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SHORT COMMUNICATIONS

Prevalence of Coccidia Infection in the European mole (*Talpa europaea* L.) under Conditions of Industrial Pollution

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Unlike other small mammals, the European mole is rarely used as an object of ecotoxicological research due to the specificity of methods for taking census of these animals [1]. Meanwhile, it is important to include in analysis this highly specialized subterranean species in order to understand the general reactions of mammals to industrial pollution. Therefore, we have performed studies in the impact areas of copper smelters in the Middle and Southern Urals to analyze the distribution of mole [2], its population structure and morphophysiological characteristics [3, 4], and accumulation of heavy metals [4].

Histological analysis of the mole liver revealed the presence of parasitic Protozoa, which were subsequently identified as coccidia. Although the infection of European mole by these parasites has been described repeatedly [5–8], many of its ecological aspects (morbidity, occurrence in different population groups) are poorly known. For example, it has not been studied how the extensiveness of infection is related to industrial pollution level, but this issue is important, because the state of host animals is influenced by both factors (pollution and parasitism), while the effects may vary depending on the parasite and host species, as well as on the type of pollution [9]. According to one of possible scenarios discussed in ecological parasitology, the leading role is played by the ecotoxicological factor: environmental pollution has an effect both on the parasite, increasing its abundance and pathogenicity, and on the host, reducing its resistance to infection [10].

The purpose of this study was to analyze the relationship between the infection of European mole by coccidia and the level of industrial pollution. The hypothesis was tested that animals exposed to pollution are more vulnerable to infection than animals in the background territory.

The European mole, *Talpa europaea* L., 1758 (Talpidae, Insectivora), is ubiquitous in forest ecosystems of the Middle and Southern Urals. Mole trapping was carried out in the vicinities of the Middle Ural Copper Smelter (MUCS, Revda, Sverdlovsk oblast, Middle Urals) and Karabash Copper Smelter (KCS, Karabash, Chelyabinsk oblast, Southern Urals). The amounts of emissions from these plants and the main pollutants they contain (SO_2, heavy metals) are similar. Studies in each region were performed in the buffer and background zones (6–10 and 25–30 km from the pollution source, respectively), because moles are completely absent in the impact zone with a radius of up to 5–7 km [2].

The animals were captured with mole traps from June to September 2008–2013 (Table 1). They were divided into two age groups: young (1–4.5 months) and adult (older than one year). The absolute age was determined according to Klevezal [11]. Liver samples for micromorphological analysis ($n = 76$) were fixed in 10% formalin, then paraffin sections were prepared (5–7 μm). In addition, water suspensions were prepared from dried or frozen intestinal contents for taxonomic diagnosis of the parasite.

The dependence of infection on region, pollution level, sex, and age was studied (with account of the effect produced by other factors) using multiple logit regression. Young females from the background zone around the MUCS were used as a reference group. Following the exponential transformation, the odd ratios and their confidence intervals (CI) were interpreted directly as the hazard ratios [12]. Statistical analysis was performed with the Statistica package (StatSoft Inc., 2001).

Coccidia (class Coccidia, type Apicomplexa (Leuckart, 1879)) are intracellular parasites infecting invertebrates and vertebrates. They are characterized by a complex life cycle that always includes endogenous and exogenous stages. The endogenous stages are merogony and gametogony, ensuring active colonization of host cells/tissues. The exogenous stages

Table 1. Prevalence of coccidia infection in European mole (*T. europaea*)

Region (pollution source)	Zone	Age group		In total
		young	adult	
Middle Urals (MUCS)	Background	9(3) 6(4)	8(8) 7(6)	17(11) 13(10)
	Buffer	9(6) 11(7)	12(11) 5(5)	21(17) 16(12)
Southern Urals (KCS)	Background	1(0) 2(2)	4(4) 0	5(4) 2(2)
	Buffer	2(2) 0	0 0	2(2) 0
Total		40(24)	36(34)	76(58)

Figures above and below the line refer to males and females, respectively; figures in parentheses how the number of infected animals.

