

Review articles

Migrations and the introduction of wild ruminants as a source of parasite exchange and emergence of new parasitoses

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ABSTRACT. The relationship between European bison and cervidae is a good model for studies on the influence of migration and introduction of new species on the helminthofauna of wild ruminants and the occurrence of new parasitoses. Changes in the helminthofauna of bison and deer under the influence of changes in the environment and living conditions, as well as the introduction and migration of other species, are discussed in detail. The exchange of helminths between bison, cervids and domestic ruminants is demonstrated. Examples of helminth introduction from specific Cervidae species, the formation of the new host-parasite systems and the appearance of new parasitoses are also presented.

Key words: European bison, Cervides, helminthofauna

The relationship between European bison and deer represents a good model for studies on the influence of migration and introduction of new species on the helminthofauna of wild ruminants and the occurrence of new parasitoses. As the parasitofauna of these animals is well known in Poland, and it has been recently exposed to numerous environmental changes and living conditions, the bison is an important subject for such studies.

Due to its endangered species status, which began during the reign of the Polish kings and continued through that of the Russian tsars, populations of bison survived in a wild state on the territory of Białowieża Forest until the First World War. However, as a result of military action and poaching, the last wild bison in Białowieża Forest died in 1919. However, ten years later, an attempt was made to restore the population in closed reserves by importing two bison cows from Sweden and one bull from Germany, all three of which had originally been taken from Białowieża Forest. The breeding process was successful and the bison survived the Second World War relatively well. In 1952, because of the significant growth in the number of bison, a couple were released from the closed reserve into the forest. The following years saw more bison released to several forest complexes including Białowieża Forest, Borecka Forest and Knyszyńska Forest, as well as in the Bieszczady Mountains [1].

The first reports of helminths living in bison in the Białowieża Forest were published by Kułagin and Wróblewski at the turn of the XX century [2,3]. Subsequent long-term studies on the helminths were first undertaken by Dróżdż in the 1950s, when bison were being kept only in closed reserves [4,5], and continued after they had been released into the wild [6–8]. Hence, the body of information concerning bison infection with helminths extends for around 100 years.

Sixteen species of helminths were identified in bison living wild at the turn of the XX century, all being typical cattle parasites: 3 species of trematodes, 5 species of cestodes and 8 species of nematodes. All the bison studied had been infected with *Fasciola hepatica* flukes and the lung nematodes of the genus *Dictyocaulus*. Other common bison parasites were *Dicrocoelium dendriticum* and *Paramphistomum cervi*

trematodes, cestodes of the *Monezia* genus and *Gongylonema pulchrum* nematodes. It is not surprising that the free living bison were intensively infected with parasites typical of domestic ruminants, considering that in 1914, 8343 cows were being pastured, and 3–4,000 cattle and 1,000 sheep were being herded through Białowieża Forest [2,3].

In the 1950s, studies were undertaken on the helminthofauna of the bison kept in closed reserves. Parasitological necropsies of the 25 bison that died from various causes in reserves revealed 21 species of helminths: 3 species of trematodes, 2 species of cestodes and 16 species of nematodes. However, in bison from closed reserves, no invasions of *Taenia hydatigena* larvae*, Moniezia expansa* cestode or *Dictyocaulus filaria* and *Gongylonema pulchrum* nematode were detected, all of which were very common in free living bison at the turn of the XX century. However, an infection with another 12 species was detected: *Moniezia* sp., *Oesophagostomum radiatum*, *Bunostomum trigonocephalum*, *Trichostrongylus axei*, *Ostertagia ostertagi*, *O. lyrata*, *Spiculopteragia boehmi*, *Cooperia surnabada*, *Nematodirus helvetianus*, *Thelasia gulosa*, *T. skrjabini and Aonchotheca bilobata*.

Although 18 of the 21 species of helminths identified in these samples were typical of domestic ruminants, it is difficult to ascertain whether the bison is a primary or a secondary host for these species. The remaining 3 species were *Moniezia* sp. cestodes, which are distinctly different from other helminths of that genus, *S. boehmi* nematodes, which are typical deer parasites that have not yet been found in Bovidae, and *Aonchoteca bilobata* nematodes, which are common cattle parasites in India and Vietnam, and were probably acquired by the bison while staying in a zoo. Some of the observed species, including *Oe. radiatum*, *O. ostertagi*, *O. lyrata*, *T. gulosa*, *T. skrjabini* and *N. helvetianus*, are especially specific to cattle and are quite rare in other hosts [4,5].

