

Occurrence of helminths in shrews and small rodents on territories transformed by reclamation

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ABSTRACT. Shrews and small rodents inhabit the drainage channel banks in reclaimed areas and have their own helminth complex. The aim of the study is to conduct the 3rd research period during 2015–2019 the helminth fauna of these animals living on the drainage channel banks of model reclamation systems in Brest Polesie (south-western part of Belarus), to establish the species composition of helminths and the animal infection by these, and to compare the data obtained with previous research periods. 4,000 trap-days were worked out. 151 specimens of shrews of 4 species and 510 small rodents of 8 species were caught. Animals were examined by the method of complete helminthological dissections. Their numbers were 3.78 and 12.75 individuals per 100 trap-days, and helminth infection was 94.7% and 65.9%, respectively. 66 helminth species were found in animals. The dominant helminth species in infection have been identified. The trematode *Prosolecithus danubica* Tkach et Bray, 1995 (definitive host: common shrew), the acanthocephalans *Centrorhynchus aluconis* (Müller, 1780) (larval host: lesser shrew) and *Moniliformis moniliformis* (Bremser, 1811) (definitive host: striped field mouse) are new species of helminths for Belarus. New hosts in Belarus have been found for 6 helminth species. Shrews and small rodents are involved in the life cycles of bird, non-ruminant artiodactyl and carnivorous mammal helminths. Nine helminth species have significance for medicine and 7 species for veterinary science. The results are compared with data from the 1st (1996–1999) and 2nd (2005–2010) research periods.

Keywords: helminths, shrews, rodents, drainage channel banks, Brest Polesie, Belarus

Introduction

Many areas in the world have been drainage and are used by humans for agriculture (plant-growing, animal husbandry). So, large-scale drainage reclamation carried out in the 60–80s of the twentieth century on the territory of the Belorussian Polesie (southern part of Belarus, mainly Brest and Gomel regions), led to the transformation of many natural ecosystems. The emerging network of drainage channels significantly changed the natural landscapes of this region. The channels and their banks began to be populated by living organisms, including shrews and small rodents (mainly voles and mice) with their own complex of helminths, among which there are species of medical and veterinary significance, may also function there the centers of helminthoses dangerous to humans, domestic and farm animals.

I have been conducting a helminthological investigation of shrews and small rodents inhabiting

the drainage channel banks on model reclamation systems located in Brest Polesie (Brest, Zhabinka and Malorita districts of the Brest region; southwestern part of Belarus) since 1996. Two periods of work were carried out: the 1st period (fundamental research) in 1996–1999 [1,2], and the 2nd period (monitoring study) in 2005–2010 [3,4]. 15,500 trap-days were worked on the drainage channel banks running in mixed forests, on arable lands, pastures and along roads. The habitat of 4 species of shrews and 13 species of small rodents was established. 31 species of helminths were found in shrews and 47 species of helminths in rodents. The total infection of shrews with helminths in the 1st period was 88.8% and rodents was 64.7% [1,2], and in the 2nd period was 94.2% and 56.0%, respectively [3,4]. Common shrews dominated among shrews and were the background species during all research periods on the channel banks in mixed forests, on arable lands, pastures and near roads. Common voles and striped field mice

dominated among rodents. Red-backed voles (2 periods) and yellow-necked mice (1st period) were background species on the channel banks in mixed forests, common voles (1st period) and field mice (two periods) were on arable lands, common voles (two periods) were on pastures and near roads. Infection of each animal species was dominated by its own helminth species. For example, in the common shrew these are the nematode *Eucoleus oesophagicola* (Soltys, 1952) (1st period), the cestodes *Monocercus arionis* (Siebold, 1850) and *Neoskrjabinolepis singularis* (Cholodkowsky, 1912) (2nd period), in the lesser shrew – cestodes *N. singularis* and *Ditestolepis diaphana* (Cholodkowsky, 1906), in the water shrew – the trematode *Neoglyphe locellus* (Kossack, 1910), in the bicolored shrew – the cestode *Staphylocystis uncinata* (Stieda, 1862) (2nd period), in the red-backed vole – the nematode *Heligmosomum mixtum* Schulz, 1954, in the common vole – the cestode *Paranoplocephala omphalodes* (Hermann, 1783) and the nematode *Syphacia nigeriana* Baylis, 1928, in the striped field mouse – the nematode *Heligmosomoides polygyrus* (Dujardin, 1845), in the yellow-necked mouse – the nematodes *H. polygyrus*, *Syphacia frederici* Roman, 1945 and *S. stroma* (Linstow, 1884), in the wood mouse – the nematode *S. stroma*.

After the 1st research period, it was proposed to consider channels in reclaimed areas as one of the potential helminthoses centers of medical and veterinary significance, and to organize constant ecological and parasitological monitoring the helminth fauna of shrews and small rodents there [1,2]. This made it possible to establish that the infection of small rodents with helminths of medical significance can exceed 9% [4], and also to identify 8 helminth species of veterinary significance [1–4].

The purpose of the investigation is to conduct the 3rd research period the helminth fauna of shrews and small rodents living on the drainage channel banks of model reclamation systems in Brest Polesie, to establish the species composition of helminths and the infection of these animals, and to compare the data obtained with previous research periods.

Materials and Methods

The 3rd research period the helminth fauna of shrews and small rodents inhabiting the drainage channel banks on model reclamation systems in

Brest Polesie (Brest, Zhabinka and Malorita districts of the Brest region) was carried out in 2015–2019. The channel banks running in mixed forests, on arable lands, pastures and near roads were examined. The banks and slopes of channels on arable lands, pastures and near roads were periodically mowed by humans using special equipment, but the banks and slopes of channels in mixed forests were not.

The shrews and small rodents were caught by mousetraps. 25 mousetraps were placed in line along the banks of drainage channels in mixed forests, on arable lands, pastures and near roads at intervals of 1.5–2 m from each other for 4 days. This equaled 100 trap-days. The total number of trap-days was 4,000: 1,000 at each place of passage of the drainage channel. Pieces of rye bread, cut into cubes and lightly fried in sunflower oil, were bait for animals. 661 specimens of animals of 12 species were caught (151 specimens of shrews of 4 species and 510 specimens of small rodents of 8 species). Among them there were 317 males and 344 females, 313 adults and 348 immature individuals.

