Nematode *Ashworthius sidemi* Schulz, 1933 (Trichostrongylidae: Haemonchinae) in mountain ecosystems – potential risk for the Tatra chamois *Rupipacra rupicapra tatrica* (Blahout, 1971/1972)

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Abstract

Background

Native to Asia highly pathogenic nematode *Ashworthius sidemi* is now in Europe, and several dozen years after its introduction is a widespread parasite of all wild cervids. For bovids, the nematode is a significant threat to the European bison (*Bison bonasus*) population and has also been found in mouflon (*Ovis aries musimon*). This study aimed to assess the risk of infection for the endemic subspecies of northern (Alpine) chamois (*Rupicapra rupicapra*) – Tatra chamois (*R. r. tatrica*), having a critically endangered status.

Methods

The study was conducted in mountainous areas of Slovakia and Poland occupied by Tatra chamois (*R. r. tatrica*), Alpine chamois (*R. r. rupicapra*), red deer (*Cervus elaphus*) and roe deer (*Capreolus capreolus*). Animals (n = 93) shot during licensed hunting and killed in road accidents (roe deer, red deer), or died a natural death (chamois) were post-mortem examined on the presence of Haemonchinae.

Results

A. sidemi affected all of the roe deer, and 90.0% of red deer examined. As regards chamois, it was found in one *R. rupicapra* originating from the Low Tatras, but not in any pure *R. r. tatrica* individual living in High and Western Tatras. The present work is the first confirmation of northern chamois infection with this alien, blood-sucking nematode.

Conclusions

Due to an important health hazard related to *A. sidemi* infection for the Tatra chamois (*R. r. tatrica*), appropriate measures should be taken to reduce the possibility of parasite transmission between various cervid species living in the Tatra area, as well as the affected population of chamois, and the pure Tatra chamois population existing in the higher parts of the mountains, constituting their natural habitat.

Background

Ashworthius sidemi Schulz, 1933 is an alien and ecologically invasive parasite species of ruminants, which has been spreading in Europe since the second half of the twentieth century. Its occurrence has gradually increased over recent years, especially in cervids, but also among free roaming wild bovids. While for Cervidae it is a typical parasite and occurs in infections usually not exceeding several hundred specimens, for non-specific and new Bovidae hosts, its intensity of infection may reach tens of thousands of specimens, and cause pathogenesis even leading to mortality [1, 2]. Moreover, in cervids, a

typical infection site for *A. sidemi* is the abomasum, in other highly affected ruminant hosts, the nematode also parasitises the small and large intestines [3]. The pathological ashworthiosis-related changes include oedema, hyperaemia and effusion in the gastrointestinal mucosa, leading to chronic diarrhoea, deterioration and cachexia, or the animal's death [2].

The first description of this trichostrongylid worm was by Schulz [4] in sika deer (*Cervus nippon* Temmink, 1838) living in farm conditions in the Russian Far East. *A. sidemi* was also discovered in introduced sika deer in the former Czechoslovakia [5] and registered in maral (*Cervus elaphus sibiricus* Severtzov, 1873) introduced from Asia into the European part of Russia [6]. Therefore, its presence among wild ruminants in several European countries can be explained by parasite translocation with sika deer from Asia [7]. In France, *A. sidemi* was found in sika deer, fallow deer (*Dama dama* Linnaeus, 1758), roe deer (*Capreolus capreolus* Linnaeus, 1758) and red deer (*Cervus elaphus* Linnaeus, 1758) [8]. In Sweden, it was registered in fallow deer of Hungarian origin [9]. In the European part of Russia, apart from sika deer and maral, the worm species was registered in native elks (*Alces alces* Linnaeus, 1758) and roe deer [6, 10]. In Belarus, it was found in European bison (*Bison bonasus* Linnaeus, 1758) [11] and in the Ukraine, it was detected in roe deer [12]. In Czechoslovakia, apart from sika deer, red deer and mouflon (*Ovis aries musimon* (Pallas, 1811)) have also harboured this parasite [13].

