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BRIEF REPORT

Clinical evaluation of sarcoptic mange (*Sarcoptes scabiei)* in maned wolves (*Chrysocyon brachyurus*)

Flávia Fiori[1,2] · Rogério Cunha de Paula[1,3] · Ricardo Luiz Pires Boulhosa[1] · Ricardo Augusto Dias[2]

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Abstract

Sarcoptic mange is a disease potentially threatening to Brazilian carnivores, especially maned wolves (*Chrysocyon brachyurus*). Recently, an outbreak of sarcoptic mange has affected maned wolves in part of their range; therefore, it is a priority to assess the clinical manifestation of the disease. A total of 20 maned wolves were evaluated in Southeast Brazil, 12 of which from research projects and eight were rescued between 2008 and 2023. Since the clinical signs of the sarcoptic mange vary considerably, the maned wolves were classified according to the degree of clinical manifestation and the lesion severity. According to the extension of the body affected by sarcoptic mange, two maned wolves (10%) were classified as level I (<25% of the body affected), five (25%) as level II (26–50% of the body affected), three (15%) as level III (51–75% of the body affected), and ten maned wolves (50%) as level IV (76–100% of the body affected). By lesion severity, five maned wolves (25%) had type A lesions (mild lesions), ten (50%) had type B lesions, and five (25%) had type C lesions (severe lesions). The maned wolves classified as III-C and IV-C were transferred to captivity to receive intensive veterinary care. The definitive diagnosis was challenging due to the low sensitivity of the available diagnostic tests, suggesting that future research should use a diagnostic protocol that combines blood serum antibody testing with skin scrapings and histopathology.

Keywords Sarcoptic mange · Maned wolf · Treatment · Diagnosis

Introduction

The maned wolf (*Chrysocyon brachyurus*), the largest canid in South America, is considered vulnerable in Brazil (Paula et al. 2013; ICMBIO 2024). It regulates the population of its preys and disperses seeds in the Brazilian savannah (known as Cerrado) (Rodrigues 2002; Motta-Junior and Martins 2002). The conversion of natural areas into agricultural fields and pastures increases the contact with humans and domestic animals, resulting in conflicts and pathogen transmission (Paula et al. 2013).

Sarcoptic mange, caused by the burrowing mite *Sarcoptes scabiei* (Taylor et al. 2017), negatively impacts wildlife. The disease is highly contagious and widespread, affecting 148 mammalian species worldwide (Pence and Ueckermann 2002; Gakuya et al. 2012; Astorga et al. 2018; Escobar et al. 2021; Fiori et al. 2023). Among the mammalian families, Canidae is the second most affected, with 20 susceptible species (Escobar et al. 2021). Clinical signs include intense pruritus accompanied by erythematosis, papules, seborrhea and alopecia, although not all individuals present all signs (Bornstein et al. 2001). Crusting, hyperkeratosis, lichenification, and skin thickening have been observed in chronic cases (Bornstein et al. 2001).

The clinical signs vary from species to species (Trainer and Hale 1969; Pence et al. 1983; Morner 1992; Pence and Windberg 1994; Skerratt et al. 1999; Pence and Ueckermann 2002; Bates 2003; Nimmervoll et al. 2013). Two main clinical expressions of mange have been reported in wildlife: hyperkeratotic (with type I hypersensitivity), and alopecic

✉ Ricardo Augusto Dias
ricardodias@usp.br

1 Pro-Carnívoros Institute - Institute for the Conservation of Neotropical Carnivores, Atibaia, Brazil

2 Department of Preventive Veterinary Medicine and Animal Health, School of Veterinary Medicine, University of São Paulo, São Paulo, Brazil

3 National Research Center for Carnivores Conservation (CENAP)/Chico Mendes Institute for Biodiversity Conservation (ICMBio), Ministry of Environment and Climate Change, Atibaia, Brazil

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(with type IV hypersensitivity) (Bates 2003; Skerratt 2003; Oleaga et al. 2012; Espinosa et al. 2017; Valldeperes et al. 2023; Ráez-Bravo et al. 2024; Tiffin et al. 2025).

The coevolution of the *S. scabiei* mite with canids has likely occurred periodically over the last 20,000 years (Andrews 1983). This recent coevolution may account for the exuberant signs of sarcoptic mange even at low mite loads, as evidenced by the outbreak of sarcoptic mange in maned wolves in Brazil (Fiori et al. 2023). This situation affects the direct diagnosis of sarcoptic mange (skin scrapings and histopathology) in maned wolves, even with exuberant lesions, can produce false negatives with a high probability (Walton and Currie 2007), as also seen in Brazil (Fiori et al. 2023). The available laboratory tests for *S. scabiei* are (a) skin scrapings for microscopic analysis, (b) histopathology, (c) serology and (d) molecular testing (Niedringhaus et al. 2019).