The animals were subjected to a full helminthological examination (dissection and organ compression) according to Skrjabin [5]. Identification and synonymy of helminths was carried out with the aid of Keys to the helminths [6–11], monographs [12–15] and articles [16–26].

The percentage of animal infection by helminths, the prevalence of infection by each species of helminth, the minimum, maximum, total and mean number of helminths found were calculated during statistical processing of the material.

The species composition, number of shrews and small rodents examined and infected with helminths are given in Table 1.

Results and Discussion

Four species of shrews and 13 species of small rodents living on the drainage channel banks in Brest Polesie. The water vole, the field vole, the harvest mouse, the brown rat, and the northern birch mouse disappeared in the collections of the 3rd period.

The number of shrews and small rodents on the drainage channel banks in Brest Polesie in 2015–2019 (3rd period) is quite high (16.53 individuals per 100 trap-days). It is higher in small rodents than in shrews (12.75 and 3.78, respectively). The number of shrews increased from

Table 1. Species composition, number of small shrews and rodents examined and infected with helminths (2015–2019)

Animal species	Number									
	investigated					infected				
	males	females	adults	immatures	per 100 trap days	males	females	adults	immatures	total
Shrews										
Bicolored shrew – <i>Crocidura leucodon</i> Hermann, 1780	1	1	2	–	0.05	1	1	2	–	–
Common shrew – <i>Sorex araneus</i> Linnaeus, 1758	62	65	21	106	3.18	61	64	21	104	93
Lesser shrew – <i>S. minutus</i> Linnaeus, 1766	4	10	4	10	0.35	3	5	4	4	4
Water shrew – <i>Neomys fodiens</i> Pennant, 1771	6	2	1	7	0.2	6	2	1	7	4
Total for shrews:	73	78	28	123	3.78	71	72	28	115	101
Rodents										
Hazel dormouse – <i>Muscardinus avellanarius</i> Linnaeus, 1758	1	–	–	1	0.025	–	–	–	–	–
Common vole – <i>Microtus arvalis</i> Pallas, 1778	76	96	55	117	4.3	63	73	49	87	113
Root vole – <i>M. oeconomus</i> Pallas, 1776	21	41	29	33	1.55	9	20	19	10	15
Red-backed vole – <i>Myodes glareolus</i> (Schreber, 1780)	47	46	64	29	2.325	34	31	54	11	58
Striped field mouse – <i>Apodemus agrarius</i> Pallas, 1771	50	40	70	20	2.25	32	20	41	11	49
Yellow-necked mouse – <i>A. flavicollis</i> Melchior, 1884	40	39	59	20	1.975	26	25	40	11	31
Wood mouse – <i>A. sylvaticus</i> Linnaeus, 1758	7	4	7	4	0.275	1	2	2	1	2
House mouse – <i>Mus musculus</i> Linnaeus, 1758	2	–	1	1	0.05	–	–	–	–	–
Total for rodents:	244	266	285	225	12.75	165	171	205	131	268
Total for all:	317	344	313	348	16.53	236	243	233	246	369

individuals per 100 trap-days in the 1st period [2] to 3.78 in the 2nd [3] and 3rd periods. The common shrew dominates in all places where the channels pass: 2.22, 3.02 and 3.18 individuals per 100 trap-days, respectively for the study periods. But the number of small rodents from 12.31 individuals per 100 trap-days in the 1st period [1] increased to 18.7 in the 2nd period [4] and decreased to 12.75 in the 3rd period. The common vole dominates: 4.79, 4.92 and 4.3 individuals per 100 trap-days, respectively for the study periods. She it prefers open spaces, being in the 3rd research period the background species among small rodents on the banks of channels on arable lands (10.3 individuals per 100 trap-days) and pastures (5.3 individuals), but near roads gave the dominant position to the striped field mouse (4.2 individuals, while the common vole had 1.6 individuals).

The main body of shrews and small rodents living on the drainage channel banks in Brest Polesie are the common shrew, the common vole, the red-backed vole, the root vole (its numbers increased in the 3rd period), the striped field mouse and the yellow-necked mouse. Common shrews, red-backed voles and yellow-necked mice are background species on the banks of channels in mixed forests, common shrews, common voles and striped field mice are on arable lands, common shrews and common voles on pastures (here the number of root voles increased up to 2.9 individuals per 100 trap-days in the 3rd period), common shrews, common voles and striped field mice near roads (there the latter dominated in the first two research periods, and the latter increased their numbers in the 3rd period; here in the 3rd period the number of root vole also increased to 1.8 individuals per 100 trap-days).

The total helminth infection of shrews and small rodents remains high. It is higher in shrews compared to small rodents. In shrews it increased from 88.8% in the 1st period to 94.2% and 94.7% in the 2nd and 3rd periods, respectively. In small rodents it decreased from 64.7% in the 1st period to 56.0% in the 2nd, and then increased to 65.9% in the 3rd. Prevalence of helminth infection during of research periods was high in the common shrew (95.3%, 97.4%, 94.7%), the water shrew (100%, 77.8%, 100%), the lesser shrew (41.2%, 86.4%, 57.1%), the common vole (68.4%, 52.4%, 79.1%), the red-backed vole (85.9%, 71.1%, 69.9%), the striped field mouse (66.9%, 59.2%, 57.8%) and the yellow-necked mouse (44.8%, 43.7%, 64.6%).

Male shrews and small rodents are slightly more likely than females to become infected with helminths (88.7% and 88.9%, respectively and as an exception, 66.1% and 62.9% in the 1st period; 96.6% and 92.2%, 56.5% and 55.4% in the 2nd period; 97.3% and 92.3%, 67.6% and 64.3% in the 3rd period). But the infection rate of adults is significantly higher than that of immature individuals. The difference in shrew infection is approximately 1.0–1.1 times traced throughout all research periods (91.3% versus 85.7% in the 1st period; 95.2% versus 94.1% in the 2nd period; 100% versus 93.5% in the 3rd period). The difference in small rodent infection was 1.2 times in the 1st period (72.1% versus 59.9%) and increased 1.5 times in the 2nd period (67.1% versus 45.6%) and again returned to 1.2 in the 3rd period (71.9% versus 58.2%).

