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CONTAMINATION OF LANDS AND HABITATS OF WILD UNGULATES BY EGGS AND LARVIES OF HELMINTHS OF THE STRONGYLATA SUBORDER

Different types of forest land are not the same, as are the places of circulation of eggs and larvae of helminths of the Strongylata suborder. Plant formations with a low risk of infection are young pine forests, middle-aged and old pine forests, old mixed forests, spruce forests. Potentially dangerous in terms of infection are bushes of river floodplains and forest meadows. Plant formations with a high risk of infection are young mixed forests, middle-aged mixed forests with undergrowth. The most dangerous for infection are swampy forests and forest swamps. The degree of contamination and accumulation of invasive larvae of helminths of the Strongylata suborder in different lands and habitats is different and differs depending on the season of the year. The most favorable for mass infection is the end of summer, the beginning of autumn, namely August-September. The distribution of eggs and larvae of helminths of the Strongylata suborder in forest lands has a mosaic character. The number of plots depends on the areas preferred by wild ungulates. The movement of wild ungulates across the land occurs also under the influence of the anthropogenic factor, which affects the distribution of infection. If we know the habitats of wild ungulates, we can assess the degree of contamination by eggs and larvae of species and characterize the risk of infecting wild ungulates with them. The number of eggs and larvae of helminths of the Strongylata suborder in excrement may vary over time depending on weather conditions. Infection with helminths of the suborder Strongylata occurs through the trophic links of wild ungulates. The addition of young grass vegetation to the diet of wild ungulates in spring leads to an increase in eggs and larvae of helminths of the Strongylata suborder in excrement. In the autumn season, when wild ungulates switch to rough forages, the number of eggs and larvae of helminths of the Strongylata suborder in excrement decreases.

Keywords: contamination; helminths of the Strongylata; wild ungulates.

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Introduction

The biosphere in the evolutionary-ecological time was structured by episodes of geographic and host colonization, which led to the spread of complex complexes of micro- and macroparasites, including circulating among vertebrates' helminths. Biological invasion is a complex phenomenon, often associated with «out-of-range dispersal» and the establishment of exotic (non-native) species and populations substantially outside their natural range (Hoberg, 2010). As a biotic factor, the state of populations of wild ungulates and their numbers are significantly affected by helminths of the suborder Strongylata. When studying the biological diversity of species of the suborder Strongylata, it was found that infection rates depend on the ecological characteristics of biotopes (Akhmedov et al., 2022). The most dangerous biotopes where wild boar is heavily contaminated with parasite germs are young pine forests, oak forests, birch forests, floodplain willow forests, alder forests, abandoned villages and mixed deciduous forests (Penkevich, 2012).

When considering the influence of various risk factors on the prevalence of most genera of gastrointestinal tract nematodes, the highest were noted in roe deer from coastal areas, where climatic conditions are more favorable for the development and survival of third-stage larvae. In terms of animal sex, prevalence is generally higher in males than females, likely due to behavioral and physiological sex differences. On the contrary, no differences were found depending on the age of the animals (Pato et al., 2013). Exposure of wild animals to dangerous parasitic diseases often ends in death, loss of commercial qualities of meat and other products. They cause damage to the abundance of species and reduce the prestige of hunting game animals (Kokolova et al., 2019).

It has been established that individuals of wild ungulates of different species infested with helminths, including those belonging to the suborder Strongylata, have a significant decrease in slaughter rates with an increase in the content of bone and cartilage tissue in carcasses. This indicates a decrease in meatiness at a high intensity of helminth invasion (Golubev, 2017). With regular monitoring of the parasitic ecosystem of game animals, it is possible to prevent their negative impact on public health. An important element of the epizootological analysis of this problem is the preservation of the species composition of wild game animals, an increase in their numbers (Kokolova et al., 2019), which is possible if a set of preventive veterinary measures aimed at maintaining the sanitary well-being of biocenoses is observed (Tretjakov et al., 2021). Measures to prevent strongylosis should be aimed at dispersing animals from dangerous to safe lands (Samoilovskaya, 2014).