Several treatments for sarcoptic mange in wildlife have been reported (Rowe et al. 2019; Van Wick et al. 2020; Jorge et al. 2009), based on the treatments for domestic dogs. However, the effectiveness of population control or eradication is inconclusive because most of the studies present an individual clinical treatments rather than population management, and ignore the population and environmental effects of antiparasitic treatments (Rowe et al. 2019; Moroni et al. 2020).

Materials and methods

Assessment of maned wolves

The aim of the present study was to explore the performance of diagnostic tools for sarcoptic mange in maned wolves captured and rescued in an epidemic area. The present study was part of the Maned Wolf National Conservation Program, carried out by Brazilian Research Center for Carnivores Conservation (CENAP/ICMBio). A total of 20 maned wolves was examined, eight of which were rescued and kept in captivity and 12 of which were captured in the wild. The study was carried out between 2008 and 2023. The maned wolves were captured with box traps set at predetermined locations, where their presence had been previously confirmed either directly from sightings or indirectly from feces, urine, tracks, and footprints, according to Dietz (1984), with adaptations. The traps were placed in four municipalities in the state of São Paulo and were checked daily in the early morning. The maned wolves were chemically restrained with Zoletil 50® (tiletamine hydrochloride 125.0 mg and zolazepam hydrochloride 125.0 mg) at a dose of 4 mg/kg, administered intramuscularly (May-Júnior et al. 2009).

Under sedation, the maned wolves were weighed and placed in the top of the trap for examination. The maned wolves underwent a complete physical examination. The size and weight were recorded and their age estimated by tooth wear (of canines, incisors and molars) and gingival retraction (of canines), according to Gipson et al. (2000), with adaptations. The maned wolves were classified as juvenile (< 1 year old), subadult (1 to 2 years old), and adult (≥ 2 years old). Clinical parameters, such as heart rate, respiratory rate, temperature, capillary filling time, eye, anal and foot reflexes and degree of muscle relaxation, were monitored every 10 min.

A number of maned wolves were rescued from the wild. Their handling was limited to physical restraint until they reached a facility for intensive care.

Diagnosis

The maned wolves were diagnosed with sarcoptic mange by (1) skin scraping or (2) histopathology (Miller et al. 2013). If the results of the laboratory tests were negative, a (3) clinical/epidemiological diagnosis was considered if the lesions were compatible with sarcoptic mange and if there was a positive maned wolf in the family group (Walton and Currie 2007).

Classification of lesions

Clinical examination was performed on 20 individuals. The characteristics, extent, and location of the lesions were observed and registered by photo and videos.

The lesion severity was classified into types A, B or C, according to Nimmervoll et al. (2013). In type A lesions, alopecia may be present, crusts are absent, but hyperpigmentation and thickening of the skin are present. In type B lesions, alopecia may be present, and in addition to hyperpigmentation and thickening, fine crusts may eventually form. Type C lesions may have alopecia, thick crusts, and skin fissures. The maned wolves were graded according to the predominant lesion and and its extent on the body (Fig. 1).

Regarding the extension of the body affected, lesions were classified into levels I, II, III and IV, according to Pence et al. (1983), with adaptations. The maned wolf's body was divided into ten regions (Fig. 2). In terms of extension of lesions, the maned wolves with < 25% of their body affected were considered level I; 26–50% were considered level II; 51–75% were considered level III; and 76–100% were considered level IV (Fig. 2).

The association between lesion severity (A-C) and lesion extension (I-IV) was verified using the chi-square test. The association between diagnostic tests with severity and

Fig. 1 Examples of sarcoptic mange lesion severity (**A**, **B**, and **C**) in affected maned wolves

