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Parasites in Bears (Ursidae): Sampling Gaps in the Spectacle Bear (*Tremarctos ornatus*)

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Abstract

Parasites are part of the natural processes that help regulate populations and maintain ecosystems balanced. There is a growing recognition of parasites as important factors in the conservation of species, mainly those vulnerable to extinction in a changing environment. Bears are good biological models for monitoring infectious agents in wildlife, given their life cycle, broad home range, and severity of interactions with humans and their domestic animals as a result of their behavioral plasticity, intelligence, and omnivorous food habits. In the Andean region, the only bear species listed as vulnerable is the *Tremarctos ornatus*. To determine the sampling gap and prioritize the approach for understanding parasite diversity in bears, I performed a systematic review and metanalysis of the documented parasites of bears across the world and discussed the possibility of the parasites recorded in these other species being present in the *T. ornatus* in the Andean region, specifically Colombia. In 283 relevant references, 647 records were found of 189 parasites in 37 countries. Of the bears with parasites recorded, *Ursus americanus* had the most numerous and complete records. The tropical species *H. malayanus*, *M. ursinus*, and *T. ornatus* showed the smallest parasite diversity and unseen species estimate, despite being the region where the greatest diversity of parasites was expected. Of interest are around 80 parasites that have been recorded in seven non-Colombian bear species but are documented in other species in this country.

Keywords: Epidemiological risk; infectious agents; *Tremarctos ornatus*; Ursids.

* Artículo de investigación

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Parásitos en osos (*Ursidae*): vacíos de muestreo en oso de anteojos (*Tremarctos ornatus*)

Resumen

Los parásitos son parte de los procesos naturales que ayudan a regular las poblaciones y mantener el equilibrio del ecosistema. Existe un reconocimiento creciente de los parásitos como factores importantes para la conservación de las especies, principalmente aquellas vulnerables a la extinción en un entorno cambiante. Los osos son buenos modelos biológicos para monitorear agentes infecciosos en vida silvestre, dado su ciclo de vida, su amplio rango de hogar y la gravedad de las interacciones con los humanos y sus

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animales domésticos como resultado de su plasticidad conductual, inteligencia y hábitos alimentarios omnívoros. En la región andina, la única especie de oso, *Tremarctos ornatus,* está categorizada como vulnerable. Con el fin de determinar los vacíos de muestreo y priorizar el enfoque para comprender su diversidad de parásitos, se realizó una revisión de los parásitos documentados en los osos en todo el mundo y se analizó la probabilidad de que los parásitos registrados en estas otras especies estén presentes en *T. ornatus* en la región andina, específicamente en Colombia. En 283 referencias relevantes, se encontraron 647 registros de 189 parásitos en 37 países. De las especies de osos con parásitos registrados, *Ursus americanus* tuvo los registros más numerosos y completos. Las especies tropicales *H. malayanus*, *M. ursinus* y *T. ornatus* mostraron la menor diversidad de parásitos y la estimación de especies no vistas. Son de interés alrededor de 80 parásitos que se han registrado en las siete especies de osos no colombianos, pero que están documentados en otras especies en el país.

Palabras clave: Agentes infecciosos; riesgo epidemiológico; *Tremarctos ornatus*; úrsidos.

Introduction

Parasites are part of the natural processes that help regulate populations and maintain ecosystems balanced. They can affect population parameters such as birth and death rates, and some mathematical models suggest that they could play a determinant role in their hosts' population and evolutionary dynamics. There is a growing recognition that parasites are essential in the biology and conservation of species, as they often lead to deleterious health effects, fitness reduction, and mortality (1-3). These could cause local extinction in wildlife populations (4, 5), so any factor that can modify the ecosystem that is the natural reservoir of such infectious agents has the potential to disturb their epidemiology (6). As such, high rates of abnormal mortalities in wildlife must be further investigated epidemiologically to prevent further infections (7). These ecological processes are altered by natural and anthropogenic changes, and parasites could become a threat to species conservation together with habitat reduction, poaching, and pollution. In response to environmental changes, parasites could change their effect on wildlife and domestic and human health by increasing contact between hosts and infectious agents.