Shrews are more often infected with cestodes (86.1%), somewhat less with nematodes (66.9%) and trematodes (57.6%), and sporadically with acanthocephalans (0.7% in the 3rd period). Similar results were obtained in the 2nd period (85.7% of animals were infected with cestodes, 65.6% with nematodes, and 43.9% with trematodes) [3], in contrast to the 1st period (68.5% of animals were infected with nematodes, 64.9% with cestodes and 33.0% with trematodes) [2]. Infection of small rodents by nematodes dominates in all research periods (50.7%, 42.6% and 52.6%, respectively by periods). In second place is infection with cestodes (28.9%, 22.0% and 26.9%), in third place is infection with trematodes (3.5%, 4.3% and 4.1%) and, as an exception, infection with acanthocephalans (0.2% only in the 3rd period).

2–14 species of helminths were localized in 86.8% of shrews in the 3rd period. This is slightly higher than in previous research periods: 70.6% and 2–8 species in the 1st period, 81.0% and 2–12 species in the 2nd period. If in small rodents in the 1st period 23.3%, and in the 2nd period 18.7% were found to have 2–5 species of helminths living together in one individual, then in the 3rd period 27.3% had 2–4 species of helminths.

Shrews and small rodents are host for 66 species of helminths (15 trematode species, 25 cestode species, 24 nematode species, 2 acanthocephalan species) which were found in the 3rd period (Table 2). Animals are more often infected on the channel banks on arable lands (96.7% of shrews and 76.8% of small rodents) and in mixed forests (96.3% and 66.7%, respectively) than on pastures (94.1% and 61.9%) and near roads (93.0% and 49.1%).

Occurrence of helminths

A total of 3,803 parasites were found in shrews and 4,916 parasites in small rodents with the average intensity of infection being 26.6 and 14.6 specimens, respectively. The range of trematode intensity was 1–88 and 1–13 specimens, and overall mean was 10.1 and 3.9 specimens, cestode was 1–240 and 1–386 specimens, and overall mean was 18.0 and 10.2 specimens, nematode was 1–28 and 1–450 specimens, and overall mean was 5.8 and 12.8 specimens, acanthocephalan was 1 and 1 specimens, and overall mean was 1.0 and 1.0, respectively.

Most of the helminths were in the intestine. Two trematode species of genus *Rubensstrema* Dollfus, 1949 were located in the esophagus, the stomach and the intestine, trematode *Brachylaima fulvum* Dujardin, 1843 in the esophagus and the stomach, nematodes *Aonchotheca kutori* (Ruchljadeva, 1946), *Mastophorus muris* (Gmelin, 1790) and *Skrjabinoclava soricis* (Tiner, 1951) in the stomach, nematode *E. oesophagicola* in the esophagus, nematodes *Capillaria konstantini* Romashov, 1999 and *Liniscus incrassatus* Diesing, 1851 in the urinary bladder, cestode *Anoplocephaloides dentata* (Galli-Valerio, 1905), trematode *Notocotylus noyeri* Joyeux, 1922 and nematode *Trichuris muris* (Schrank, 1788) in the caecum, nematodes of genus *Syphacia* Seurat, 1916 mainly in the caecum and rare in the intestine, larvae of trematodes *Alaria alata* (Goeze, 1782) and *Strigea sphaerula* (Rudolphi, 1803) in the lungs, fat deposits on the neck, back and liver, trematodes *Prosolecithus danubica* Tkach et Bray, 1995 and *Skrjabinoplagiorchis polonicus* (Soltys, 1957), nematode *Calodium soricicola* (Yokogawa et Nischigori, 1924), larvae of cestodes *Cladotaenia globifera* (Batsch, 1786), *Taenia mustelae* Gmelin, 1790 and *T. taeniaeformis* (Batsch, 1786) in the liver (trematode *P. danubica* also in the gall bladder and trematode *S. polonicus* also in the intestine), larvae of cestode *Taenia martis* (Zeder, 1803) in the pectoral and abdominal cavities, larvae of cestode *Mesocestoides lineatus* (Goeze, 1782) in the abdominal cavity, larvae of the nematode *Ascarops strongylina* (Rudolphi, 1819) in the intestinal wall and fat deposits on the neck, larvae of nematodes of the genus *Porrocaecum* Railliet et Henry, 1912 in fat deposits on the back and neck, in the liver, wall of the stomach and intestine, larvae of acanthocephalan *Centrorhynchus aluconis* (Müller, 1780) in fat deposits in the neck area.

34 species of helminths (9 trematode species, 13 cestode species, 11 nematode species, 1 acanthocephalan species) were found in shrews in the 3rd period (Table 2). Approximately the same number of helminth species (33) was present in the 1st and 2nd periods [2,3]. According to studies from 2015–2019, the most species of helminths (27) were found in animals caught on the channel banks running on arable land and pastures. Here, in common shrews, the largest number of helminth species was identified in one individual: 12 species (adult male; channel bank on pasture) and 14 species (immature female; channel bank on arable land). This animal, among all shrews, is distinguished by the species diversity of helminths: 28 species were found (8 trematode species, 10 cestode and nematode species each). The species composition of shrew helminths is complemented by the bicolor shrew (1 species), the lesser shrew (2 species) and the water shrew (3 species) (Table 2). The cestodes *N. singularis* (50.3% infected, hosts: common shrew and lesser shrew) and *M. arionis* (42.4% infected, host: common shrew) dominated in the infection of shrews, as in the 2nd period. The nematode *Longistriata depressa* (Dujardin, 1845) (39.7% infected, hosts: common shrew and lesser shrew) was their subdominant. The nematode *E. oesophagicola* gradually lost its dominant position in infection the common shrew in the 2nd and 3rd periods. Common shrews were also often infected with the trematode *Rubensstrema exasperatum* (Rudolphi, 1819), bicolored shrews with the cestode *S. uncinata*, and water shrews with the trematode *N. locellus*. Lesser shrews were often infected with the nematode *L. depressa*, the cestode *Neoskrjabinolepis schaldybini* Spassky, 1947, and the trematode *R. exasperatum* in the 2nd and 3rd research periods. Their infection with the cestode *N. singularis* decreased by 5.8 times in the 3rd period compared to the 2nd period, and the cestode *D. diaphana* was not detected at all in the collections of the 3rd period.