Kristjanovski showed a comparative analysis of the intensity of strongylates infection of wild ungulates in protected areas without deworming and with deworming. He found that with a low infestation in the autumn period and without deworming in the spring, the infestation increases. Carrying out deworming reduces infection or heals. Routine deworming of wild ungulates kept in small protected areas is recommended. (Kristjanovski et al., 2021). In natural habitats, various species of strongylate pose a serious threat to the health and productivity of wild animals. Therefore, control of these parasites is necessary (Mutviri, 2013).

However, there is another point of view. With the transformation of wilderness into wilderness parks and the return of developed areas to the forces of nature, intermediate hybrid areas are emerging in which wilderness and managed nature are increasingly intertwined. The lack of intervention such as deworming allows these mixed territories to be left relatively unexplored (Claver, 2002). Human activity interferes with wild animals and results in the loss of many animal populations. It has been shown that deworming will negatively affect the intestinal microbiome of wild animals, significantly changing the number of microorganisms (Mustafa et al., 2021).

Thus, the question of the need to control the spread of helminths in the natural habitat remains controversial. However, the inclusion of deworming in the management of biological resources leads to indisputable benefits. This allows to reduce the antigenic load on the organism of animals, free them from helminths (for a while), and increase their resistance.

The aim of our work was a comparative ecological and helminthological assessment of the habitats of wild ungulates, regarding the sources of infection of the Strongylata suborder.

Materials and methods

Study Area and Data Collection

The work was carried out in the Osipovichi experimental forestry. The forestry is located in the northern part of the Mogilev region of the Republic of Belarus. The area of forestry grounds is 45.7 thousand hectares, of with: 32.3 thousand hectares – forest, 10.5 thousand hectares – field, 2.9 thousand hectares - wetlands (fig. 1) from 2017 to 2019.

To determine the source of infection in the external environment we regularly examined the excrement of wild ungulates throughout all seasons.

Laboratory Assays

Excrement of wild ungulates was regularly examined during all seasons to establish the source of infection in the external environment. To do this, we used the Fülleborn method in the classical version and in modification (Jimenez-Albarran and Odda, 1994; Karmaliyev et al., 2017), and later, the McMaster test method in the original and in modification (Moriya, 1954; Cringoli et al., 2004). The Fülleborn method consisted in the fact that 3 g of excrement was first filled with water and left for a while. Then they were thoroughly crushed, the supernatant liquid was left until clear, and it was poured off. Washing was carried out several times. Then the sediment was microscopically examined for the presence of larvae and eggs of helminths.

The modification of the Fülleborn method was as follows: 3 g of excrement was preliminarily filled with water and left for 24 h. Filled with saturated salt solution and centrifuged at 3000 rpm for 15 minutes. The surface of the film was examined with a parasitological loop 5 mm in diameter. Three loops were taken from each sample and the average number of helminth eggs in the sample was calculated.

When using the Mac-Master test, the studies were carried out as follows: 3 g of feces were thoroughly mixed with water and filtered. The filtrate was placed in centrifuge tubes and centrifuged for 3 min. The supernatant was discarded and the precipitate was re-diluted with brine and thoroughly mixed. With a Pasteur pipette, the suspended sediment was collected from the test tube and filled with it into the McMaster chamber and microscoped at 10x4 lenses. Helminthes eggs and larvae were counted in the chamber.

When establishing the accumulation of larvae on plants, studies were carried out in all seasons. When evaluating the lands, the biomass of grass stand per unit area was considered. The average number of larvae per 1 g of vegetation was determined.

The sex of wild ungulates was determined by ex-

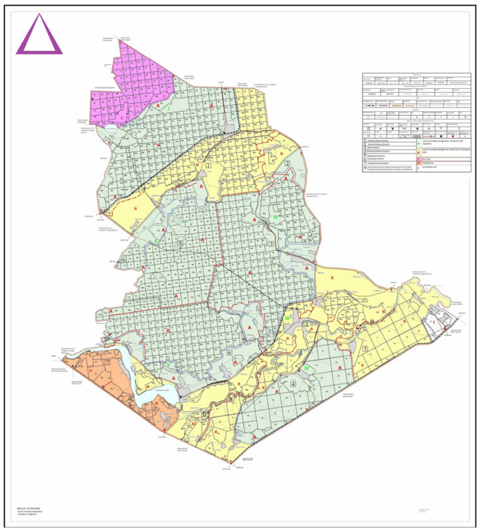

Fig. 1. Map of the location Osipovichi experimental forestry (https://disk.yandex.ru/i/4r6vEQzIBTZW7A open original)

crement according to (Romanov et al., 2005).

