https://doi.org/10.22319/rmcp.v10i4.4959

Article

Endoparasites in captive *Odocoileus virginianus* and *Mazama temama* in Veracruz, Mexico

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Abstract:

Parasitosis in commercially important captive wild species can cause losses due to decreased productivity, increased veterinary expenses, secondary infections and animal mortality. An analysis was done to quantify endoparasite prevalence and abundance in the cervids *Odocoileus virginianus* and *Mazama temama* in captivity. Fecal samples (n= 60) were collected during the rainy and dry seasons from six *O. virginianus* and four *M. temama* of different ages and sexes. Endoparasites were extracted using the flotation technique with a saturated sugar solution, and the parasites identified by anatomical comparison. Seven parasite genera were identified: *Ascaris* sp.; *Eimeria* sp.; *Estrongilido*

sp.; *Strongyloides* sp.; *Parascaris* sp.; *Paragonimus* sp.; and *Taenia* sp. In both cervid species *Ascaris* sp. and *Eimeria* sp. exhibited the highest abundance. Males and females of each cervid species exhibited different parasite prevalences. *Parascaris* sp. and *Paragonimus* sp. were found only in *O. virginianus*. No differences ($P>0.05$) were present in parasite abundance between the rainy and dry seasons. The genus *Ascaris* was generally more abundant than the other parasite genera ($P<0.05$). These results will be useful in the control and prevention of parasites in captive ungulates.

Key words: *Ascaris* sp., Cervids, Parasitosis, Flotation technique, Zoonosis.

Received: 28/06/2018

Accepted: 05/10/2018

Introduction

The ecology of diseases and parasitosis in wildlife has been studied for over a century, with special emphasis on species used for hunting and eating[1,2]. An animal health approach has been used to address this issue in recent decades because zoonotic diseases can occur that affect domestic animals and humans, leading to death in both wild and captive animal populations[3,4,5,6].

White-tailed deer (*Odocoileus virginianus*) is in high demand for hunting and other uses[7,8]. The diversity of parasites that cause infectious diseases in this cervid have been described[5]. These can affect behavior, reproduction and even morbidity and mortality[2,9,10]. The Central American red brocket (*Mazama temama*) is distributed from southeast Mexico to northern Columbia. Very little study has been done of its parasitosis[11], and only minimal data is available on the conditions needed to maintain it in captivity and conserve its populations.

Protozoa, helminths, arthropods and pentastomides are the most abundant parasites in domestic animals[12]. In cervids the most common diseases are caused by viruses, bacteria, infectious conditions and parasitosis[2]. Gastrointestinal parasitosis is a major pathology in deer and is mainly caused by helminths and protozoa[13]. Factors such as climate[14], the presence or absence of intermediate hosts, soil composition, vegetation type and water quality are principal factors influencing parasite prevalence[12]. Mortality in wild *O. virginianus* populations due to gastrointestinal parasites is approximately 2.7 %[15].

Wildlife Conservation Management Units (UMA) have been implemented in Mexico as a management strategy for wildlife conservation and exploitation. When intensive management of wild animals in UMAs involves inadequate animal health protocols, losses can be incurred due to decreased reproduction and productivity[16], and higher incidences of secondary infections, increased digestive tract lesions, anaphylactic reactions, anemia, and even death. Mismanagement can also increase the chance of these conditions becoming zoonotic diseases, and inadequate prevention and mitigation measures raise the risk of contagion between wildlife and livestock[3,17,18]. Cervid management programs need to consider the prevention and control of the most common infectious and parasitic diseases to ensure population viability and reproductive success[2].

Research and data on parasitosis in captive wildlife is scarce[15,19,20], and management plans for successful *in situ* and *ex situ* production of cervids in UMA have not met expectations[21]. Greater knowledge is needed on the parasites that affect the health of *ex situ* cervid populations. The present study objective was to quantify parasite prevalence, abundance, and endoparasite diversity in a captive population of *O. virginianus* and *M. temama*.

Material and methods

Study area

The study was done at El Pochote, an intensive mode UMA registered with the Ministry of Environment and Natural Resources (SEMARNAT; UMA-IN-CR-0122-VER/og). Located in the municipality of Ixtaczoquitlán, in the state of Veracruz, Mexico (18°52’13.70” N; 97°02’59.97” W) it is at 1,137 m asl. Regional climate is semi-warm humid (Cwa) with abundant summer rains, an annual temperature ranging from 18 to 24 °C and annual average rainfall from 1,900 to 2,600 mm. Vegetation around the El Pochote UMA is mainly evergreen tropical and second-growth forests[22]. The main objective of this UMA is conservation and reproduction of *O. virginianus* and *M. temama*.