In Poland, the introduction of *A. sidemi* has been documented from 1997 [14]. The parasite was observed for the first time in the country in a few European bison in the Bieszczady Mountains (Eastern Carpathians, south-east of Poland). Following confirmation of ashworthiosis in red deer and roe deer living in this region, Dróżdż et al. [15] concluded that the origin of *A. sidemi* was local red deer, which brought the parasite from the neighbouring Ukraine and Slovakia along the Carpathian ecological corridor. Next, in 2001, the nematode was observed in lowland European bison in Białowieża National Park [16]. Another documented focus of ashworthiosis was Dulowa Primeval Forest, south of Poland, where fallow deer introduced from Hungary turned out to be infected [17]. Recently, further and rapid expansion of the nematode has been observed among all Cervidae species living in the country, including elk [18], and the parasite has also been identified for the first time in domestic cattle (*Bos taurus* Linnaeus, 1758), by means of a polymerase chain reaction [19].

The Tatra chamois (*Rupicapra rupicapra tatrica* (Blahout, 1971/1972)) is a representative of the Bovidae family and is the northernmost subspecies of the northern (Alpine) chamois (*Rupicapra rupicapra* (Linnaeus, 1758)), which is native to the mountainous parts of central and southern Europe and Asia Minor. In the Alps, where the bulk of the northern chamois population is found, the species is relatively secure and consequently, it is assessed as least concern (LC) in the International Union for Conservation of Nature's Red List of Threatened Species [20]. However, several chamois subspecies, including the Tatra chamois which are listed as critically endangered (CR), qualify as globally threatened and require urgent conservation action.

The Tatra chamois occur in the Tatra mountains of Poland and Slovakia, and live in areas protected by the national parks of both countries, i.e. in the High, Belianske and Western Tatras. The population has

been declining steadily in number since the 1960s and had dropped below 200 individuals by 2002 [20]. Since then, by strict regulation of tourism and suppression of poaching, the population started to recover, reaching the highest ever population of 1,431 individuals recorded in 2018 [21].

In Slovakia, Tatra chamois have also been artificially introduced (30 individuals) to the Low Tatras, to create a reserve population there [22]. However, in Slovakia, the Alpine chamois were introduced for hunting purposes before the Tatra chamois were officially classified as a separate subspecies, and the Low Tatra population of *R. r. tatrica* crossbred with Alpine chamois migrating from the Fatra mountains and the Slovak Paradise National Park. Therefore, as a no longer pure population, it cannot act as a reserve population for the Tatra chamois. On the contrary, according to Shackleton et al. [22], the *R. r. rupicapra* introduced into Slovakia should be removed as they pose a threat to the wild population of *R. r. tatrica* living in the High Tatras, from which they are separated only by a single valley – a distance of about 30 km.

The present study aimed to determine the threat to both populations of chamois living in the Tatras from an alien *Ashworthius sidemi* nematode. Due to the greater opportunity of contact with cervids of the crossbred population living in the Low Tatras, particular attention was paid to the emergence of infection with this parasite there. If confirmed, then a much higher risk of *A. sidemi* appearance in the second, pure *R. r. tatrica* population living in the High, Belianske and Western Tatras, could be indicated.

Methods

Study area and material collection

This study was carried out in the mountainous territory of Tatra National Park (High and Western Tatras; altitude from 800 to 2655 m a.s.l.), Piwniczna Forest District (Beskid Sądecki Mountains, West Carpathians; up to 1114 m a.s.l.), as well as other hunting areas managed by Slovak State Forests, i.e. Liptovky Hradok and Presov (Low Tatras; up to 2043 m a.s.l.). The areas are occupied by Tatra chamois (*R. r. tatrica*; High and Western Tatras), Alpine chamois (*R. r. rupicapra*; Low Tatras), and stable populations of red deer (*C. elaphus*) and roe deer (*C. capreolus*). Animals shot during licensed hunting or killed in road accidents (roe deer, red deer), and that died a natural death (chamois), constituted the research material.

Laboratory analysis and identification of worms

Parasitological examinations of abomasa collected from a total of 93 wild ruminants (Fig. 1, Table 1) were conducted according to a modified Hansen and Perry method [23]. The whole contents and washings of the mucosa were rinsed over a sieve with a 250 μ mesh, and then transferred in small portions into Petri dishes to be examined under a binocular microscope. All nematodes isolated were preserved in hot 75% alcohol. The Haemonchinae were identified to the species on the basis of the morphometric features of the bursa copulatrix, spiculae in males and cuticular lobe around the vulva of females [4, 24].

