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REVIEW

Innocent Until Proven Guilty: Systematic Review of the Effect of Livestock on South American Wild Canid Parasites

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Abstract

Purpose Livestock is regarded as a source of parasites to wildlife populations, but no assessment of the nature and magnitude of parasite transmission from livestock to South American canids is available.

Methods Here we systematically reviewed articles that evaluate protozoa, helminths and arthropods in wild canids living in areas with and without the presence of livestock.

Results There is an unbalanced study effort which precludes proper testing of the assumption that livestock increase the incidence and prevalence of parasites in wild canids. Most of the parasites reported are shared with domestic carnivores.

Conclusion Available information strongly suggests that the role played by livestock and their associated dogs on wild canid parasitism should be re-evaluated.

Keywords Disease reservoirs · Transmission · Foxes · Wild animals · Carnivores

Introduction

Livestock is regarded as a source of parasites to wildlife populations; transmission poses a growing threat at the wildlife–livestock interface increases [1, 2]. Seven out of the eleven South American canid species are threatened by diseases, which are the most frequent menace besides retaliatory hunting and habitat change [3–9]. Paradoxically, several carnivore species will have to rely on livestock ranges to survive as the land provided by protected areas will not suffice to hold viable populations of wide-ranging species, such as canids [10, 11]. Although diseases from domestic animals, including livestock seems to be a common threat, there is no assessment of the nature and magnitude of parasite transmission from livestock to South American canids. Here, we systematically review the parasitism in wild canids living in livestock ranges in South America attempting to test the hypothesis that livestock increase the incidence and prevalence of parasites in wild canids following the PRISMA protocols [12], in order to inform management plans for the conservation of these wild carnivores.

Materials and Methods

We focused on protozoa, helminths and arthropods hereafter "parasites", based on their predominance in cross-species transmission at the domestic/wildlife fauna interface [13], where livestock acts as an intermediate or definitive hostin the shared cycle of arthropods and helminths [14] or can be a reservoir for arthropod-borne protozoa that affect wild canids (e.g. [15–18]). We performed a systematic review of publications in any language dealing with these parasites in the eleven South American wild canids species in the ISI Web of Science and SciELO electronic databases, using as keywords and Boolean codes "*Atelocynus OR Cerdocyon OR Chrysocyon OR Lycalopex OR Speothos OR Urocyon OR Pseudalopex AND parasite**". Retrieval was performed in April 2021 without date limit. The snowball effect in the

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reference lists was used to increase the scope of the search. In the analysis, we only included publications that reported research performed in wild canids located in South American countries, and that performed diagnosis or worked with samples from confirmed diagnosis of parasites. After an initial review by the first author, the excluded articles were assessed by the second author. Data management, to avoid the double count of duplicates or multiple reports, was performed by author, title and year using the ISI Web of Science option of export to Excel.

A summary of the identity of the parasites and hosts was extracted with the lowest level of taxonomic resolution reported. Nomenclature follows the Taxonomy browser of the National Center for Biotechnology Information Search Database for parasites (https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi). We use the term parasite taxon to refer to each different parasite reported to account for the variety of taxonomic levels reported. As an additional analysis, the similarity between the list of parasites reported and the lists of parasites hosted by domestic animals [19] was estimated with the Jaccard index to assess if livestock or dogs, which usually accompany livestock operations, are the reservoir of parasites found in South American wild canids.

Publications were primary classified as: (1) "with livestock", if they explicitly indicated the presence of livestock, domestic animals other than pets, or the study was performed in a ranch; or (2) "without livestock" if they explicitly indicated their absence in the study area. Other articles were classified as (3) "zoo animals" when zoo animals were sampled and iv. "non-identifiable", those who neither indicate nor allow determining the environments in which the studied canid species lived. We based our analyses on information provided by papers of the first two categories. From these articles, for each canid species we extracted data regarding presence/absence of livestock in the study area, number of samples evaluated, taxa of parasites reported, and incidence and prevalence of the parasites, being the data extraction performed by one author with verification by another as the PRISMA protocol suggest [12].

Results

A total of 109 articles were retrieved, 3 (2.8%) of which were reviews and only 106 (97.2%) were articles that properly diagnosed parasites. Another 60 articles, 49 articles and 11 reviews, were obtained through the snowball effect. Of the 155 articles thus collated, only one (> 1%) explicitly compared between environments with and without livestock. In publications that do mention livestock, 42 (27%) articles published research performed in areas with livestock, while only three (2%) were performed in natural areas without livestock. Of the remaining articles, 87 articles (56%) did not refer to livestock and the remaining 22 articles (14%) provided information regarding animals in zoos.