In general, on the drainage channel banks in Brest Polesie two species of cestodes dominated in the infection of the common shrew: *M. arionis* and *N. singularis* (Table 2), as in the 2nd period [3]. They were dominant or subdominant in the infection on the channel banks running in different places. The nematode *L. depressa* predominated in infection the common shrew, which lives only on the channel banks in mixed forests and on arable lands. This nematode belongs to the subdominants

Table 2. Helminth infection of small shrews and rodents living of drainage channel banks in Brest Polesie (2015–2019)

Helminth species	Host	Prevalence, %	No. helminths (min-max; total; mean)
Trematoda			
Brachylaimidae			
<i>Brachylaima fulvum</i> Dujardin, 1843	Common shrew	26.8	1-9; 93; 2.7
	Water shrew	25.0	1-2; 3; 1.5
Panopistidae			
<i>Pseudoleucochloridium soricis</i> (Sołtys, 1952)	Common shrew	9.5	1-52; 101; 8.4
Strigeidae			
<i>Strigea sphaerula</i> (Rudolphi, 1803), larvae ³	Common shrew	4.7	1-18; 56; 9.3
	Water shrew	25.0	4-6; 10; 5.0
Diplostomidae			
<i>Alaria alata</i> (Goeze, 1782), larvae ^{1, 2, 4}	Common shrew	3.2	1-2; 5; 1.25
	Red-backed vole	3.2	1-4; 7; 2.33
Echinostomatidae			
<i>Echinostoma revolutum</i> (Frölich, 1802) ^{1, 2, 3}	Striped field mouse	1.1	1; 1; 1.0
Psilostomidae			
<i>Psilotrema spiculigerum</i> (Mühling, 1898) ³	Common vole	0.6	1; 1; 1.0
Notocotylidae			
<i>Notocotylus noyeri</i> Joyeux, 1922	Common vole	0.6	1; 1; 1.0
Dicrocoeliidae			
<i>Prosolecithus danubica</i> Tkach et Bray, 1995	Common shrew	3.9	1-32; 51; 10.2
Plagiorchiidae			
<i>Plagiorchis arvicolae</i> Schulz et Skvorzov, 1931	Root vole	1.6	1; 1; 1.0
	Striped field mouse	1.1	1; 1; 1.0
	Yellow-necked mouse	1.3	9; 9; 9.0
<i>P. elegans</i> (Rudolphi, 1802) ^{1, 2, 3}	Root vole	17.7	1-13; 59; 5.36
	Red-backed vole	1.1	1; 1; 1.0
<i>Skrjabinoplagiorchis polonicus</i> (Sołtys, 1957)	Red-backed vole	1.1	1; 1; 1.0
Omphalometridae			
<i>Neoglyphe locellus</i> (Kossack, 1910)	Water shrew	100	3-34; 125; 15.6
	Common shrew	18.9	1-88; 279; 11.6
<i>N. sobolevi</i> (Schaldybin, 1953)	Common shrew	36.2	1-14; 116; 2.5
	Lesser shrew	14.3	1-1; 2; 1.0
	Water shrew	50.0	1-7; 14; 3.5
<i>Rubestrema exasperatum</i> (Rudolphi, 1819)	Common shrew	8.7	1-5; 21; 1.9
<i>R. opisthovitellina</i> (Sołtys, 1954)	Common shrew	8.7	1-5; 21; 1.9
Cestoda			
Anoplocephalidae			
<i>Anoplocephaloides dentata</i> (Galli-Valerio, 1905)	Common vole	1.7	1-2; 4; 1.33
	Root vole	4.8	1-2; 4; 1.33
<i>Paranoplocephala omphalodes</i> (Hermann, 1783)	Common vole	33.1	1-32; 131; 2.3
	Root vole	12.9	1-1; 8; 1.0
Catenotaeniidae			
<i>Catenotaenia cricetorum</i> Kirschenblatt, 1949	Red-backed vole	11.8	1-4; 17; 1.55
<i>Skrjabinotaenia lobata</i> (Baer, 1925)	Yellow-necked mouse	26.6	1-56; 183; 8.71
Dilepididae			
<i>Dilepis undula</i> (Schränk, 1788) ³	Common shrew	1.6	1-1; 2; 1.0
<i>Monocercus arionis</i> (Siebold, 1850)	Common shrew	50.4	1-34; 297; 4.6

Occurrence of helminths

Table 2. Helminth infection of small shrews and rodents living of drainage channel banks in Brest Polesie (2015–2019)