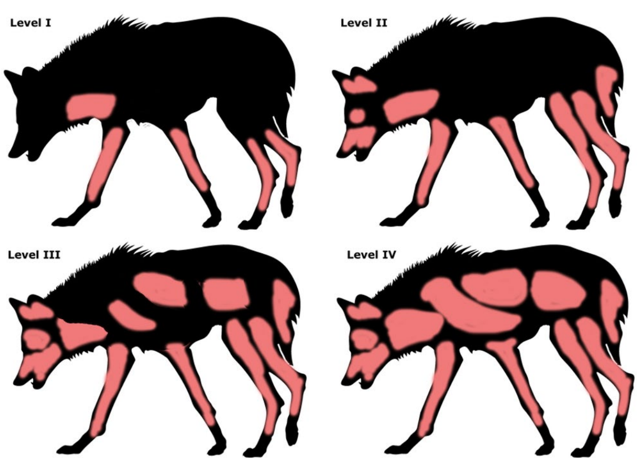

Fig. 2 Extension (I, II, III, and IV) of sarcoptic mange lesions in affected maned wolves

extension of the lesions was verified using the chi-square test. In addition, the associations of severity types and lesion extension levels with the captured and rescued status were verified using the chi-square test. Finally, the association of diagnostic tests performed with the captured and rescued status was also verified using chi-square test. The analysis was performed in R using the chisq.test() function.

Results

Of the 20 maned wolves examined, one (Cbr 8) was captured twice and infested in both events. Another individual was captured in 2008 (the first maned wolf in which *S. scabiei* was detected in Brazil), and the others, between 2017 and 2023. The sampling effort was 763 trap*days. A total of 67 capture events of 20 maned wolves occurred in all the 14 monitored sites. An initial assessment of the maned wolves' behavior and apparent health was made upon capture. Eight captured maned wolves had no suggestive signs of mange infestation. The maned wolves were obtained from three Brazilian states: São Paulo ($n = 17$), Minas Gerais ($n = 2$) and Rio de Janeiro ($n = 1$), with 13 males (65%) and 7 females (35%). Moreover, 18 (90%) maned wolves were adults, one was subadult and one juvenile. The clinical history of each maned wolf is presented in Table 1.

Regarding lesion extension, two maned wolves (10%) were classified as level I, five (25%) as level II, three (15%) as level III, and ten (50%) as level IV. Regarding lesion severity, five maned wolves (25%) had type A lesions, ten (50%) had type B lesions, and five (25%) had type C lesions. The most affected areas were the head, ear, neck, chest and thoracic limbs, regardless of the lesion extension (Table 2).

As for the relationship between lesion severity and extension, the results are: two maned wolves were A-I, two were A-III (Table 3). The maned wolves classified as III-C and IV-C were transferred to captivity to receive intensive veterinary care.

The number of sarcoptic mange diagnoses by diagnostic test, lesion severity and lesion extension are summarised in Table 3. No association was observed between the severity and extension of sarcoptic mange lesions in maned wolves ($p = 0.41$). No association between diagnostic tests and severity of lesions was observed ($p = 0.28$), but an association between diagnostic tests and extension of the lesions was observed ($p = 0.007$), with higher positivity of skin scraping in more extensive lesions and clinical/epidemiological in more restrict lesions.

No association was observed between severity types and captured and rescued status ($p = 0.10$), but lesion extension was associated with the captured and rescued status ($p = 0.0009$), being more extensive in in rescued maned wolves. Finally, the diagnostic tests performed were associated with captured and rescued status ($p = 0.009$), with skin scraping more frequent in rescued maned wolves and clinical/epidemiological diagnosis more frequent in captured wolves.

Discussion

The sampling effort during this study resulted in a significant number of maned wolves being examined for sarcoptic mange in an area where the disease is epidemic (Fiori et al. 2023). Half of the maned wolves examined had moderate severity of lesions. Half of the maned wolves also had lesions over almost the entire length of the body. However, there was no association between the severity of the lesions and whether the maned wolves were captured or rescued. Skin scraping positivity is associated with extensive lesions and clinical/epidemiological diagnosis with less extensive lesions. In addition, an association was observed between the extent of the lesions and captured and rescued maned wolves. In terms of the diagnostic tests used, skin scraping was more common in rescued maned wolves and clinical/

Table 1 General information, lesion severity and extension, and diagnostic tests performed on sampled maned wolves with sarcoptic mange indications