The crab-eating fox *Cerdocyon thous* was the most studied species (referred to in 55% of publications), followed by the maned wolf *Chrysocyon brachyurus* (28%) and the Pampas fox *Lycalopex gymnocercus* (20%), while no research has been carried out (or published) from South American populations of gray fox *Urocyon cinereoargenteus* in any environment, and no data is available for the short-eared dog *Atelocynus microtis* and the Sechuran fox *Lycalopex sechurae* from areas either with or without livestock (Table 1). A

Table 1 Number of articles, samples and parasite taxa reported from South American canid host species in areas with and without presence of livestock

Canid species	With livestock		Without livestock		Total[a]		
	N samples	*N* parasite taxa	*N* samples	*N* parasite taxa	*N* articles	*N* samples	*N* parasite taxa
Atelocynus microtis	0	0	0	0	1	1	1
Cerdocyon thous	710	48	4	4	86	1746	103
Chrysocyon brachyurus	352	50	1	13	44	782	81
Lycalopex culpaeus	84	10	3	14	13	162	42
Lycalopex fulvipes	67	9	0	0	5	291	17
Lycalopex griseus	222	12	0	0	8	272	17
Lycalopex gymnocercus	510	33	5	0	31	622	53
Lycalopex sechurae	0	0	0	0	1	19	1
Lycalopex vetulus	141	9	0	0	22	281	23
Spheotos venaticos	1	1	0	0	17	148	20
Urocyon cinereoargenteus	0	0	0	0	0	0	0
All species	1918	102	13	31	155	4136	175

[a]Total refers to combined information from all studies (in areas with and without livestock, zoo animals and those from undetermined locations). See Supplementary information (SI) for the list of parasites by host species

total of 115 parasite taxa are reported in canids from areas with and without livestock (Supplementary information SI). Helminths are the most common parasite (68 taxa, 59% of reported taxa), followed by arthropods (25 taxa, 22% of reported) and protozoans (22 taxa, 19% of reported). More than three times more parasite taxa are reported from canids in areas with livestock than in areas without (Table 1). These differences can be attributable to a sampling bias. There were significantly more samples studied at sites with livestock (median 84, range 0–710 samples at sites with livestock vs. median 0, range 0–5 samples in areas without: Wilcoxon test, $Z=2.7$ $p=<0.001$). The number of parasite taxa reported per species was significantly correlated with both number of articles published ($r^2=0.89$; $p<0.001$) and the number samples evaluated ($r^2=0.85$; $p<0.001$) per species. Similarly, using all data, prevalence was negatively correlated with sample size ($r_s=-0.36$; $p<0.001$).

Of the 115 parasites reported in areas where mention livestock status, 95 are also present in domestic animals, five of which are exclusively shared with livestock, 48 are shared with domestic carnivores (dogs and cats) and 41 other taxa are shared among canids, livestock, and domestic carnivores (Fig. 1).

Similarity in species composition was higher among canids inhabiting livestock ranges with dogs (Jaccard $J=0.45$) than among wild canids from areas without livestock and dogs ($J=0.05$) and between wild canids from areas with and without livestock ($J=0.01$).

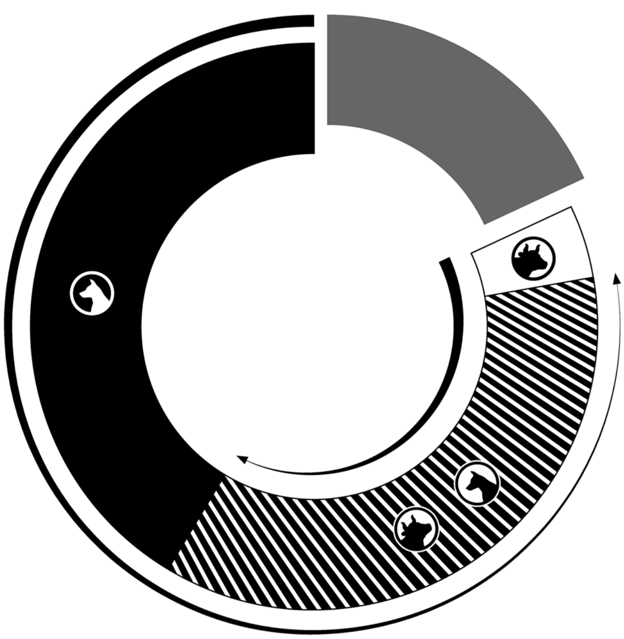

Fig. 1 Parasites diagnosed in wild canids separated by the host group with which they are shared. Grey represents parasites shared with wildlife, black represents parasites shared with dogs, white represents parasites shared with livestock, and striped represents parasites shared with dogs and livestock. Large arrow indicates the proportion that can come from dogs. Small arrow indicates the proportion that can come from livestock