Helminth species	Host	Prevalence, %	No. helminths (min-max; total; mean)
Hymenolepididae			
<i>Ditestolepis diaphana</i> (Cholodkowsky, 1906)	Common shrew	19.7	1-240; 767; 30.7
<i>Lineolepis skutigera</i> (Dujardin, 1845)	Common shrew	20.5	1-24; 131; 5.0
<i>Hymenolepis diminuta</i> (Rudolphi, 1819) ¹	Red-backed vole	7.5	1-2; 9; 1.29
	Striped field mouse	5.6	1-8; 15; 3.0
	Yellow-necked mouse	3.8	1-6; 9; 3.0
	Wood mouse	9.1	3; 3; 3.0
<i>H. horrida</i> (Linstow, 1901)	Red-backed vole	1.1	6; 6; 6.0
<i>Neomylepis magnirostellata</i> (Baer, 1931)	Water shrew	37.5	1-6; 12; 4.0
<i>Neoskrjabinolepis schaldybini</i> Spassky, 1947	Lesser shrew	28.6	1-34; 51; 12.8
<i>N. singularis</i> (Cholodkowsky, 1912)	Common shrew	59.1	1-82; 857; 11.4
	Lesser shrew	7.1	8; 8; 8.0
<i>Rodentolepis asymmetrica</i> (Janicki, 1904)	Common vole	0.6	4; 4; 4.0
<i>R. fraterna</i> (Stiles, 1906) ¹	Striped field mouse	2.2	2-4; 6; 3.0
<i>Soricinia infirma</i> (Žarnowsky, 1955)	Common shrew	2.4	1-6; 11; 3.7
	Lesser shrew	7.1	28; 28; 28.0
<i>Staphylocystis furcata</i> (Stieda, 1862)	Common shrew	22.8	1-16; 93; 3.2
<i>S. uncinata</i> (Stieda, 1862)	Bicolored shrew	100	1-26; 27; 13.5
<i>Urocystis prolifer</i> Villot, 1880	Common shrew	4.7	1-8; 31; 5.2
<i>Vigisolepis spinulosa</i> (Cholodkowsky, 1912)	Common shrew	1.6	2-2; 4; 2.0
Mesocestoididae			
<i>Mesocestoides lineatus</i> (Goeze, 1782), larvae ^{1, 2, 4}	Striped field mouse	1.1	98; 98; 98.0
	Yellow-necked mouse	1.3	112; 112; 112.0
Paruterinidae			
<i>Cladotaenia globifera</i> (Batsch, 1786), larvae ³	Common shrew	2.4	2-12; 24; 8.0
	Red-backed vole	6.5	2-386; 458; 76.3
	Striped field mouse	3.3	52-188; 312; 104.0
Taeniidae			
<i>Taenia martis</i> (Zeder, 1803), larvae ^{1, 4}	Red-backed vole	1.1	3; 3; 3.0
	<i>T. mustelae</i> Gmelin, 1790, larvae ⁴	Red-backed vole	1.1
Root vole		1.6	1; 1; 1.0
Yellow-necked mouse		1.3	4; 4; 4.0
<i>T. taeniaeformis</i> (Batsch, 1786), larvae ^{1, 2, 4}	Common vole	1.2	1-1; 2; 1.0
	Root vole	1.6	1; 1; 1.0
	Yellow-necked mouse	7.6	1-2; 7; 1.17
Nematoda			
Capillariidae			
<i>Aonchotheca kutori</i> (Ruchljadeva, 1946)	Common shrew	6.3	1-6; 19; 2.4
<i>Calodium soricicola</i> (Yokogawa et Nischigori, 1924)	Common shrew	3.2	2-4; 10; 2.5
<i>Capillaria konstantini</i> Romashov, 1999	Water shrew	12.5	4; 4; 4.0
	<i>Eucoleus oesophagicola</i> (Sołtys, 1952)	Common shrew	33.1
Water shrew		37.5	1-4; 6; 2.0
<i>Liniscus incrassatus</i> Diesing, 1851	Common shrew	22.1	1-18; 114; 4.1
<i>Pterothominx sadovskoi</i> (Morosov, 1956)	Red-backed vole	5.4	4-28; 58; 11.6
	Yellow-necked mouse	5.1	1-6; 13; 3.25

Table 2. Helminth infection of small shrews and rodents living of drainage channel banks in Brest Polesie (2015–2019)

Helminth species	Host	Prevalence, %	No. helminths (min-max; total; mean)
Trichuridae			
<i>Trichuris muris</i> (Schrank, 1788)	Red-backed vole	2.2	1-1; 2; 1.0
Ascarididae			
<i>Porrocaecum depressum</i> (Zeder, 1800), larvae ³	Common shrew	5.5	1-2; 8; 1.1
	Water shrew	12.5	3; 3; 3.0
<i>Porrocaecum</i> sp., larvae ³	Common shrew	4.7	1-2; 7; 1.2
Heterakidae			
<i>Heterakis spumosa</i> Schneider, 1866	Striped field mouse	2.2	1-14; 15; 7.5
Oxyuridae			
<i>Syphacia agraria</i> Sharpilo, 1973	Striped field mouse	17.8	1-86; 220; 13.8
<i>S. frederici</i> Roman, 1945	Yellow-necked mouse	21.5	1-450; 779; 45.8
<i>S. nigeriana</i> Baylis, 1928	Common vole	47.1	1-92; 644; 7.95
	Root vole	17.7	1-12; 70; 6.36
<i>S. petrusewiczii</i> Bernard, 1966	Red-backed vole	9.7	1-96; 367; 40.8
<i>S. stroma</i> (Linstow, 1884)	Yellow-necked mouse	2.5	2-4; 6; 3.0
	Wood mouse	18.2	3-16; 19; 9.5
Strongyloididae			
<i>Parastrongyloides winchesi</i> Morgan, 1928	Common shrew	0.8	3; 3; 3.0
	Water shrew	12.5	2; 2; 2.0
Acuariidae			
<i>Skrjabinoclava soricis</i> (Tiner, 1951)	Common shrew	1.6	1-1; 2; 1.0
Spirocercidae			
<i>Ascarops strongylina</i> (Rudolphi, 1819), larvae ^{2, 5}	Common shrew	3.9	1-3; 7; 1.4
<i>Mastophorus muris</i> (Gmelin, 1790)	Red-backed vole	1.1	2; 2; 2.0
	Yellow-necked mouse	1.3	6; 6; 6.0
Heligmosomidae			
<i>Heligmosomoides laevis</i> (Dujardin, 1845)	Common vole	19.8	1-15; 152; 4.47
	Root vole	8.1	1-3; 7; 1.4
<i>H. polygyrus</i> (Dujardin, 1845)	Striped field mouse	50.0	1-238; 557; 12.4
	Yellow-necked mouse	26.6	1-52; 187; 8.91
<i>Heligmosomum costellatum</i> (Dujardin, 1845)	Common vole	18.0	1-24; 159; 5.13
<i>H. mixtum</i> Schulz, 1954	Red-backed vole	59.1	1-11; 173; 3.15
<i>Longistriata depressa</i> (Dujardin, 1845)	Common shrew	44.1	1-28; 286; 5.1
	Lesser shrew	28,6	1-8; 14; 3.5
Acanthocephala			
Centrorhynchidae			
<i>Centrorhynchus aluconis</i> (Müller, 1780), larvae ³	Lesser shrew	7.1	1; 1; 1.0
Moniliformidae			
<i>Moniliformis moniliformis</i> (Bremser, 1811) ^{1, 2}	Striped field mouse	1.1	1; 1; 1.0
Total for shrews (34 species of helminths):	4 host species	94.7	1-240; 3803; 26.6
Total for rodents (34 species of helminths):	8 host species	65.9	1-450; 4916; 14.6
Total for all (66 species of helminths):	12 host species	72.5	1-450; 8719; 18.2