Data Analysis

The computational program used was Excel version 2010.

Results

Seasonal dynamics of environmental contamination by eggs and larvae of helminths of the Strongylata suborder in the natural lands of the Osipovichi Experimental Forestry

Climatic factors and weather conditions have a direct impact on the accumulation of eggs and the survival of larvae of helminths of the Strongylata suborder. In different seasons of the year, the number of allocated eggs is different.

It has been established that helminths are characterized by two periods with the greatest accumulation of eggs in excrement of female and male of wild ungulate. This is the spring (April-May) and autumn (September-October) periods. Less helminth eggs accumulate in late autumn, winter and early spring. In the event of a long warm autumn, warm winter with little snow cover, the number of eggs in excrement reaches a maximum in May (tab.1).

The presence of frosts and frequent snowfalls in spring leads to a delay in the grass cover development and reduction of accumulation of helminth eggs in excrement.

High humidity in autumn and high ambient temperature contributes to the abundant growth of herbaceous vegetation and, accordingly, increased survival of larvae of helminthes of the Strongylata suborder.

Dry summer periods contribute to the active movement of larvae to plants, shifting the biological development cycle with a later infection of wild ungulates. Therefore, in autumn, the presence of eggs and larvae in the excrement of wild ungulates was minimal. When the previous year is rainy, in spring the number of eggs and larvae in the excrement is small, and in summer, when there is an abundance of precipitation, it is high. When there is a period without precipitation, the number of larvae in the excrement decreases and remains low until early October. A warm autumn and snowless winter contribute to an increase in the number of helminth larvae in the excrement of wild ungulates. The maximum number is reached by the middle of winter. At the end of winter and beginning of spring, the number of helminth larvae in excrement decreases. With a warm beginning of spring, already at the end of March to mid-May, an increase in the number of helminth eggs in excrement is noted. Then their number decreases, remaining at the same level until mid-autumn, and then increases again. At the end of autumn and the beginning of winter, when low temperatures set in, the number of eggs and larvae of helminths decreases. So, in 2018, which was preceded by 2017 with high humidity, warm autumn and late snow cover, the spring peak of eggs and larvae in excrement was high in May. During the cold March with frosts, the grass growth was delayed. The number of helminth eggs of the Strongylata suborder was less than usual during this period. The accumulation of moisture in the autumn of the previous year led to an abundant grass growth in the spring and summer of the current year, which determined the high survival rate of larvae in all forest habitats (fig. 2).

The distribution of the infection of the Strongylata suborder of wild ungulates in natural lands in different periods of the season is not the same and is determined by weather conditions. The time and duration of periods of intensive accumulation of hel-

Table 1. Introduction of helminths eggs of the Strongylata suborder in wild ungulates into hunting lands

Research period	January – February	March – April	April – May	May – June	Jun – July	July – August	August – September	September – October	October – November	November – December
Average number of eggs in 3 g of excrement	0.5	5.2	24.2	19.6	3.6	4.8	17.2	19.6	18.4	1.4
The number of helminth eggs in the excrement of females / day	1600	17140	82430	66820	10250	16810	62200	68780	65240	4480
The number of helminth eggs in the excrement of males / day	2520	25160	142320	104160	18640	24780	86200	105730	5880	6420

minth eggs in the excrement depends on the ecology of wild ungulates. An increase in the number of helminth eggs in excrement in spring begins after the appearance of young grassy vegetation. At the beginning of summer, wild ungulates are freed from helminths that got to them last autumn. Therefore, until the middle of summer, few eggs and larvae of helminths get into natural areas. There is no mass infection of wild ungulates with helminths at this time. Periodically occurring dry periods reduce the survival rate and movement activity of invasive larvae. In summer time, wild ungulates (*Cervus elaphus* and *Alces alces*) eat only the tops of herbaceous plants, which helps to prevent active infection in dry times. During the rainy season, wild ungulates spread out over the lands, which also protects them from mass infection. In spring, the intensity of the accumulation of invasion in excrement significantly depends on weather conditions. In autumn, wild ungulates switch to roughage, which also protects them from intense infection. In late autumn and winter, the alternation of snowy periods and periods without snow leads to fluctuations in the intensity of accumulation of helminth eggs of the Strongylata suborder in the excrement of wild ungulates.