Discussion

Richness of parasite species is higher in fissiped carnivores that are large bodied, have high population densities and are widely distributed [20]. How these patterns might be affected by parasite transmission from livestock is yet to be assessed among South American canids. Although they are a well-studied group, data regarding their parasitology have long been a pending issue [21], even now four taxa have no information from any area, while seven have not been studied in livestock ranges. The unbalanced study efforts toward animals living in livestock ranges does not allow proper testing of the assumption that livestock increase the incidence and prevalence of parasites in wild canids. Besides, in articles comparing parasites between natural and anthropic areas, the latter include plantations, roads, and highways as well as livestock grazing areas (e.g. [22]).

The greater richness of parasite taxa among canids living in ranges of livestock areas is, based on the current information, a sampling artifact which hampers independent evaluation of the roles of livestock and habitat changes in the parasitic status of wild canids, not allowing evaluation of what is causing the presence of more parasites and thus increasing the risk posed by the potential emergence of zoonotic diseases. For instance, differences in tick abundance between distinct biomes in Brazilian foxes (*C. thous*, *C. brachyurus*, *L. vetulus* or hoary fox and the bush dog *S. venaticus*) [23, 24] could modify the role of these canids and their arthropods in the vectorization of zoonotic diseases. To control these diseases, it would be enough to modify the factors that cause their abundance in these foxes and consequently in these biomes; however, no information is yet available to determine the effect of the human activities, including raising livestock, on the abundance of these ticks, which may modify the zoonotic risks.

The conservation of the species and its threatened status have not prompted investigation. Darwin's fox, *Lycalopex fulvipes*, the most endangered canid in South America, has only five articles, and others, such as *Urocyon cinereoargenteus* do not have information about their parasitic status in South America, although this is being studied in North and Central America (17 articles about parasitism since 1975), Although both canid species are regarded as threatened by parasitism from dogs (e.g. [8, 9]).

The higher number of parasite taxa in wild canids that are shared with dogs and fewer exclusively with livestock could be a result of phylogenetic closeness, since pathogens in the wildlife/domestic fauna interface may be more easily transmitted between closely related groups [25]. Therefore, the presence of domestic carnivores could represent a higher risk for the wild canids than livestock itself, but both could act synergically as working dogs are required to manage livestock. Among parasites present in wild South American canids, domestic dogs, and livestock, most of them are heteroxenic (78%), the others being non-specific external monoxenic parasites are that can be transmitted by contact (22%).

Although *Neospora caninum* was the most commonly reported parasite in South American wild canids ($n = 8$) and *Toxoplasma gondii* was the parasite with more prevalence reports ($n = 39$), focusing only on articles where livestock are reported in the study area, the parasites identity changes, but they are still heteroxenic species more related to dogs than livestock. In these articles, *Toxoplasma gondii* is the parasite present in more host species ($n = 5$) while *Amblyomma* sp. is more often reported is ($n = 19$). However, the number of parasite taxa reported correlates to the number samples evaluated; therefore, it is not possible to determine if a host with more parasites reported is due to the characteristics of the host or it is only asampling artifact.

What role, if any, working dogs are playing in the transmission of parasites in livestock ranges has yet to be evaluated, which is a critical issue in species such as the South American gray fox *L. griseus* or the culpeo *L. culpaeus*, which in addition to the stress they face when living in livestock areas [26] and suffering retaliatory hunting because they predate sheep would suffer the potential effects of increased parasitism, which might synergically impinge upon their survival. Paradoxically, the use of an additional type of working dog, the livestock guardian dogs, is advanced as an environmentally-friendly solution in order to avoid livestock predation, reduce retaliation and foster the coexistence between *Lycalopex* spp. (and other carnivores) and livestock [27] that could also have effects on parasitism [28]. However, these dogs could be a hitherto ignored menace if they transmit parasites in addition to those that could be transmitted by livestock. Potential spillover from dogs, be it livestock guardian or other working dogs associated with livestock raising, could impact wild canids negatively (cf. [29]). The paucity of available information calls for the application of the preventive principle in order to promote preventive health programs that target dog populations, which ought to reduce the risk of pathogens in wildlife populations, including canids (e.g. [30, 31]).

The scant information available strongly suggests the need to evaluate jointly what role livestock and the associated dogs play, if any, on wild canid parasitism, if we are to advance to a carnivore-friendly livestock industry. So far, livestock is innocent until proven guilty.

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Availability of Data and Material The manuscript contains supplementary information (SI).

Code Availability Not applicable.

Declarations

Conflict of interest The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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