Cervid specimens

The experimental animals were six *O. virginianus* (three females [2, 3 and 5 yr of age] and three males [3, 4 and 9 yr of age]) and four *M. temama* (two females [2 and 4 yr of age] and two males [both 3 yr of age]. All were apparently healthy and had good body condition. One year before sampling began all animals were administered the Hemoplex® supplement (2 ml per 10 kg weight) and the Catosal® metabolic stimulant, both by intramuscular injection. The two cervid species were kept in separate corrals (30 m long by 12.5 m wide) surrounded by deer fence and with 50 m distance between corrals. Each corral was equipped with two drinking bottles, was roofed, and an 80 % shade mesh placed at head height (1.2 to 60 cm above ground surface) to avoid eye contact between the species. Feces were cleaned daily. The animals were fed daily at 0800 h with alfalfa (20% ~ 2 kg per animal) and a balanced feed for sheep (80% ~ 4 kg per animal) containing crude protein (34%), fat (2%), crude fiber (5%), ash (17%) and moisture (13%). Water was freely available.

Feces samples

Parasite incidence and abundance can vary between seasons[23]. Fecal samples were therefore collected during two seasons: rainy (September-November) and dry (March-May). In each sampling period, feces were collected from all animals once a month. At the first spontaneous defecation, approximately between 0600 and 0900 h, the portion of excreta not in direct contact with the ground was collected manually using latex gloves, placed in a sealed, marked plastic bag, and stored at 4 °C in a cooler. For analysis the samples were transported to the Optical Microscopy Laboratory of the Faculty of Biological and Agricultural Sciences, Orizaba-Córdoba region, Universidad Veracruzana. A total of 60 stool samples were collected from each species, 30 during the rainy season (2016) and 30 during the dry season (2017).

Feces analysis

Parasites and their eggs were extracted using flotation in a saturated sugar solution, based on the separation of particles of greater and lesser density. Eggs and whole individual parasites were collected and fixed on slides for later morphological identification[24].

Endoparasite morphological identification and abundance

The extracted parasites were identified by comparison of anatomical characteristics with those reported in the Parasitological Catalogs[25], and books on parasitology and the parasite diseases of domestic animals[12]. Oocyst taxon genus was identified based on the number of sporozoites present[26]. Abundance was considered the number of endoparasites recorded in each cervid host, since this is an indirect measure of prevalence[20,27].

Statistical analysis

Cervid species (*O. virginianus* and *M. temama*), sex (males and females) and collection season (dry and rainy) were treated as sources of variation. The response variable was parasite abundance in each cervid host since this is considered an indicator of nematode parasite infection[27]. Prevalence (%) by sex, and cervid species was calculated, and descriptive statistics of abundance generated for each source of variation. A Kruskall-Wallis test was applied together with the Fisher's LSD (least significant difference) means comparison test ($\alpha = 0.05$) to identify which parasite species was most abundant in each cervid species, sex and season (rainy or dry). A χ^2 test was run to determine the association of parasite abundance to cervid species and sex.

Results

Seven endoparasite genera were identified among the two studied cervid species: *Ascaris* sp., *Eimeria* sp., *Estrongilido* sp., *Paragonimus* sp., *Parascaris* sp., *Strongyloides* sp. and *Taenia* sp. Abundances varied between the seasons and cervid species (Figure 1; Table 1). All (100%) the experimental animals exhibited endoparasites. The gastrointestinal parasite genera *Parascaris* sp., *Paragonimus* sp., and *Taenia* sp. were prevalent in *O. virginianus* and absent in *M. temama*.

Figure 1: Endoparasite abundance in *O. virginianus* and *M. temama* in the El Pochote UMA. Different lowercase letters above the bars indicate significant difference ($P \leq 0.05$)