Distribution of eggs and larvae of helminths of the Strongylata suborder in the natural lands of the Osipovichi Experimental Forestry. Characterization of forest lands with respect to contamination by helminths of the Strongylata suborder of wild ungulates

The degree of contamination of lands with helminth eggs and larvae depends on the food and topical preferences of wild ungulates. Each landscape has its own peculiarities in the distribution of various species of wild ungulates. The degree of their preference and significance for wild ungulates in different seasons of the year is different. In the conditions of the Osipovichi experimental forestry, deer constantly live near feeding areas, salt licks and fodder fields, and heaps of excrement were mainly found near them.

Cervus elaphus and *Alces alces* prefer young pine forests, which are their winter feeding stations, therefore there, in early spring, contamination with eggs and larvae of helminths of the Strongylata suborder is the highest per unit area. There are almost the same numbers of them in the mixed forest.

Sufficiently high contamination of medium-aged mixed forests is observed. In the middle of spring, elk excrement was more often found in swampy forests along river floodplains, in mixed young forests, and also in young pine forests. It has been established that in winter with snow cover, there is a high contamination with eggs and larvae of helminths of the Strongylata suborder of the feeding habitats of the *Alces alces*. Low contamination is registered in winter in open areas and in light forests. In the spring, feeding habitats change and animals are redistributed. In spring, the number of eggs and larvae in the excrement is high, and the lands are heavily contaminated with wild ungulates. The highest concentration of them was noted in swampy areas of the forest and in mixed young forests. Almost wild ungulates visit forest and floodplain meadows, agrocenoses less frequently and their degree of contamination is insignificant. *Alces alces* avoids open areas of land, preferring forests.

For the circulation of helminths of wild ungulates of the Strongylata suborder, climatic conditions and geobotanical characteristics of the habitats of wild ungulates are important. This is confirmed by the study of the timing of their biological development, the features of the physical activity of larvae and their survival in forest lands. This means that different types of forest land are not the same in terms of the places of circulation of helminths of wild ungulates of the Strongylata suborder.