Results

A total of 12 067 Haemonchinae specimens, i.e. 12 046 of *A. sidemi*, and 21 of *H. contortus* species, were collected from the abomasa of infected ruminants. Only one chamois, which was the sole one originating from the Low Tatras, was infected with *A. sidemi* (Fig. 1). In the abomasum of that animal, 25 nematode specimens were found (Table 1). No chamois from the High and Western Tatras were affected. Instead, *A. sidemi* was common in cervids from both mountainous ranges. All 42 roe deer examined harboured this parasite species, and of 20 red deer, 18 (90.0%) were infected, with a mean intensity of 196 (1–2276) and 210 (2–1756) parasites, respectively. The other Haemonchinae, *H. contortus*, was not found either in chamois or in red deer, but in roe deer occurred with a prevalence of 7.1%, and in two of the three infected animals co-occurred with *A. sidemi*. The intensity of *H. contortus* infection did not exceed several specimens..

Table 1
Haemonchinae infection in wild ruminants (n = 93) examined post-mortem

Host species	*Ashworthius sidemi*			*Haemonchus contortus*		
	P [%]	I	R	P [%]	I	R
Rupicapra rupicapra (n = 31)	3.2 [1]	25	25	0.0	–	–
Capreolus capreolus (n = 42)	100.0	196	1–2276	7.1	7	4–9
Cervus elaphus (n = 20)	90.0	210	2–1756	0.0	–	–

P – prevalence given as percentage of infected / examined animals, I – mean intensity, and R – range [1] *A. sidemi* derived from one Alpine / crossbred chamois *Rupicapra rupicapra*; the pure Tatra chamois *R. r. tatrica* were not infected

Discussion

This is the first confirmation of *A. sidemi* infection in chamois *R. rupicapra*. Although in the methodological work of Lehrter et al. [25] one can find a statement on the infection of northern chamois with *A. sidemi* – which was later quoted, e.g. by Kuznetsov et al. [10] – the results of that work [25] indicate another Haemonchinae species, *H. contortus*, isolated from the chamois host examined.

The generalist nematode, *H. contortus*, is transmitted in the Alps between populations of domestic and wild ruminants, and is commonly found in northern chamois [26, 27]. However, the nematode was never found in chamois living in the Tatras, and the current study also failed to confirm the presence of *H. contortus* in Tatra chamois. Instead, the presence of *A. sidemi* was revealed.

In the present research, we found cervids to be highly infected with ashworthiosis – both roe deer and red deer, while only in roe deer were *H. contortus* specimens observed. *A. sidemi* expansion may limit *H. contortus* infection [16]. Double infections of *Ashworthius* and *Haemonchus* were not found in roe deer

studied by Ferté et al. [8], and in red deer, only *A. sidemi* occurred – similar to our findings. In a study carried out by Demiaszkiewicz et al. [28] in red deer from the Lower Silesian Wilderness, south-western Poland, *A. sidemi* were exclusively found, albeit some European authors [13, 29] declare the presence of *H. contortus* in this host species. On the other hand, in roe deer, *H. contortus* was observed as a coparasite of *A. sidemi* in Ukraine [12] and in France [25] – although here, only a few individuals were found, which was also the case in our present investigation.

A. sidemi, as an alien and ecologically invasive parasite species of wild ruminants, is spreading extremely quickly across Poland [30]. The present work confirms its spread in high mountain regions also. An important issue associated with the lower risk of *R. r. tatrica* acquiring *A. sidemi* infection may only be the fact that, while for Alpine chamois it is normal to descend below the forest border of the mountains in winter, and the animals occur from 500 m to 3100 m a.s.l. in the Alps [20], the Tatra chamois do so sporadically with hiking ranges from 1200 m upwards – to 2630 m a.s.l. [31].

However, roe deer in the Tatras reach a height of about 1660 m a.s.l. and red deer are found up to a height of 1800–2000 m a.s.l. [31]. Further, on the Slovak side of the Tatras, feeding racks for animals are exposed at an altitude of 900 m a.s.l. In severe winter, when chamois can descend into exposed racks, and during the red deer rut – when the cervids climb to high altitudes – the risk of infection is highest. Special attention should also be paid to minimising likely contact between the pure Tatra chamois population and the other from the Low Tatras, which have already been affected by this highly pathogenic parasite.

Conclusions

It seems that, hopefully, no pure *R. r. tatrica*, as a critically endangered subspecies of *R. rupicapra* but only the chamois crossbred population from Low Tatras has been affected by ashworthiosis. Nevertheless, the risk of *A. sidemi* appearing in the wild Tatra chamois is presently very high and requires constant monitoring. It is particularly important to take appropriate countermeasures to reduce the possibility of parasite transmission between cervids and chamois living in the High, Belianske and Western Tatras.

Declarations

Ethics approval and consent to participate:

The study was performed in accordance with the law regulations in Poland and Slovakia.