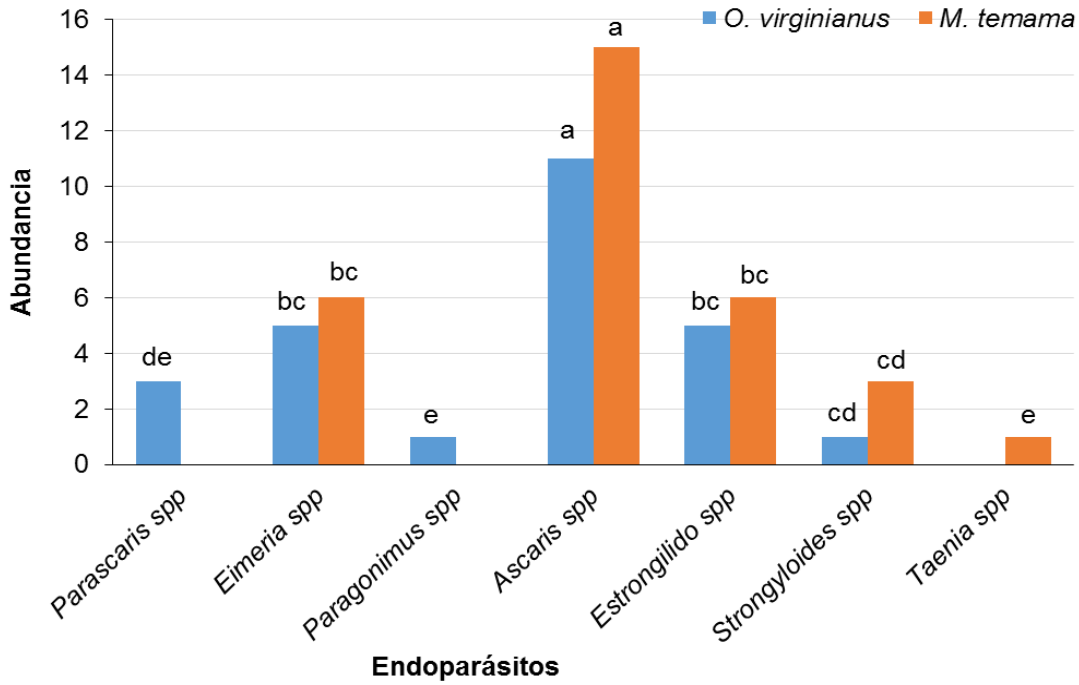

Table 1: Endoparasite genera identified in *O. virginianus* and *M. temama*, and their average abundance during the rainy and dry seasons at El Pochote UMA, Veracruz, Mexico

Season	Cervid	Parasite Species	Average abundance	SD
Rainy	*M. temama*	*Ascaris sp.*	2.00	1.4
		Eimeria sp.	1.67	1.7
		Estrongilido sp.	1.67	1.2
		Strongyloides sp.	0.67	1.1
		Taenia sp.	0.33	0.8
	O. virginianus	*Ascaris sp.*	2.33	2.0
		Eimeria sp.	1.67	1.2
		Paragonimus sp.	0.33	0.8
		Parascaris sp.	0.33	0.8
Dry	*M. temama*	*Ascaris sp.*	3.00	0.0
		Eimeria sp.	0.33	0.8
		Estrongilido sp.	0.33	0.8
		Strongyloides sp.	0.33	0.8
	O. virginianus	*Ascaris sp.*	1.33	1.1
		Estrongilido sp.	1.67	1.7
		Parascaris sp.	0.67	0.8
		Strongyloides sp.	0.33	0.8

SD= standard deviation.

No significant effect ($P>0.05$) on parasite abundance was observed for season or cervid species (Table 2). Differences ($P<0.05$) in abundance were identified between the endoparasite genera, with *Ascaris* sp. being the most abundant genus (Table 3).

Table 2: Effect of season (dry *vs.* rainy), host cervid species (*O. virginianus* and *M. temama*) and endoparasite genus

	SS	DF	MS	F	*P*-valor
Model	13.06	8	1.63	2.98	0.007
Seasons	0.14	1	0.14	25	0.619
Cervid species	1.07	1	1.07	1.95	0.167
Parasite	11.86	6	1.98	3.61	0.004*
Error	31.2	57	0.55		
Total	44.26	65			

SS= sum of squares; DF= degrees of freedom; MS= mean squared; F= table value; *P*-valor = significance value.

Table 3: Average abundance by endoparasite genus in the two studied cervid species

Endoparasite	N	Average	SE	Differences
Taenia sp.	6	0.17	0.57	a
Paragonimus sp.	6	0.17	0.57	a
Strongyloides sp.	12	0.33	0.4	a
Parascaris sp.	6	0.5	0.57	a
Estrongilido sp.	12	0.92	0.4	a
Eimeria sp.	12	0.92	0.4	a
Ascaris sp.	12	2.17	0.4	b*

N= sample size; SE= standard error; *differences at $\alpha = 0.05$.

The parasite genus *Eimeria* sp. was associated with male *M. temama* and female *O. virginianus* (X^2= 8.57, d.f. 1; *P*= 0.0034). *Taenia* sp. was present in one male *M. temama* and *Paragonumus* sp. in one female *O. virginianus* (X^2, $P<0.05$). The genera *Parascaris* sp., *Ascaris* sp., *Estrongilido* sp., and *Strongyloides* sp. exhibited no association (X^2, $P>0.05$) to sex or cervid species.