The main habitats of wild ungulates, especially *Alces alces*, are young pine forests. In the winter season, a significant number of animals are concentrated there. At the same time, contamination with eggs of helminths of the Strongylata suborder is more than 69 thousand per 1 ha. While in the spring this indicator is more than 42 thousand per 1 ha. From late spring to the beginning of the autumn season, young pine forests are passing stations for wild ungulates, therefore eggs and larvae of helminths are rare there. In these plant formations, the height of the grass layer is low. Young pine forests can be attributed to lands with a low risk of infection with wild ungulate helminths of the Strongylata suborder. Middle-aged pine forests can also be classified as low-risk areas for wild ungulate helminth infestation, as they are predominantly resting and passing habitats for wild ungulates. The level of contamination in the winter season was more than 4.8 thousand per 1 ha, and in the spring more than 8.8 thousand per 1 ha. Old pine forests are only passing habitats and all year round. In the winter season, their contamination is 0.1 thousand per 1 ha, in the spring - more than 2.1 thousand per 1 ha. Therefore, this type of plant formations can also be attributed to lands with a low risk of infection. Young mixed forest formations with abundant motley grass are of high food value for wild ungulates (*Cervus elaphus* and *Alces alces*) in all seasons of the year. Contamination in the winter season here is more than 58.4 thousand eggs per 1 ha, in the spring season - more than 27.4 thousand. Therefore, this type of vegetation formations can be attributed to lands with a high risk of infection. Middle-aged mixed forests with deciduous undergrowth are frequently visited by wild ungulates in the winter season. Contamination there is up to 29.5 thousand per 1 ha. In other seasons, the forests of this formation are used by wild ungulates as food partially. In the spring season, contamination is 4.1 thousand per 1 ha. The grass cover is also abundant here. This type of formation can also be classified as a land with a high risk of contamination. Old mixed forests with sparse herbage are migratory habitats for wild ungulates and belong to lands with a low risk of contamination. Spruce forests with low herbage and sparse vegetation are lands with a low risk of contamination. In winter, swampy forests serve as passing and partially feeding habitats for *Alces alces*. Their contamination is 1.7 thousand eggs and larvae per 1 ha. In the spring season, the appearance of grassy vegetation in wetlands attracts *Alces alces*. They are the richest in food, since the herbaceous cover is represented by plants, the height of which reaches the feeding layer and the *Alces alces* remains there throughout the summer-autumn season. Swampy forests with abundant vegetation are among the lands with a high risk of infection with helminths of the Strongylata suborder of wild ungulates. In the winter season, wild ungulates rarely visit the bushes along the river floodplain. During this period, contamination is less than 0.026 thousand per 1 ha. In the spring, visits to these habitats become more frequent, and contamination also increases to 3.5 thousand per 1 ha. In summer, the *Alces alces* changes its location, but these lands serve as feeding habitats for *Cervus elaphus* and *Capriolus capriolus*. Shrub thickets along the river floodplain belong to the lands with the risk of infection with helminths of the Strongylata suborder of wild ungulates. Contamination of forest meadows with helminths of the Strongylata suborder in winter and spring is low, although in the spring season these habitats are rich in food, and in the winter season they are rarely visited by wild ungulates. More often these habitats are visited by a *Cervus elaphus*. *Alces alces* usually avoid open areas and after using them as food, they move to forest lands. Forest meadows are dangerous in terms of infection with helminths of the Strongylata suborder for *Cervus elaphus* and potentially dangerous for *Alces alces*. Wild ungulates in different seasons of the year prefer to visit different lands. This preference depends on the availability of food at the habitats. Most preferred are habitats with abundant vegetation (mixed young growth, forest meadows). Features of the herbage of these lands are reflected in the mobility of larvae of helminths of the Strongylata suborder. Contamination with eggs of helminths of the suborder Strongylata per 1 ha in the spring period in a swampy forest can exceed that by more than 10 times in mixed young stands and more than 100 times in forest meadows (tab. 2).

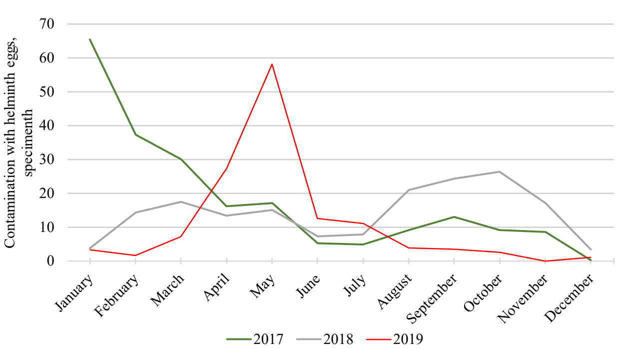

Fig. 2. Seasonal dynamics of contamination of wild ungulates by helminths of the Strongylata suborder

Table 2. Distribution of eggs of the Strongylata suborder in lands and habitats of wild ungulates

Lands and habitats	Season of the year	
	Winter	Spring
	Number of eggs per 1 ha, ind.	
Forest meadow	0	4124
Swamp forest	172	486422
Young mixed forest	58442	27462
Medium aged mixed forest	29545	4168
Old mixed forest	42	0
Young pine forest	69284	42420
Middle-aged pine forest	4882	8865
Old pine forest	100	2146
Shrubs along the floodplain	26	3546
Agrocenoses	0	2436

Accumulation of larvae of helminths of the Strongylata suborder in the natural lands of the Osipovichi Experimental Forestry

In forest lands, larvae of helminths of the Strongylata suborder accumulate on plant parts corresponding to the food layer of wild ungulates. The contamination degree of plants by larvae of helminths of the Strongylata suborder in habitats with dense herbage differs depending on the season of the year. The smallest contamination is observed in April and Maj. Then there is a gradual increase until the middle of summer. After a slight decrease is registered with an increase in early August. The maximum contamination of plants with larvae of helminths of the Strongylata suborder is recorded in September.