Consent for publication:

Not applicable.

Availability of data and materials:

The datasets analysed during the current study are available from the corresponding author on reasonable request.

Competing interests:

The authors declare that they have no competing interests.

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Authors' contribution:

PN and JK designed the study. JK and GC coordinated and performed the sampling. JK, AW-P and PN carried out laboratory works and analysed the data. PN was a major contributor in writing the manuscript. All authors read and approved the final manuscript.

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Figures

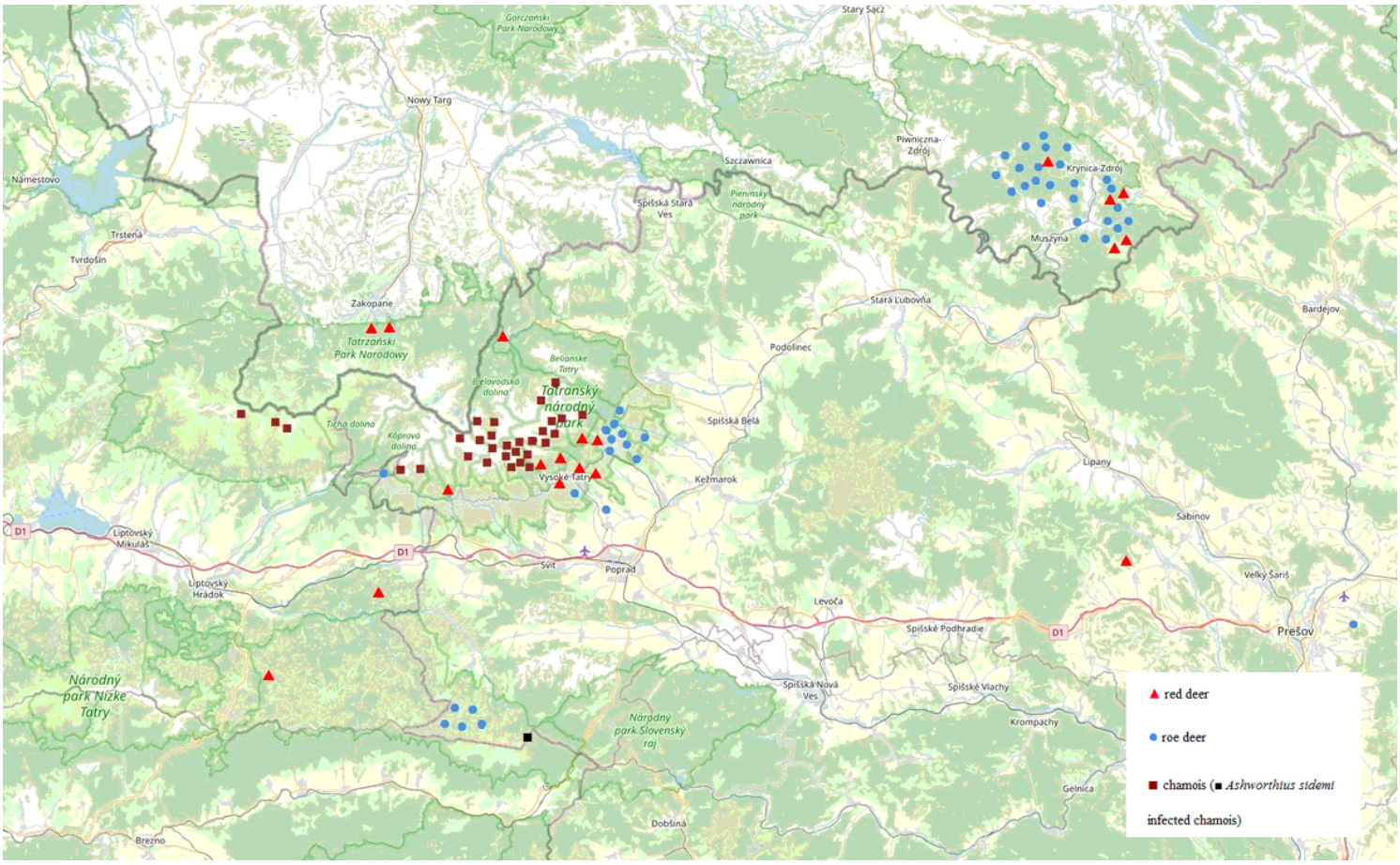

Figure 1

Map showing the geographical origin of the animals included in the study. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

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