ID[1]	State[2]	Gender	Age	Source	Lesion severity	Lesion extension	Diagnostic test[3]
Cbr 1	SP	Male	Adult	Capture	B	IV	HP
Cbr 2	SP	Male	Adult	Capture	B	II	CE[c]
Cbr 3	SP	Female	Adult	Capture	B	IV	CE[c]
Cbr 4	SP	Male	Adult	Rescue	B	IV	SS[b]
Cbr 5	SP	Female	Subadult	Capture	A	II	CE[d]
Cbr 6	SP	Female	Adult	Capture	C	III	HP
Cbr 7	SP	Male	Juvenile	Capture	B	I	SS[e]
Cbr 8 − 1	SP	Male	Adult	Capture	A	II	CE
Cbr 8 − 2	SP	Male	Adult	Capture	B	I	CE[f]
Cbr 9	SP	Male	Adult	Capture	B	II	CE[g]
Cbr 10	SP	Female	Adult	Capture	B	IV	HP
Cbr 13	SP	Male	Adult	Rescue	C	III	HP[a]
Cbr 14	SP	Male	Adult	Capture	A	III	SS
Cbr 27	SP	Male	Adult	Rescue	B	IV	SS[b]
Cbr 42	RJ	Male	Adult	Rescue	C	IV	SS[a]
Cbr 48	SP	Female	Adult	Rescue	A	IV	SS[b]
Cbr 49	SP	Female	Adult	Capture	A	II	CE[h]
Cbr 54	MG	Female	Adult	Rescue	C	IV	SS[a]
Cbr 63	SP	Male	Adult	Rescue	C	IV	SS[a]
Cbr 74	MG	Male	Adult	Rescue	B	IV	SS[b]

[1]Cbr: Acronim for *Chrysocyon brachyurus*

[2]Brazilian State: MG - Minas Gerais; RJ - Rio de Janeiro; SP - São Paulo

[3]Diagnosis: SS = Skin scraping; HP = Histopathology; CE = Clinical/Epidemiological

[a]Transferred to captivity for intensive treatment and rehabilitated

[b]Transferred to captivity for intensive treatment and died

[c]Epidemiologic diagnosis due to presence of clinical signs, were captured in the same area as Cbr 1 (positive), and were paired

[d]Clinical diagnosis due to capture at a young age within the area of its parents (Cbr 6 and Cbr 14), both of which had previously been definitively diagnosed with sarcoptic mange

[e]Later offspring of Cbr 6 and Cbr 14 (and brother of Cbr 5)

[f]Epidemiologic diagnosis due to capture in an area where positive individuals were found (Cbr 6, Cbr 7 and Cbr 14)

[g]Clinical and epidemiological diagnosis due to capture in the same area as positive individuals (Cbr 10, Cbr 11 and Cbr 12); these four individuals formed a family unit consisting of a pair and two offsprings

[h]Clinical diagnosis based on signs and symptoms but had no previous epidemiological history

epidemiological diagnosis was more common in captured wolves.

The body parts more frequently affected by lesions caused by the *S. scabiei* vary according to the species involved (Trainer and Hale 1969; Pence et al. 1983; Morner 1992; Skerratt et al. 1999; Ryser-Degiorgis et al. 2002; Oleaga et al. 2011, 2012, 2019; Speight et al. 2017). The disease course and symptomatology vary according to the immunity of the host (Pence and Ueckermann 2002; Bates 2003; Nimmervoll et al. 2013). In canids, such as red fox (*Vulpes vulpes*) and coyote (*Canis latrans*), initial lesions have been observed in the posterior part of the animals' body, such as the pelvic limbs and ischium (Pence et al. 1983; Morner 1992; Nimmervoll et al. 2013). In this study, the extension of lesions classified as level I and II, the initial lesions were observed on the thoracic and pelvic limbs. Based on the severity and extension of the lesions, they usually start at the frontal region of the body, i.e., from the thoracic limbs to the head and ears and progress to the rest of the body. According to Roberts and Janovy (2009), the areas most affected by the mite are those covered by short hair. In maned wolves, the areas with the shortest and least dense coat are precisely the head, especially the snout, around the eyes, and ears, and the distal thoracic and pelvic limbs become affected; these were the first areas to show signs of sarcoptic mange in this study. As the disease progressed, the areas with the longest and densest coats, such as the neck, chest, abdomen, thighs and tail, are affected.

Two types of scabies have been described in humans and red foxes (*Vulpes vulpes*) (Oleaga et al. 2012): hypersensitive and hyperkeratotic (Maghrabi et al. 2014), while only hypersensitive mange has been observed in gray wolves (*Canis lupus*) (Oleaga et al. 2012). The development of both types of mange depends on the host immune response:

Table 2 Body parts of maned wolves infested with *Sarcoptes scabiei* mites according to lesion severity and extension