Different lands differ in the composition of vegetation, incl. biomass, especially depending on the season of the year. The maximum biomass is recorded in summer, especially in swamp parts of the forest. It is slightly less in meadow areas and old fellings. A significant biomass of herbaceous vegetation was recorded in separate areas of pine forests, both middle-aged and old, in mixed young forests, as well as in areas with rare crown density. Insignificant biomass of herbaceous vegetation is in young pine forests and spruce forests. The accumulation of larvae of helminths of the Strongylata suborder in forest lands has a localized character. Their horizontal migration is negligible. It was established that the invasive larvae were mainly within a radius of 30 cm from the place of excrement excreted by wild ungulates. In a number of habitats, a significant number of such locations can be found per unit area (one heap - 0.5 m^2) and mass number of infective larvae (tab. 3).

In this way, the infection of *Capriolus capriolus* and *Alces alces* with helminths of the Strongylata suborder in the habitats of this region can occur from mid-summer to early autumn (July-September) with a peak in the second half of August and the first half of September.

Differences in the biomass of herbaceous vegetation of forest formations determine their significance in relation to helminths of wild ungulates of

Table 3. Distribution of larvae of helminths of the Strongylata suborder by habitats and areas (2017)

Habitats and lands	Biomass of herbage, g / 0.5 m^2	Number of larvae, ind. / 0.5 m^2
Forest meadow	1179.0	16152.0
Swamp forest	1600.0	6560.0
Old felling	1208.0	16504.5
Young pine forest	50.0	250.0
Middle-aged pine forest	342.5	3409.0
Old pine forest	96.7	3980.5
Old pine forest with dense herbage	388.0	15946.5
Young spruce forest	30.0	0
Old spruce forest	41.5	0
Young mixed forest	333.0	6357.5
Medium-aged mixed forest	300.0	1230.0
Old mixed forest	220.5	150.0

the Strongylata suborder, especially of the genus *Trichostrongylus*. The biomass of herbaceous vegetation in swamp forests exceeds by more than 5 times the biomass of mixed young forests and by 1.3 times the biomass of forest meadows. The activity of movement of larvae of helminths of the Strongylata suborder on the herbaceous vegetation of meadows is lower than that of forests, especially mixed young forests. The highest activity of the movement of helminth larvae is recorded in swampy forests with deciduous undergrowth and dense herbaceous vegetation. In the rainy and warm summer season, up to 21 larvae can be counted in 1 g of herbaceous vegetation in mixed forest areas, up to 5 larvae in swampy forests, and 11 larvae in forest meadows. At the same time, the safety and activity of the larvae is also very high.

It should be noted that anthropogenic impacts also have a significant impact on the ecology of the *Capriolus capriolus* (agricultural and active logging operations). Therefore, in the helminth fauna of the *Cervus elaphus*, there are species of the Strongylata suborder which are found at livestock. However, *Alces alces* most often choose small areas of swampy forests and forest swamps. In the summer season, females with young animals move over short distances. Their concentration in a limited area contributes to the presence of an increased risk of infection with helminths characteristic of this species. Unlike females, males are more dispersed geographically and the risk of infection is much lower.

Discussion

Historically, the role of parasites in the functioning of ecosystems was considered trivial, since a cursory examination reveals, that their relative biomass is low compared to other trophic groups. However, there is increasing evidence that parasite-mediated effects may be significant: they shape the dynamics of the host population, alter interspecific competition, affect energy flow and appear to be important biodiversity contributors (Hudson et al., 2006).

Pathogens and parasites are fascinating to epidemiologists and ecologists alike; as well as causing disease in individual species, they can perturb the normal functioning of a community and thus give insights into the way that the community ‘functions’. Several recent studies on diseases in animal populations have confirmed the importance of pathogens and parasites as components of ecological systems, while also revealing the underlying structure of complex multispecies communities (Dobson, Hudson, 1986).

Shrinking ecosystems concentrate both individuals and species into restricted areas, promoting transmission and exchange of parasites. Fragmentation increases edge and brings an influx of new species into the disturbed or agricultural habitats between fragments, introducing new parasites and possibly leading to the development of new and more pathogenic strains of parasite. Environmental contaminants act as stressors, and may compromise immune systems. Global climate changes challenge the adaptability of organisms, and may allow the invasion of new parasites. Because each of these effects increases the potential for parasites to become pathogenic, the importance of disease is expected to increase in shrinking ecosystems, with the emergence of new diseases and increasing numbers of epidemics. Increased pathogenicity of generalist parasites may pose a threat to species with restricted distributions or small populations (Holmes, 1996).