Note: Index ¹ denotes helminths, known in the world as human parasites; index ² – having veterinary significance; index ³ – the obligate definitive hosts of which are birds; index ⁴ – obligate definitive hosts of which are carnivorous mammals; index ⁵ – the obligate definitive hosts of which are non-ruminant artiodactyl mammals

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of the above cestodes: 42.4% of common shrews were infected with it in the 2nd period [3], and 44.1% in the 3rd period (Table 2). The cestode *D. diaphana* dominated in infection the common shrew only on the channel banks in mixed forests (its subdominants: cestodes *M. arionis* and *N. singularis*).

34 species of helminths (7 trematode species, 13 cestode species, 13 nematode species, 1 acanthocephalan species) were identified in small rodents in the 3rd period (Table 2). The largest number of helminth species (13) were found in the red-backed vole (69.9% of animals were infected). Next in descending order are the yellow-necked mouse (11 species, 64.6% infected), the striped field mouse (10 species, 57.8% infected), the common vole (9 species, 79.1% infected), the root vole (8 species, 46.8% infected), and wood mouse (2 species, 27.3% infected). The hazel dormouse (1 immature male) and the house mouse (2 males: adult and immature) were uninfected. Each host was dominated by its own species of helminths. Thus, in the common vole it is the nematode *S. nigeriana* (47.%) and the cestode *P. omphalodes* (33.1%), in the root vole – the nematode *S. nigeriana* (17.7%) and the trematode *S. polonicus* (17.7%), in the red-backed vole – the nematode *H. mixtum* (59.1%), in the striped field and yellow-necked mice – the nematode *H. polygyrus* (50.0% and 26.6%, respectively), as well as in the yellow-necked mouse also the cestode *Skrjabinotaenia lobata* (Baer, 1925) (26.6%), in the wood mouse – the nematode *S. stroma* (18.2%). But the nematode *S. frederici* in the yellow-necked mouse (1–450 specimens; mean 45.8), the nematode *Syphacia petrusewiczii* Bernard, 1966 and the larvae of the cestode *C. globifera* in the red-backed vole (1–96 specimens and 2–386 specimens; mean 40.8 and 76.3, respectively) and the nematode *S. nigeriana* in the common vole (1–92 specimens; mean 7.95) were distinguished by the number of helminths. This information is largely similar to that obtained in the first two research periods. Particular attention should be paid to the root vole, which increased its numbers in the 3rd period and intensively became involved in the circulation of the trematode *S. polonicus* on the drainage channel banks, and also acquired many species of helminths typical for the common vole (Table 2).

Helminth species parasitize shrews and small rodents in the adult stage are specific to these animal groups. Only larvae of trematode *A. alata* and cestode *C. globifera* were common to them

(Table 2). Larvae of trematodes *Strigea falconis* Szidat, 1928 and *S. sphaerula*, larvae of nematode *Porrocaecum* sp., cestode *Dilepis undula* (Schrank, 1788) were also common in the first two research periods [1–4]. Their obligate definitive hosts are canid mammals (for trematode *A. alata*) and birds (for other species of helminths).

To the helminth species localized in shrews in the 3rd period, another 9 should be added (3 trematode species, 2 cestode species, 4 nematode species) found in the first two research periods [2,3]. These are larvae of trematodes Echinostomatidae gen. sp. (host: common shrew; see description in [27]), *S. falconis* (host: common shrew) and *S. strigis* (Schrank, 1788) (host: common shrew), cestodes *Sacciuterina paradoxa* (Rudolphi, 1802) (syn.: *Polycercus paradoxa* (Rudolphi, 1802)) (hosts: common shrew and lesser shrew) and *Triodontolepis sumavensis* (Prokopič, 1957) (host: water shrew), nematodes *Stefanskostrongylus soricis* (Sołtys, 1954) (host: lesser shrew), *Longistriata neomi* Lubarskaja, 1962 (host: water shrew) and *Gongyлонema soricis* Fain, 1955 (host: common shrew), larvae of nematode *Physocephalus sexalatus* (Molin, 1860) (host: common shrew). The trematode *S. polonicus* (host: common shrew), cestodes *Soricinia soricis* (Baer, 1928) (hosts: common shrew and lesser shrew) and *Staphylocystis tiara* (Dujardin, 1845) (host: common shrew) should be excluded from the list of shrew helminths, of which the first should be assigned to the species *P. danubica* [28], the second to the species *Soricinia infirma* (Żarnowsky, 1955) (syn. *Insectivorolepis infirma* Żarnowsky, 1955), and the third to the species *Staphylocystis furcata* (Stieda, 1862).

Taking into account these data and a critical assessment of the species composition of helminths, in just three research periods, 43 species of helminths were found in shrews living on the drainage channel banks in Brest Polesie (12 trematode species, 15 cestode species, 15 nematode species, 1 acanthocephalan species). The most species of helminths (36) were found in the common shrew, the least (4) in the bicolor shrew. 14 and 13 species were identified in the lesser shrew and water shrew, respectively.