Thirty years after releasing the first few bison to Białowieża Forest, their helminthofauna was examined again. Forty-six parasitological necropsies of bison were conducted. All examined bison were found to be infected with parasites, with the highest intensity being found in gastro-intestinal nematodes, which demonstrated 100% prevalence. Thirty-three species of helminths were also found. Eleven species typical of Cervidae, 10 of which were new to bison, were found within the helminthofauna of the free-living bison but not in bison kept in closed reserves: *Parafasciolopsis fasciolaemorpha*, *Trichostrongylus capricola*, *Ostertagia leptospicularis*, *O. kolchida*, *Spiculopteragia boehmi*, *S. mathevossiani*, *S. assymetrica*, *Cooperia pectinata*, *Nematodirus roscidus*, *N. europaeus* and *Nematodirella alcidis.* Among the parasites acquired from cervids, the highest prevalence (86%, mean intensity of 512 specimens) was shown by *O. leptospicularis*, a dominant species in the majority of bison. Another species permanently adopted by the bison was *N. roscidus,* which showed the highest prevalence and intensity among other species of that genus. The species *N. roscidus*, *N. europeaus* and *N. alcidis* were identified for the first time in Bovidae. The gastro-intestinal nematode infection as observed to be greater in free-living bison than in bison living in closed reserves [6–8].

More recently, all the examined bison in the Białowieża Forest were found to be infected with a new parasite: *Ashworthius sidemi* [9,10]. *A. sidemi* infections have been found to be continually growing over time, reaching several thousand specimens in some bison. This blood sucking nematode is new to Poland and bison, and is a dangerous parasite for the ruminant abomasum. It used to be typical of Asiatic cervids, mainly sika deer (*Cervus nippon*), through which it was introduced to many republics of the former Soviet Union, Ukraine, Slovakia, Czech Republic and France [11–14]. It is the 12th species known to have been acquired by bison from cervids.

In 2001, the bison helminthofauna was found to have been enriched by two more species of nematodes typical of elk, *Ostertagia antipini* and *Mazamastrongylus dagestanicus* [9]*,* increasing the number of species acquired from cervids to 14. A recent study reports the presence of one new species – *Bunostomum trigonocephalum* nematode – in the intestines of one free living bison, a typical elk parasite which is the 15th species acquired by bison from cervids and the 37th helminth species identified in bison [15]. The acquisition of typical elk parasites by bison has been associated with the increase of the elk population in Białowieża Forest in recent years.

Bison infected with ashworthiosis demonstrated a reduction in the number of gastro-intestinal nematode species from 21 to 8: *Aonchoteca bilobata*, which is a typical parasite of Asiatic cattle, *Ashworthius sidemi*, a typical parasite of the Asiatic

sika deer, *Ostertagia ostertagi* and *O. lyrata*, which are typical Bovidae parasites, as well as *Ostertagia leptospicularis*, *Ostertagia kolchida*, *Spiculopteragia boehmi* and *Nematodirus roscidus*, which are typical parasites of red deer and roe deer. As the numbers of *A. sidemi* were found to increase, possibly due to transmission from cervids, the intensity of infection with other species from the Trichostrongylidae family (*O. leptospicularis*, *O. kolchida*, *S. boehmi* and *N. roscidus*) significantly decreased. The infection with *O. ostertagi*, which is a typical Bovidae parasite, remains unchanged [own data unpublished].

The first focus of ashworthiosis was found in the Bieszczady Mountains in 1997. Initially, it concerned the Lutowiska Forest District where a total of 629 adult specimens of *A. sidemi* were found in four necropsied bison. In subsequent years, the focus spread to Stuposiany, Brzegi Dolne, Baligród and Komańcza, four forest districts also in the Bieszczady, where *A. sidemi* nematodes were found in all examined wild ruminants: 18 red deer, 9 roe deer and 13 bison. The maximal intensity of infection in the roe deer was 656 nematodes, 570 in the red deer and 4000 in the bison [16–18]. In subsequent examinations, 10 roe deer and 5 red deer from the Komańcza and Cisna Districts were found to be infected with *A. sidemi*. The intensity of infection of the roe deer ranged from 42 to 416 nematode specimens and the mean intensity was 161, while for red deer in these districts, the intensity ranged from 18 to 296 nematodes and the mean intensity was 148. In addition, all four examined red deer from the Lutowiska Forest District were found to be infected with *A. sidemi*: the intensity of infection ranged from 4 to 291 nematodes, with a mean intensity of 148. The prevalence of infection of red deer in the Baligród District was found to be 90%, with only one in ten red deer found to be uninfected. The intensity of infection ranged from 27 to 209 specimens of *A. sidemi* and the mean intensity was 103 nematodes. In the abomasum of one red deer from the Krasiczyn Forest District located in the Przemyśl Foothills, only three specimens of *A. sidemi* were found; this represents a northern extension of the Bieszczady ashworthiosis focus [19].

In 2009, 467 juvenile *A. sidemi* nematodes were found in the abomasum of one cow aged 12 in Knyszyńska Forest. The low intensity of this infection implies that *A. sidemi* penetrated the area around 3–4 years earlier. Around that time, in February 2005, two young bison heifers were relocated from Białowieża Forest to Knyszyńska Forest. As all the examined bison from Białowieża Forest were infected with ashworthiosis at that time, it is possible that the imported bison could have brought *A. sidemi* with them. On the other hand it cannot be excluded that the infection could be due to migration of cervids. The presence of ashworthiosis in Knyszyńska Forest represents a northern extension of the Białowieża focus of ashworthiosis [20].