Discussion

Seven endoparasite genera were identified in *O. virginianus* and *M. temama*. This study constitutes the first report of these endoparasites in UMAs *in situ* or *ex situ* in the state of Veracruz. The genera *Ascaris* sp. and *Eimeria* sp. were recorded in both seasons and both

cervid species, whereas *Taenia* sp. was present only during the rainy season ($P>0.05$) in *M. temama*.

In various studies analyzing different sample sizes (20 to 200 feces samples) at different times of year (dry, transition and rainy seasons), eight parasite genera have been described of which *Eimeria* sp. and *Strongyloides* sp. had the highest abundances[20,27,28]; both these genera were also recorded in the present results. Another study of approximately 1,000 feces samples from *O. virginianus* collected from three corrals during a one-year period identified seven endoparasite genera[15]. These included *Eimeria* sp. and *Strongyloides* sp., both of which were reported in previous studies and the present results.

In the present study *Ascaris* sp. was the most prevalent genus in both cervid species, with levels significantly higher than the other identified parasite genera. Ascarididae Family parasites are present throughout the animal kingdom, and are commonly found in the intestines of fish, amphibians, reptiles, birds and mammals. However, they tend to cause the most damage in domestic species such as pigs, horses, cattle, poultry, dogs and cats, but can also be found in wild mammals such as foxes[27]. *Ascaris* sp. nematode eggs have been identified in the primates *Alouatta fusca* and *A. seniculus*, most probably via anthropozoonotic contamination[29], that is, cross-contamination from caregivers. Species belonging to the genus *Eimeria* sp. mainly parasitize mammals, and are common parasites of the host digestive canal where they take root in the epithelial cells and destroy them, causing the disease known as coccidiosis[25].

Compared to wild populations, captive ungulates have a higher number of endoparasites[13]. This may be due to an increased risk of parasite transmission from their general dependence on feed prepared by humans, often without proper sanitary protocols, and excess moisture in corrals from puddles and water leaking from drinking bottles[30]. In addition, the stress of captivity can reduce immunological capacity, and promote parasitosis and greater parasite diversity and abundance[31].

The lack of inter-seasonal differences in parasite types and abundance observed in the present results coincide with previous studies[20,28]. A favorable climate for parasite transmission in both of the seasons is the most probable reason for this lack of difference. All the identified parasites utilize intermediate hosts, meaning greater or lesser parasite frequency in the studied cervids would depend on the presence of these hosts[32].

Wild animals are hosts to a variety of parasites but are normally able to keep their parasite communities in balance, preventing disease symptoms from appearing[33]. Factors that can weaken a host's immune system include age, malnutrition and stress, among others, all of which can increase the risk of excessive parasitization[34]. The spread of endoparasites between wild and domestic species can be dangerous[35]. Variations in parasite abundance and richness between cervid species can be related to habitat, coexistence with other species, enclosure size and characteristics, and population density[36,37]. Future research will need to consider the characteristics of enclosures at UMAs to detect the risk factors associated with parasitosis.

Parasite dynamics over time may be influenced by host sex since parasite prevalence by host sex is linked to individual traits such as age and body condition[38]. For example, adult *Alces alces* have a higher parasite load than sub adults during the mating season[39], whereas in *O. virginianus* this occurs outside the mating season[40]. In the present study *Eimeria* sp. and *Paragonumus* sp. were prevalent in *O. virginianus* females during the mating season, possibly due to infection by males. Of note is that the presence of *Taenia* sp. in one male *M. temama* was not necessarily sex-dependent but more probably due to high humidity in the enclosure, tree leaves falling into the corral and/or ingestion of plant sprouts. Further study is needed on the parasitology of *M. temama* to strengthen management programs for captive populations, and contribute to their conservation, as has been done successfully with other ungulates (e.g. *Gazella gazella*)[41].

Conclusions and implications

The analyses reported here of gastrointestinal parasite prevalence and diversity in captive *O. virginianus* and *M. temama* identified seven parasite genera among the two cervid species. Both species can be treated with specific deparasitization treatments to prevent excessive parasite load, which can cause host morbidity or mortality. Based on the present data the dry season would be the best season in which to apply deparasitization treatments. *Ascaris* sp. was the most abundant in both cervids, followed by *Estrongilido* sp. and *Eimeria* sp. These findings highlight the importance of identifying parasitosis risk factors in captive wildlife to optimize prevention and mitigation strategies. The present results have implications for the conservation and management of captive *O. virginianus* and *M. temama*, as well as for prevention of zoonotic diseases that can affect wild and domestic animal populations, with possible financial impacts for producers.

Acknowledgements

The authors thank Arantxa Penagos de la Llave for technical assistance and access to El Pochote UMA; Carlos Manuel Galán Páez for laboratory assistance; and the Genetic Resources Management and Conservation Unit of the Faculty of Biological and Livestock Sciences for bioinformatic analyses.

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