To the helminth species identified in small rodents in the 3rd period, it is necessary to add another 16 (2 trematode species, 7 cestode species, 7 nematode species) found in the first two research periods [1,4]. These are the larvae of the trematodes *S. falconis* (hosts: striped field mouse and yellow-

necked mouse) and *S. sphaerula* (hosts: red-backed vole and striped field mouse), the cestodes *Paranoplocephala gracilis* Tenora et Murai, 1980 (host: red-backed vole), *Paranoplocephala* sp. (hosts: common vole, red-backed vole, field vole, root vole), *D. undula* (hosts: striped field mouse and yellow-necked mouse) and *Rodentolepis straminea* (Goeze, 1782) (host: striped field mouse), larvae of cestodes *Echinococcus multilocularis* Leuckart, 1863 (hosts: common vole and red-backed vole), *Taenia crassiceps* (Zeder, 1800) (hosts: common vole and striped field mouse) and *T. polyacantha* Leuckart, 1856 (hosts: common vole and red-backed vole), the nematodes *Calodium hepaticum* (Bancroft, 1893) (host: red-backed vole), *Liniscus papillosus* (Polonio, 1860) (host: brown rat), *Syphacia obvelata* (Rudolphi, 1802) (host: house mouse), *S. vandenbrueli* Bernard, 1966 (host: harvest mouse) and *Rictularia cristata* Frölich, 1802 (hosts: striped field mouse and wood mouse; this species appears in the 1st period as the species *Rictularia proni* Seurat, 1915), larvae of nematode *Baylisascaris devosi* (Sprent, 1952) (hosts: red-backed vole and yellow-necked mouse) and *Porrocaecum* sp. (hosts: common vole, red-backed vole, striped field mouse and wood mouse).

Thus, the total number of helminth species identified in small rodents living on the drainage channel banks in Brest Polesie was 50 (9 trematode species, 20 cestode and nematode species each, 1 acanthocephalan species). The red-backed vole dominates in terms of the number of helminth species – 24. The striped field mouse is the host of 22 species, the common vole – 21, the yellow-necked mouse – 19, the root vole and wood mouse – 12, the brown rat and the harvest mouse – 5, field vole – 4, water vole and house mouse – 3.

Based on the results of three research periods, a total 87 species of helminths (18 trematode species, 33 cestode species, 34 nematode species, 2 acanthocephalan species) parasitize shrews and small rodents living on the drainage channel banks in Brest Polesie. Six species of helminths are common to both, and their obligate definitive hosts are birds (for 5 species of helminths) and canid mammals (for 1 species of helminths).

The common shrew is involved in the life cycle of the trematode *A. alata*. Its mesocercariae were found in this animal in the 2nd and 3rd research periods. They infected 0.7% of animals in the 2nd period [3] and 3.2% of animals in the 3rd period (Table 2). The number of larvae varied from 1 to 2.

Shrews also participate in the life cycles of helminths, the obligate definitive hosts of which are birds (trematodes Echinostomatidae gen. sp., *S. falconis*, *S. sphaerula*, and *S. strigis*, cestodes *C. globifera*, *D. undula* and *S. paradoxa*, nematodes *P. depressum* and *Porrocaecum* sp., acanthocephalan *C. aluconis*) and non-ruminant artiodactyl mammals (nematodes *A. strongylina* and *P. sexalatus*). This is confirmed by three research periods (see [2,3] and Table 2). Larvae of the nematode *A. strongylina* were found in the common shrew in all research periods (infection was recorded at 1.3%, 0.7% and 3.9%, respectively by periods; the maximum number of larvae of 20 specimens was detected in the 1st period, in the 2nd there were 8 of them, and in the 3rd 3). This helminth species is of veterinary significance, being a parasite of domestic pigs, like the nematode *P. sexalatus*, the larvae of which were found in the common shrew only in the 1st research period (2.6% infected; the number of larvae varied from 1 to 60 [2]), as well as the trematode *A. alata*, which is capable of infecting domestic dogs, cats and pigs.

Small rodents, as in previous research periods, are involved in the life cycles of helminths, the obligate definitive hosts of which are birds (4 species of helminths) and carnivorous mammals (5 species of helminths) (Table 2). In addition, during all research periods they are hosts of helminths that have medical and veterinary significance. 8 species of helminths known in the world as human parasites were found in small rodents in the 3rd period (Table 2). In total, over 3 periods, 15 such helminth species were identified in 9 species of rodents, and their infection rate was 8.2% [29]. If in the 1st period this figure was 7.3%, then in the 2nd it increased to 9.9%, and in the 3rd period it dropped again to 7.3%. Six species of helminths were found also in the 3rd period, which at different stages of development can parasitize domestic geese and ducks ((trematode *Echinostoma revolutum* (Frölich, 1802)), rabbits (larvae of the cestode *M. lineatus*), pigs (larvae of the trematode *A. alata*), cats and dogs ((trematodes *A. alata* and *Plagiorchis elegans* (Rudolphi, 1802), cestodes *M. lineatus* and *T. taeniaeformis*, acanthocephalan *Moniliformis moniliformis* (Bremser, 1811)) (Table 2). 3.5% of the animals studied were infected with these helminths. Among rodents, their hosts are the striped field mouse (4 helminth species), the yellow-necked mouse (3 helminth species), the common vole (2 helminth species) and the red-

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backed vole (1 helminth species) (Table 2) To these should also be added the cestodes *E. multilocularis*, *T. crassiceps* and *T. polyacantha* found in rodents in the 1st and 2nd research periods [1,4]. The definitive hosts for these helminths may be domestic cats and dogs.

Mostly small rodents help maintain centers of helminthoses, which pose a danger to humans, domestic and farm animals. Among the shrews, only the common shrew is included in the circulation of the trematode *A. alata* (alariosis disease).

Thanks to monitoring carried out in the 3rd period, the list of shrew and small rodent helminths in Belarus has been replenished with three new species: the trematode *P. danubica* (host: common shrew) [28], the acanthocephalans *M. moniliformis* (host: striped field mouse) [30] and *C. aluconis* (host of the larval stage: lesser shrew). New hosts in Belarus were also identified for 6 species of helminths: for the trematode *S. polonicus* this is the root vole, for the trematode *Psilotrema spiculigerum* (Mühling, 1898) the common vole, for the trematode *Plagiorchis arvicolae* Schulz et Skvorzov, 1931 the root vole, for the trematode *E. revolutum* the striped field mouse, for the cestode *T. taeniaeformis* the root vole, for the nematode *P. depressum* the water shrew. Previously, these species of helminths were found in Belarus in other hosts [1,4,31,32]. In addition, the nematode *S. soricis* (host: common shrew) was found only in the 3rd research period.