(sporogony) are associated with the formation and spread in the external environment of specialized cysts (oocysts) and infection of new hosts. The taxonomy of coccidia is based on the specifics of life cycle and morphology of particular stages (especially oocysts) [13–15].

On the whole, 76.3% of the examined animals contained coccidia at the stages of gametogony (macro- and microgamonts, macrogametes, and unripe oocysts) in epithelial cells lining the interlobular bile ducts. Immature oocysts were also found in the suspension of intestinal contents from these animals. Most of bile ducts in the infected animals were colonized by parasites. In addition to the direct destruction of epithelial cells, biliary dilatation and polymorphic cellular infiltration with the involvement of eosinophils (a symptom of inflammation) around bile ducts were revealed. Based on the shape, size, and localization of immature oocysts, the parasite was assigned to the order Eimeriorina (Leger, 1911), or true coccidia. A more accurate diagnosis is possible based on the morphology of mature oocysts, but have not found them.

The prevalence of coccidia infection in moles from the Ural populations is comparable to that in England, where coccidia were recorded in 88% of animals [16]. Notably, the same animal may be simultaneously infected by several species of coccidia. The mole can host at least 13 species of the genera *Eimeria, Cyclospora* (family Eimeriidae) and *Isospora* (family Isosporidae), but most of them have not been sufficiently studied with respect to localization of endogenous stages, sporulation period, and other aspects of the life cycle [6–8, 16, 17].

Coccidia cause a number of diseases (eimeriosis, cyclosporosis, isosporosis), all defined by the general term coccidioses, which are well-known in the medical and veterinarian practice. Since the mole was formerly an object of fur trade, not only the cases of coccidioses were recorded in this species but also the symptoms were described (such as severe diarrhea) that are similar to those observed in humans and domestic animals [18]. Prevalence of coccidia infection in moles is not correlated with animal sex, region, or zone of pollution but depends only on age: the probability of finding coccidia in adult animals is 1.6 (1.2–2.1) times higher than in young animals (Table 2). Since the infection is acquired alimentarily, young animals may become invasive within the first two months of life, before dispersal. The almost total infection of adult animals (94.4%) is facilitated by joint use of the closed system of underground tunnels.

The extensiveness of infection is similar in moles from the background and polluted areas and therefore the level of their resistance to infection, at least to coccidia, is the same. This is indirectly confirmed by the results of the analysis of general morphophysiological status: the body weight and size and the indices of internal organs do not differ between animals from the background and polluted territories [3]. It appears that the current pollution level also has no effect on coccidian oocysts, because it is well-known that they are resistant to various impacts [19]. The generally high prevalence of coccidia infection in moles may also be evidence for the high resistance of the host–parasite system, which is not influenced by industrial pollution.

Unfortunately, we could not compare our results with published data, because no such studies on the European mole have been performed to date. Most publications on the problems of ecological parasitology deal with very few groups of parasites and their hosts (mostly aquatic animals) [9, 10, 20]. The deficit in such studies is explained by the interdisciplinarity of the research field and insufficient collaboration between ecologists and parasitologists [9, 21].

Thus, we demonstrated that European moles in the Urals, as well as in Europe, are infected by coccidia. The prevalence of infection is significantly dependent only on the age of animals. Industrial pollution does not increase the probability of infection. The prevalence of infection may significantly contribute to the variability of estimated parameters, especially morph-

Table 2. Estimates of the effects of risk factors on the probability of European mole (*T. europaea*) infection by coccidia, results of logit regression ($LR(4) = 17.40$)

Factor	*b*	SE	$X^2(1)$ Wald	Odd ratio [95% CI]
b_0	0.13	0.59	0.05	
Age	**2.63**	**0.82**	**10.27**	**1.57 [1.21–2.05]**
Sex	–0.50	0.62	0.64	0.98 [0.76–1.26]
Region	1.41	1.16	1.50	0.84 [0.64–1.09]
Impact zone	0.72	0.62	1.37	0.92 [0.71–1.18]

b_0, reference group; *b*, regression coefficient; SE, standard error; values significant at $p < 0.0001$ are boldfaced.

ophysiological indices, and therefore should be taken into account in ecotoxicological studies.

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