The host-parasite interaction is often seen as an arms race, when parasites try to overcome the host's resistance to infection. Herbivores are a common route of transmission for parasites, which represents the most common problem for the growth and reproduction of mammals. The starting point is that foraging seeking behavior can mitigate the impact of parasitism in three ways; hosts could: (1) avoid seeking foraging in parasite-infested areas; (2) choose diets that increase their resistance to parasites; (3) choose products that contain antiparasitic properties (self-medication). We know the skills required by herbivores if they want to fight parasitism through behavior, i.e. herbivores are capable: (a) determine their parasitic state and change their behavior in relation to this state (behavior 1, 2 and 3); (b) determine the spread of parasites in the environment (behavior 1); (c) distinguish plant species or plant parts that increase their resistance to parasites (behavior 2) or possess anti-parasitic properties (behavior 3). Herbivorous mammals cannot detect the presence of parasites themselves and must rely on such signals as feces. Despite the use of these signals, contact with parasites may be unavoidable, so mechanisms to combat parasitism are needed. Herbivorous mammals have the skills of finding foraging, necessary to exploit the heterogeneous distribution of nutrients and parasites in difficult foraging conditions, to avoid parasites and increase their resistance to them. Current evidence of the use of plant secondary metabolites (PSM) by herbivores for self-medication remains questionable (Hutchings et al. 2003).

When considering the influence of various risk factors on the prevalence of nematodes of the gastrointestinal tract of roe deer in the northwest of the Iberian Peninsula, the highest prevalence for most genera was observed in ungulates from coastal regions, where climatic conditions are more favorable for the development and survival of larvae in the coastal zone (Pato et al., 2013).

Spatial heterogeneity in parasite susceptibility and exposure is a common source of mixed differences in disease ecology research. However, it is not known whether spatial autocorrelation affects immunity on small scales in wild animal populations and whether it predicts spatial infection patterns. Spatial heterogeneity is an important factor affecting immunity and parasitism in a wide range of research systems (Albery et al., 2019).

The type of habitat, as well as livestock, significantly influence the number of parasitic larvae in roe deer, which is higher in competitive scenarios and in lower quality environments (Horcajada-Sánchez et al., 2018).

Many of the parasites in mammals are acquired through contact with infected stages, which are present in soil, faeces, or vegetation, which makes it possible to assume, that behavior at a distance will have a great influence on their distribution (Nunn et al., 2011).

Parasitism in wild mammals can vary due to a variety of internal and external factors, many of which change with the season (Albery et al., 2018).

It is known that the burden of parasites in wild animals varies with the season, and precipitation is one of the key aspects of seasonality that is associated with parasitism in a number of systems. Rainfall can have a direct effect on parasitism levels, affecting the survival and movement of parasites in the environment (Shearer, Ezenwa, 2020).

They can influence the host's susceptibility to parasites through changes in the host's health condition (Marshal et al., 2008) or immune function (Fair, Whitaker, 2008).

The seasonal output of eggs of gastrointestinal parasites of wild ungulates of the Mediterranean protected area, in the Monti Livornesi park (Livorno, Tuscany region, Central Italy) showed, that egg output peaks in different months in accordance with different biology and parasite survival strategies (Magi et al., 2005).

Heavy rainfall may also improve survival and development of parasites in the environment (O'Connor et al., 2007, 2008).

Active soil ingestion is often observed in populations of wild mammals. Soil material is never eaten at random locations in animal's habitats, but from spatially limited areas (Klaus, Schmidg, 2009).

Helminth eggs were found more often in the soil of active and abandoned feeding sites than in control plots. This may reflect a parasitic infestation or indicate that, that supplementary feeding areas are appropriate habitats for soil-dwelling nematodes (Oja et al., 2017).