While infectious diseases are not considered a determinant global threat to wildlife viability (4), they are a common driver of population depletion (temporal or permanent) at the local scale, particularly of threatened, isolated, or small populations (8, 9). The mega-biodiversity of some countries such as Colombia introduces an additional epidemiological risk factor because there are many more wild and domestic species that could serve as susceptible hosts and reservoirs for several infectious agents when the ecosystem dynamic is altered (10, 11). A challenge to conservation medicine is to plan effective actions that mitigate the effects of emerging diseases that are currently driving biodiversity loss.

Bears could potentially perpetuate disease transmissions to human and livestock, given that they often explore anthropogenic habitats in agroecosystems due to their behavioral plasticity, intelligence, and omnivorous food habits (12-14). Additionally, the current trend of increased interactions might make bears essential vectors or intermediate hosts for several zoonotic pathogens (15-17), as they could predate or scavenge an infected host (18-20). The overlapping habitat use between bears and livestock sets up a potential risk for infectious disease transmission (21-23). Bears may be exposed to humans, livestock, and other wildlife pathogens through vectors, predation, scavenging, or environmental reservoirs (e.g., water) (24, 25). The impact of infectious diseases in bear conservation may act synergistically with other threats such as isolation and low population size, reducing populations even further and increasing their vulnerability to habitat reduction and degradation, dietary stress, hunting, and pathogens (26, 27).

In high mountain Andean ecosystems, the spectacled bear (*T. ornatus*) is a good proxy for monitoring infectious agents in wildlife, given the species' life cycle, broad home range, and severity of interactions with humans and domesticated animals (28, 29). The *T. ornatus* is the only species of the Ursidae family in South America, and it is categorized as species vulnerable to extinction (VU) (30). Retaliatory killing by high mountain cattle ranchers and habitat degradation and reduction have been recognized as their main threats (31-34). Recently, it was found that the presence of unaccompanied cattle (i.e., feral) reduces the probability of bear occupation (35). The interaction between wildlife and domesticated animals plays an important role in the transmission of different infectious agents. In rural high mountain areas, domestic and feral animals excrete in areas where wildlife forage and prey, potentially leading to the transmission of different infectious agents (36).

To prioritize the monitoring effort, diagnosis methods and tools are key for knowing which parasites might be present in natural populations of the *T. ornatus*. This review discusses which agents have been found in seven other species of bears, that have been recorded from other species in the Andean region, specifically

Colombia, to infer which could be present in *T. ornatus*.

Materials and Methods

Document review. The data was obtained from different sources available on the eight species of bears from across the globe. We searched for all relevant published studies. Searches were performed until August 2023 using Google Scholar (https://scholar.google.com), Scopus (https://www.scopus.com), and Pubmed (https://www.ncbi.nlm.nih.gov/pubmed/). We restricted our search to documents in Spanish and English but included some references in Chinese with abstracts in English. Search terms included: "Ursidae – nematodes," "Ursidae – Protista," "Ursidae-Protist," "Ursidae – virus," and "Ursidae–bacteria". I did not consider "gut microbiota," "intestinal flora," "microbial population of the gastrointestinal tract," or "gastrointestinal microbiota". Duplicate articles were excluded. Reviews and research articles, theses, and meeting abstracts were included.

Parasite diversity. I estimated the specific richness index, "S", of the ursid parasites determined to species level, as well as unique records of families and genera. Additionally, I estimated the expected parasite richness for each bear species using Chao, Jack1, Jack2, and Bootraps indices, considering the year as a sampling unit. As parasite species are expected to remain unseen or undetected in a collection of sample units, we used several popular ways of estimating the number of unseen species and adding them to the observed species richness (37, 38). The incidence-based estimates use the species frequencies across a collection of years. I ran all analyses in the R package Vegan version 2.6-4 (39).

Agents found in other bear species that could be present in the Spectacled Bear. To understand more about the parasites found in the other seven bear species exclusive of *T. ornatus*, I reviewed in the same database the documented records of each parasite to the specific and generic level in the Andean Region in human, domestic or wildlife species. Search terms included "Species name or genera" and "Colombia". If a record was not found, we changed "Colombia" to "Neotropical," "Andes," or "South America". We consider at least one reference enough to count the presence of a parasite.

Results

I found 283 relevant references to parasites in bears; 37 references were not found in the original versions. The references were published between 1808 and 2023. Of around 647 records, 189 agents were determined to a specific level, 27 agents to genera, and 21 only to family level (Supplemental information 1). The recorded parasites are distributed across 121 genera, 95 families, and seven kingdoms (Supplemental information 1, Table 1). The documented records come from 37 different countries (Figure 1, Table 2).

