytic infiltration, indicating a strong humoral immune response. The intensity and nature of morphological changes directly correlated with the type of pathogen and the intensity of invasion. For example, in echinococcosis, the formation of a pronounced fibrous capsule around parasitic cysts was recorded, while in muelleriosis, a cellular reaction prevailed. The data obtained, including specific pathological indices and histological descriptions, are of fundamental importance for understanding the pathogenesis of helminthiasis in wild ungulates and serve as a scientific basis for the development of practical measures. Based on these data, effective preventive measures can be developed to preserve wild fauna populations and reduce the risk of pathogen circulation in high-altitude ecosystems. Prospects for further research include conducting monitoring studies to assess the dynamics of disease incidence, studying the role of the snow leopard as the definitive host in the development cycle of cestodiasis, as well as in-depth immunohistochemical analysis to identify subpopulations of immunocompetent cells involved in the formation of the immune response.

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Conflict of Interest

None.

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Бийик тоолуу Тянь-Шандагы илбирстердин азыктануу чынжыры, жаныбарлардын жана канаттуулардын ылаңдары

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Аннотация. Ак илбирс – жоголуу коркунучунда турган жана Кыргыз Республикасынын Кызыл китебине киргизилген сейрек кездешүүчү жана аялуу жаныбар болуп саналат. Ал Тянь-Шандын жетүүгө кыйын бийик тоолуу райондорунда жашайт, ал жерде экологиялык тең салмактуулук анын азык тизмегин түзгөн фаунанын абалына түздөн-түз көз каранды. Акыркы жылдары жапайы жана үй жаныбарлары арасында оорулардын көбөйүшү байкалууда, бул ак илбирстин популяциясынын абалына жана жалпысынан экосистеманын туруктуулугуна таасирин тийгизиши мүмкүн. Бул иштин максаты ак илбирстин азык тизмегине кирген сүт эмүүчүлөрдүн мите ооруларын изилдөө, алардын биологиялык өзгөчөлүктөрүн, булгануу булактарын жана тоолуу райондордогу эпизоотиялык кырдаалга таасирин аныктоо болуп саналат. Изилдөөнүн жүрүшүндө талаалык байкоолордун, гельминтологиялык аутопсиялардын, биоматериалдын микроскопиялык анализинин, ветеринардык изилдөөлөрдүн маалыматтарынын салыштырма морфологиялык жана сыпаттама анализинин методдору пайдаланылды. Натыйжада, аныкталган мите ооруларынын ичинен эң чоң эпидемиологиялык мааниси жапайы жана үй жаныбарлары үчүн олуттуу коркунуч туудурган альвеококкоз жана мюллериоз экендиги аныкталды. Альвеококкоздун козгогучу боорго таасир этүүчү жана инфильтративдик өсүүгө жана метастазга жөндөмдүү бир нече кистикалык мите түйүндөрүнүн пайда болушуна алып келүүчү лентанын личинка стадиясы болуп саналат. Бул митенин акыркы кожоюндары жырткычтар (иттер, мышыктар, карышкырлар, түлкүлөр, манулалар ж.б.), ал эми ортодогу майда жапайы кемирүүчүлөр. Ошондой эле патоген эчкилерде, койлордо жана жапайы кепшөөчүлөрдө өпкөнүн жабыркашын шарттайт, бул продуктивдүү альвеолиттин көп очоктору жана жаныбарлардын жалпы каршылыгынын төмөндөшү менен көрүнөт. Патогендердин биологиялык жана экологиялык өзгөчөлүктөрүн комплекстүү талдоо жаратылыш шарттарында алардын айлануу жолдорун жана адам үчүн мүмкүн болуучу тобокелдиктерди баалоого мүмкүндүк берет. Изилдөөнүн практикалык мааниси сейрек кездешүүчү жырткычтарды коргоого жана Кыргызстандын бийик тоолуу экосистемаларынын эпизоотиялык бейпилдигин турукташтырууга багытталган алдын алуу жана диагностикалык иш-чаралардын системасын иштеп чыгууда алынган маалыматтарды пайдалануу мүмкүндүгүндө турат

Негизги сөздөр: сибирь текеси; аркарлар; эликтер; альвеококкоз; мюллериоз; цистицеркоз

Болезни животных и птиц – пищевой цепи снежного барса в высокогорьях Тянь-Шаня

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Аннотация. Снежный барс (*Panthera uncia*) является редким и уязвимым видом, находящимся под угрозой исчезновения и занесенным в Красную книгу Кыргызской Республики. Он обитает в труднодоступных высокогорных районах Тянь-Шаня, где экологическое равновесие напрямую зависит от состояния фауны, составляющей его пищевую цепь. В последние годы наблюдается рост числа заболеваний среди диких и домашних животных, что может оказывать влияние на здоровье популяции снежного барса и устойчивость экосистемы в целом. Целью настоящей работы было исследование паразитарных заболеваний млекопитающих, входящих в пищевую цепь снежного барса, с определением их биологических особенностей, источников заражения и влияния на эпизоотическую ситуацию в горных районах. В ходе исследования использованы методы полевых наблюдений, гельминтологических вскрытий, микроскопического анализа биоматериала, сравнительного морфологического и описательного анализа данных ветеринарных исследований. В результате установлено, что наибольшее эпидемиологическое значение среди выявленных паразитарных заболеваний имеют альвеококкоз и мюллериоз, представляющие серьезную опасность как для диких, так и для домашних животных. Возбудителем альвеококкоза является личиночная стадия цепня *Alveococcus multilocularis*, поражающая печень и вызывающая образование множественных кистозных паразитарных узлов, способных к инфильтративному росту и метастазированию. Конечными хозяевами данного паразита выступают плотоядные животные (собаки, кошки, волки, лисицы, манулы и др.), а промежуточными – мелкие дикие грызуны. Установлено также, что возбудитель *Mullerius capillaris* вызывает поражения легких у коз, овец и диких жвачных, что проявляется множественными очагами продуктивного альвеолита и снижением общей резистентности животных. Комплексный анализ биологических и экологических особенностей возбудителей позволяет оценить пути их циркуляции в природных условиях и потенциальные риски для человека. Практическая значимость исследования заключается в возможности использования полученных данных при разработке системы профилактических и диагностических мероприятий, направленных на охрану редких хищников и стабилизацию эпизоотического благополучия высокогорных экосистем Кыргызстана

Ключевые слова: сибирский козерог; архар; косули; альвеококкоз; мюллериоз; цистицеркоз