In conclusion, the species composition of shrew mammals on the drainage channel banks in Brest Polesie is represented by 4 species: bicolor shrew, common shrew, lesser shrew and water shrew. Their total number increased from 2.63 individuals per 100 trap-days in the 1st period to 3.78 in the 2nd and 3rd research periods. The common shrew dominates (2.22, 3.02 and 3.18 individuals per 100 trap-days, respectively for the study periods). It dominates the drainage channel banks running in different places.

13 species of small rodents were caught on the drainage channel banks during all research periods, of which 8 species in the 3rd research period. The main skeleton is represented by 5 species: the common vole, the red-backed vole, the root vole, the striped field mouse and the yellow-necked mouse. The first species is background on the channel banks on arable lands, pastures and near roads, the second in mixed forests, the third on pastures and near roads (the number increased in the 3rd period), the fourth on arable lands and near

roads, the fifth in mixed forests. The number of small rodents increased in the 2nd period (18.7 individuals per 100 trap-days), while in the 1st and 3rd periods it was approximately the same (12.31 and 12.75 individuals per 100 trap-days, respectively).

The total infection with helminths in shrews increased over the study periods: from 88.8% in the 1st period to 94.2% and 94.7% in the 2nd and 3rd periods. In small rodents it first decreased from 64.7% in the 1st period to 56.0% in the 2nd, and then increased again to 65.9% in the 3rd period.

The composition of shrew mammal helminths for three research periods includes 43 species (12 trematode species, 15 cestode species, 15 nematode species, 1 acanthocephalan species). 36 species of helminths were found in the common shrew, 13 species in the water shrew, 14 species in the lesser shrew and 4 species in the bicolor shrew. The main skeleton of helminths is found in the common shrew. The nematode *E. oesophagicola*, which dominated the infection of this animal during the 1st research period, gradually lost its dominant position. The cestodes *M. arionis* and *N. singularis*, the nematode *L. depressa* and the trematode *R. exasperatum* began to be found most often in the common shrew, the cestode *S. uncinata* in the bicolor shrew, the nematode *L. depressa*, the cestode *N. schaladybini* and the trematode *R. exasperatum* in the lesser shrew, the trematode *N. locellus* in the water shrew.

The species composition of helminths found in small rodents over three research periods is quite rich 50 species (9 trematode species, 20 cestode species, 20 nematode species, 1 acanthocephalan species). The infection of each animal is dominated by its own species of helminth: in the common vole it is the nematode *S. nigeriana* and the cestode *P. omphalodes*, in the root vole the nematode *S. nigeriana* and the trematode *S. polonicus*, in the red-backed vole the nematode *H. mixtum*, in the striped field mouse and yellow-necked mouse the nematode *H. polygyrus*, as well as in the yellow-necked mouse there is also the cestode *S. lobata*, in the wood mouse the nematode *S. stroma*. The greatest species diversity of helminths is the red-backed vole (24), the striped field mouse (22), the common vole (21) and the yellow-necked mouse (19).

A total of 87 helminth species (18 trematode species, 33 cestode species, 34 nematode species, 2 acanthocephalan species) parasitize shrews and small rodents during three research periods. Six

species are common to both. Their obligate definitive hosts are birds (for 5 species of helminths) and canid mammals (for 1 species of helminths). In just three research periods, shrews and small rodents were involved in the life cycles of 13 species of helminths the obligate definitive hosts of which are birds, 2 species of helminths are non-ruminant artiodactyls, and 8 species of helminths are carnivorous mammals.

Three new species of helminths for the fauna of Belarus were identified in the 3rd research period. These are the trematode *P. danubica* (host: common shrew), the acanthocephalans *C. aluconis* (host of larval stage: lesser shrew) and *M. moniliformis* (host: striped field mouse). New hosts for 6 species of helminths have been established in Belarus: the water shrew for the nematode *P. depressum*, the common vole for the trematode *P. spiculigerum*, the root vole for the trematodes *P. arvicolae* and *S. polonicus*, the cestode *T. taeniaeformis*, the striped field mouse for the trematode *E. revolutum*.

Eighteen species of helminths medical and veterinary significance were identified in shrews (3 helminth species) and small rodents (16 helminth species) over three research periods. 15 helminth species can infect humans. It was noted that the infection of small rodents with such helminths fluctuates over the research periods, increasing from 7.3% (1st period) to 9.9% (2nd period) and decreasing again to 7.3% (3rd period). 11 helminth species at different stages of development can parasitize domestic and farm animals: geese and ducks (1 trematode species), rabbits (1 cestode species), pigs (1 trematode species, 2 nematode species), cats and dogs (2 trematode species, 5 cestode species, 1 acanthocephalan species).

The centers of alariosis (1 causative agent), echinostomosis (1 causative agent), plagiorchiosis (1 causative agent), hymenolepiosis (1 causative agent), rodentolepiosis (2 causative agents), mesocestoidosis (1 causative agent), echinococcosis (1 causative agent), taeniosis (4 causative agents), baylisascariosis (1 causative agent), calodiosis (1 causative agent), ascaropsosis (1 causative agent), physocephalosis (1 causative agent), syphaciosis (1 causative agent) and moniliformosis (1 causative agent) can function on the drainage channel banks and pose a danger to humans, domestic and farm animals. Small rodents (mainly voles and mice) help maintain them, and among the shrews, only the common shrew is affected in the centers of alariosis, ascaropsosis and physocephalosis.

This study shows that drainage channels in reclaimed areas are centers of many helminthoses have significance for medical science and veterinary medicine. The common shrew but especially voles and mice support the functioning of these centers of helminth infections.

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