The Ursid species with the most records of parasites was *U. americanus*, but the diversity could be between 132 and 203 species. So, in species with a more sampling effort, this could be between 52 and 81% of completeness. The tropical species *H. malayanus, M. ursinus*, and T. *ornatus* showed the smallest parasite diversity and unseen species estimates. This is probably due to their poor sampling coverage (Table 3). It is expected that there is a greater diversity of parasites in tropical regions (40).

Table 1. Parasites Kingdoms Distribution in Bears

Kindom	Frequency
Animalia	417
Virus	77
Protista	74
Bacteria	67
Fungi	7
Chormista	1
SAR	1
blank	3

Figure 1. Density Map of Parasite Records by Bear Species and Country

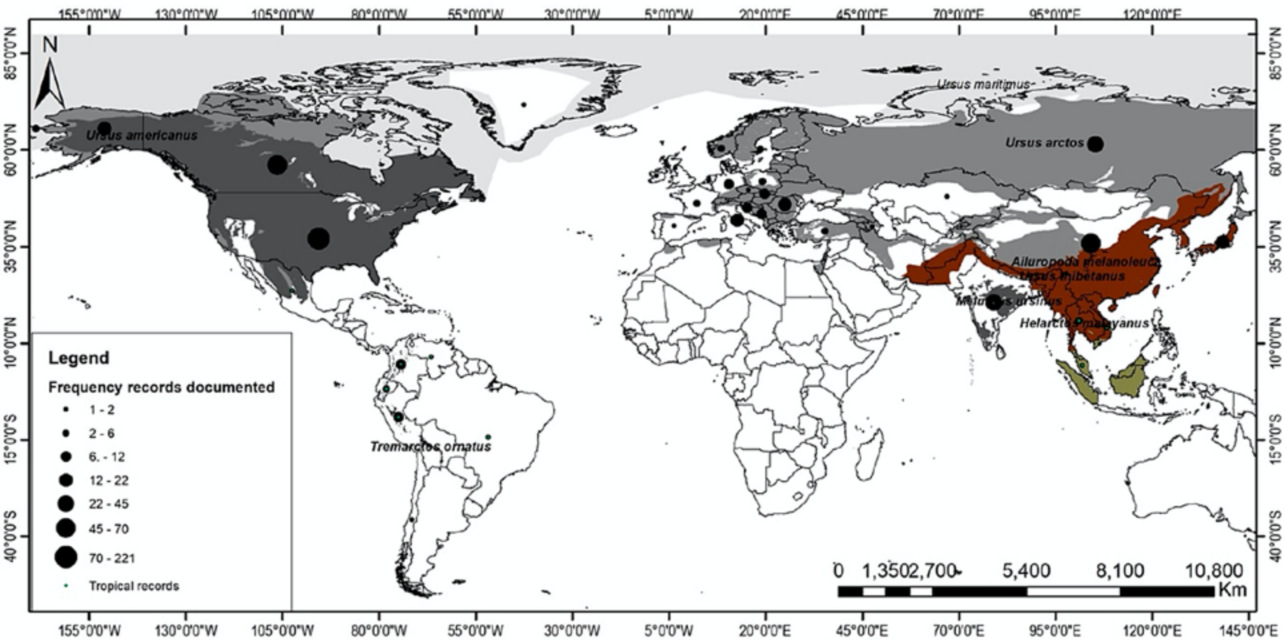

Table 2. Country Records Distribution of Parasites in Bears

Country	Frequency
USA	239
Canada	70
China	69
Russia	45
India	32
Colombia	29
Japan	22
Romania	19
Italy	14
Germany	12
Slovakia	11
Peru	10
Croatia	7
Yugoslavia	7
Thailand	6
Norway	6
Ecuador	4
Turkey	4
USA–Russia*	4
France	4
Poland	3
Sweden	3
Venezuela	2
Spain	2
UK	2
Chile	2
Brazil	2
Greenland	2
Vietnam	2
Mexico	2
Netherlands	2
Malaysia	2
Czech Republic	1
Azerbaijan	1
Kazanjian	1
Ireland	1
(blank)	1
Greece	1
Denmark	1