A ubiquitous aspect of human intervention in forest landscapes is the edges of the forest. In mammals, the proportion of individuals with multiple infections is higher in edging forest groups than in inland forest groups. The prevalence of specific parasites varies between edging and intra-forest groups. *Oesophagostomum* sp., potentially dangerous parasite, was found in mammals at the edge of the forest 7.4 times more often than in the depths of the forest. Parasitic contamination (measured as parasite eggs/g faeces) of wild animals from edging and inland forest areas differed similar to the prevalence for one species, but did not differ for the other species. For example, the number of eggs of *Oesophagostomum* sp. in one species on the edge was 10 times higher than in another species from the inside (Chapman et al., 2006).

Therefore, wildlife health surveillance programs should include routine parasite screening, because gastrointestinal parasites can influence wildlife population dynamics, affecting fertility and survival of the host (Davidson et al., 2015).

Conclusion

Different types of forest land are not the same, as are the places of circulation of eggs and larvae of helminths of the Strongylata suborder. Plant formations with a low risk of infection are young pine forests, middle-aged and old pine forests, old mixed forests, spruce forests. Potentially dangerous in terms of infection are bushes of river floodplains and forest meadows. Plant formations with a high risk of infection are young mixed forests, middle-aged mixed forests with undergrowth. The most dangerous for infection are swampy forests and forest swamps.

The degree of contamination and accumulation of invasive larvae of helminths of the Strongylata suborder in different lands and habitats is different and differs depending on the season of the year. The most favorable for mass infection is the end of summer, the beginning of autumn, namely August-September.

The distribution of eggs and larvae of helminths of the Strongylata suborder in forest lands has a focal character. The number of foci depends on the areas preferred by wild ungulates.

The movement of wild ungulates across the land occurs also under the influence of the anthropogenic factor, which affects the distribution of infection. If we know the habitats of wild ungulates, we can assess the degree of contamination by eggs and larvae of species and characterize the risk of infecting wild ungulates with them.

The number of eggs and larvae of helminths of the Strongylata suborder in excrement may vary over time depending on weather conditions. Infection with helminths of the suborder Strongylata occurs through the trophic links of wild ungulates. The addition of young grass vegetation to the diet of wild ungulates in spring leads to an increase in eggs and larvae of helminths of the Strongylata suborder in excrement. In the autumn season, when wild ungulates switch to rough forages, the number of eggs and larvae of helminths of the Strongylata suborder in excrement decreases.

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Data Availability Statement

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Полоз С.В. **Загрязнение земель и мест обитания диких копытных яйцами и личинками гельминтов подотряда Strongylata**.

Различные типы лесных угодий неодинаковы как места циркуляции яиц и личинок гельминтов подотряда Strongylata. Растительными формациями с низким риском заражения являются сосновые молодняки, средневозрастные и старые сосновые леса, старые смешанные леса, ельники. Потенциально опасными по заражению являются кустарниковые заросли поймы рек и лесные луга. Растительными формациями с высоким риском заражения являются молодые смешанные леса, средневозрастные смешанные леса с подростом. Наиболее опасными по заражению являются заболоченные леса и лесные болота. Степень контаминации и накопление инвазионных личинок гельминтов подотряда Strongylata в различных угодьях и стациях различно и отличается в зависимости от сезона года. Наиболее благоприятными для массового инфицирования является конец лета, начало осени, а именно август-сентябрь. Распределение яиц и личинок гельминтов подотряда Strongylata в лесных угодьях имеет мозаичный характер. Количество площадок зависит от угодий, которые предпочитают дикие копытные. Перемещение диких копытных по угодьям происходит и под воздействием антропогенного фактора, что оказывает влияние на распределение инфекции. Зная места обитания диких копытных можно оценить степень контаминирования яйцами и личинками видов и охарактеризовать риск заражения ими диких копытных. Количество яиц и личинок гельминтов подотряда Strongylata в экскрементах может изменяться во времени в зависимости от погодных условий. Реализация заражения гельминтами подотряда Strongylata происходит через трофические связи диких копытных. Включение молодой травяной растительности в рацион диких копытных весной приводит к увеличению яиц и личинок гельминтов подотряда Strongylata в экскрементах. В осенний сезон при переходе диких копытных на грубые веточные корма количество яиц и личинок гельминтов подотряда Strongylata в экскрементах снижается.

Ключевые слова: контаминация; гельминты подотряда Strongylata; дикие копытные.

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