In 2011, *A. sidemi* was found in a fallow deer kept on a farm homestead in Dulowska Forest, Małopolska region. The source of the infection could be fallow deer imported in 1998–1999 from Hungary to the farm for breeding purposes. Taking into account the fact that *A. sidemi* has also been found in roe deer and red deer in the wild in the nearby hunting ground, Dulowska Forest should be considered to be the third focus of this parasitosis in Poland [21]. However, the presence of ashworthiosis in roe deer in the Krynica region may be due to the extension of the Bieszczady ashworthiosis focus along the Carpathian ecological corridor [22].

Also 2 out of 10 examined elks were infected with *A. sidemi* nematodes: one of which, a mature bull from the Augustowska Forest, presented 120 aforementioned nematodes (60 males and 60 females) in the abomasum, while 7 specimens of nematodes (4 males and 3 females) were found in the abomasum of the second one, a young elk weighing 70 kg from the Biebrza marshes. This represents the first identification of *A. sidemi* in this host in this part of Poland. Also finding *A. sidemi* in elks is a further extension of the Białowieża focus towards the Biebrza marshes and Augustowska Forest. The increase in the elks population, and its long distance migrations, can cause the foci of this parasitosis to spread much further than in the case of red deers [23].

A. sidemi is a typical cervid parasite, and hence, does not typically exceed 3 thousand specimens and is not pathogenic in its proper hosts. However in bison, which act as the new hosts for this parasite, the maximal intensity of infection found so far being 77,600 specimens in the abomasum of one bison [24,25]. Such a high intensity can cause inflammation of digestive tract and chronic diarrhea that can cause cachexy and even death especially in young animals [26]. DNA analysis of faecal samples confirmed *A. sidemi* infection in 4 out of 11 herds in

the Białowieża Forest and Mazury Lake District [27]. The source of the infection was found to be the pastures used for grazing, which were also shared with wild ruminants. To prevent the spread of ashworthiosis, constant monitoring for parasitic infection of domestic animals near the detected foci is necessary.

Another parasite that appeared in Poland as a result of the introduction of wild ruminants is the *Fascioloides magna* fluke, a parasite of the white-tailed deer *Odocoileus virginianus* and wapiti *Cervus elaphus canadensis.* It was first found in Poland in 1953 in the liver of a deer shot in the Lower Silesian Forest near Bolesławiec [28]. It had been previously detected more than 23 years earlier, less than 11 km away, in the forest complex being part of Germany at the time, when the same species of fluke was found in the liver of another shot deer [29]. *F. magna* had not been registered in Poland since that time, possibly due to its characteristic anatomopathological changes in the liver being mistakenly attributed to *Fasciola hepatica.* The original source of *F. magna* is believed to be the introduction of American wapiti deer to the forests around 1850 [30]. It is interesting to note that suitable conditions and intermediate hosts existed in the hunting grounds for the development and survival of *F. magna* for over 160 years until today.

As a result of examining 75 samples of deer feces from the Ruszów Forest District, fluke eggs were found in one sample that were significantly larger than *F. hepatica* eggs. The conducted molecular examinations confirmed that they belong to *F. magna* species: this being the third identification of *F. magna* on this territory [31]. The aforementioned flukes are pathogenic for their hosts and they cause extensive anatomopathological changes in the liver, which usually increases in size and displays visible dark brown or black blotchy pigmentation on its exterior and section. Multiple ventricles (pseudocysts) filled with bloody or dark brown fluid, in which the flukes are located, can be seen in the parenchyma of the liver. The liquid contains fluke eggs and cellular detritus. Cervidae parasitosis takes place subclinically in typical hosts but in random hosts, domestic ruminants, the infection can cause clinical symptoms such as appetite loss, depression and emaciation, and can lead to the deaths of those animals [32]. *F. magna* may also pose a risk for cattle, sheep and goats grazing in forest pastures in the region of the Lower Silesian Forest. Further research is needed on the prevalence and spread of this fluke in both deer and domestic animals on the territory of Poland.

The elk liver flukes *Parafasciolopsis fasciolaemorpha* should also be regarded as invasive species. The flukes infect other species of Cervidae and, thanks to migrating elk, they have spread throughout the entire country. They also infect the domestic ruminants causing severe parasitosis, as confirmed by experimental studies performed on sheep [33,34].

Elaphostrongylus cervi is an invasive nematode occurring throughout Poland and localized in the intermuscular connective tissue and the central nervous system of deer. Wherever deer are stationary or migrating, they represent a source of infection with *E. cervi* [35,36] and the domestic ruminants grazing on pastures near the forests are exposed to elaphostrongylosis. Nematode infections of goats and sheep infected under laboratory conditions resulted in the death of the host [37].

From this incomplete review of the research on bison and deer helminthofauna in Poland, it can be seen that the exchange of parasites caused by the spontaneous migration or the deliberate introduction of other animal species exerts a considerable impact. Parasites brought to the area can cause parasitosis in the local populations of accidental hosts. In the new host-parasite systems, parasites often exhibit significant pathogenicity and cause a severe clinical course of infection, leading to the death of the host.

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