*Bering Strait

Table 3. Diversity analysis of parasites reported in ursid species

Species	S	chao	chao.se	jack1	jack.se	jack2	boot	boot.se	n
A. melanoleuca	45	192	90	79	9	107	58	4	26
H. malayanus	11	59	30	21	4	29	15	2	8
M. ursinus	20	63	33	35	7	47	26	3	10
T. ornatus	25	60	25	40	9	51	32	5	7
U. americanus	107	187	28	166	15	203	132	9	46
U. arctos	92	345	101	162	17	221	120	8	39
U. maritimus	31	102	52	51	6	68	39	3	35
U. tibetanus	21	89	59	37	5	50	27	2	16

*Species richness

The parasites with the greatest number of records in bears were Baylisascaris transfuga, Toxoplasma gondii, Trichinella sp., Trichinella spiralis, Canine morbillivirus, Dirofilaria ursi, and Canine mastadenovirus A, with 10 to 32 records. A single record metions 134 agents (Supplemental information 2). At least 80 parasite species reported in the other seven bear species have been registered in other non-ursid Colombian species, with two others being reported from the Neotropical region and South America. Four agents not reported in T. ornatus have worldwide distributions (Supplemental information 3).

Discussion

Despite being a species located in a region of overall parasite richness, including several taxa reported in other bear species, tropical bears have less documented records of agents. This is evidently due to a lack of sufficient sampling. In particular, for *T. ornatus* of the 44 records (25 potential different taxa), only four determine the taxon at the species level, 31 reach the genus and the remaining nine just at the Family, Kingdom or Domain level (41-44). This is a product of the fact that most of the research has been done with approaches based on microscopy, which in some cases only allows the identification of "forms compatible" with some agents (44-47) or with molecular approaches that do not reach sufficient taxonomic resolution for the different groups (48). Of the 44 records in *T. ornatus*, 26 belong to the kingdom Animalia: 18 are nematodes, two trematodes, one cestode, and two arthropods. 15 records are Protists distributed in 10 genera. Two of the records that were able to be determined at the species level use specific molecular and immunological diagnostic approaches (41, 42).

Of the 85 infectious agents registered in the other bear species that have been found in Colombia in other hosts, 35 belong to the Animalia kingdom, 21 are bacteria, 14 are viruses, 11 are protists and 4 are fungi. In the case of animal agents, at least 32 are endoparasites, as are protists, bacteria, fungi, and viruses. In this sense, the use of fecal samples, which in addition to being non-invasive and relatively cheap and easy to collect, once the accessibility to the sampling sites has been overcome, would allow having samples for the greatest number of agents of interest, including some hemotropics, which reach the digestive tract through different routes. However, the diagnosis of these samples demands adequate means of collection and transport to guarantee the quality of the samples (49, 50), in addition to standardized extraction processes. Likewise, it is necessary to use Metabarcoding with a combination of markers, among which 16S, 18S and ITS are suggested (51-53), and with bioinformatic approaches that contrast the sequences with different specific databases (e.g., PlusPFP: Standard plus Refeq protozoa, fungi & plant, using kraken2 [54]). Thus, it would be possible to increase, cost-effectively, the sampling in this and other types of hosts and evaluate, within the framework of One Health, the similarity between different components of the assemblies. So far, the few comparison exercises evaluate maximum similarities at the genus level and thus it is only possible to speculate about the possible transmission of agents between different hosts (44) but not to prove the hypothesis about the exchange of specific agents and to differentiate its epidemiology and the potential immunological responses stimulated in the different hosts.

All four groups of agents identified in other bear species also found in or near Colombia are potentially zoonotic. After the northern temperate zones, the tropics present some risk of zoonoses and carnivores (Order Carnivora), rodents and ungulates are particularly linked to the situation (55). In this sense, increasing sampling efforts to complete the characterization of the diversity of infectious agents, with high taxonomic resolution, is key, not only to determine the richness of this component of biodiversity but also to improve risk analysis generated by infectious diseases for wildlife, domestic animals and the human population (56).

In the Andean region, management efforts to conserve the Spectacle Bear could be faced with unknown associated epidemiological risks, potentially even affecting human welfare. The presence and load of infectious agents in wildlife and their interaction with humans, with high-level taxonomic resolution, must be a research priority for conservation and public health stakeholders.

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