Cbr[1]	Lesion severity	Lesion extension	Head	Ears	Neck	Chest	TL[2]	Toracic			Abdomen			PM[3]	Thigh	Tail
								Cervical	Medium	Ventral	Dorsal	Medium	Ventral			
49	A	II	X	X	N	X	X	N	N	N	N	N	N	X	N	N
8 −1		II	X	X	X	X	X	N	N	N	N	N	N	X	N	N
5		II	X	X	N	N	N	N	N	N	N	N	N	N	X	X
14		III	X	X	X	X	X	N	X	N	N	N	N	X	N	N
48		IV	X	X	X	X	X	X	X	X	X	X	X	X	X	X
7	B	I	N	N	N	N	X	N	N	N	N	N	N	X	N	N
8 −2		I	N	N	X	X	X	N	N	N	N	N	N	X	N	N
2		II	X	X	N	X	X	N	N	N	N	N	N	X	N	N
9		II	X	X	N	N	X	N	N	N	N	N	N	N	N	N
10		IV	X	X	X	X	X	X	X	N	X	N	N	X	X	X
1		IV	X	X	X	X	X	X	X	X	N	X	X	X	N	N
27		IV	X	X	X	X	X	X	X	X	X	X	X	X	N	N
3		IV	X	X	X	X	X	X	X	X	X	X	X	X	X	N
4		IV	X	X	X	X	X	X	X	X	X	X	X	X	X	X
74		IV	X	X	X	X	X	X	X	X	X	X	X	X	X	X
6	C	III	X	X	X	X	X	X	X	N	N	N	N	X	N	N
13		III	X	X	X	N	X	N	X	X	N	X	X	X	N	N
54		IV	X	X	X	X	X	X	X	X	N	X	X	X	N	X
42		IV	X	X	X	X	X	X	X	X	X	X	X	X	X	N
63		IV	X	X	X	X	X	X	X	X	X	X	X	X	X	X

[1]*Cbr* Acronym fo *Chrysocyon brachyurus*, [2]*TL* Thoracic limb, [3]*PL* Pelvic limb, X - Body parts with sarcoptic mange suggestive signs; N - Body parts without sarcoptic mange suggestive signs

Table 3 Number of sarcoptic mange diagnoses by diagnostic test, lesion severity and lesion extension

Lesion Severity	Lesion Extension	Diagnostic test			Total
		Skin scraping	Histopathology	Clinical/Epidemiological	
A	II			3	3
	III	1			1
	IV	1			1
B	I	1		1	2
	II			2	2
	IV	3	2	1	6
C	III		2		2
	IV	3			3
Total		9	4	7	20

(1) hyperkeratotic occurs when the animal develops a type I hypersensitivity, and (2) alopecic or hypersensitive occurs when the animal develops a type IV hypersensitivity (Bates 2003; Martínez et al. 2020). Although it was not possible to make this classification in this study because histopathologic analysis could not be performed on all the maned wolves, both alopecic and crusted lesions were observed macroscopically.

The definitive diagnosis of sarcoptic mange is made by the identification of the mite, eggs or eggshell fragments (Walton and Currie 2007) through skin scrapings and/or histopathology (Nimmervoll et al. 2013; Walton and Currie 2007; Deem et al. 2002). In the absence of identification of mites or eggs, clinical and epidemiological diagnosis has been accepted (Walton and Currie 2007). All these diagnostic methods were used in this study.

The association between skin scraping positivity and more extensive lesions and clinical/epidemiological diagnosis with less extensive lesions may indicate that more extensive lesions are more likely to have a higher availability of *S. scabiei* mites. This is supported by the fact that most of the rescued maned wolves had more extensive and severe lesions and the most common diagnosis in this category was skin scraping, probably due to the low immunity and consequent high availability of mites in the samples collected. Conversely, the most common diagnosis in the captured wolves was clinical/epidemiological, probably due to the lesser severity and extent of the lesions.

As the parasite load is usually low in canids, even in severely affected animals, cytology is not effective in detecting mites (Niedringhaus et al. 2019). In species such as black bears (*Ursus americanus*), pigs (*Sus scrofa*), and humans, cytology was effective because parasite loads are high (Niedringhaus et al. 2019). In this study, diagnosis by histopathology or cytology by skin scrapings was possible for lesion extension levels III or IV, except for Cbr 3 (level IV-B), but impossible for levels I and II, except for Cbr 7 (juvenile). Future research should include serology to increase the sensitivity of the diagnostic protocol.

At the time of writing, no information was available on the accuracy of diagnostic tests for sarcoptic mange in wild canids. In domestic dogs, while the specificity of skin scrapings for the diagnosis of *S. scabiei* var *canis* exceeded 70%, but the sensitivity was low (about 50%), compared with molecular techniques such as PCR (Nwufoh et al. 2021). The accuracy of histopathology varies considerably depending on the protocol used. The use of these two tests is not indicated in surveillance and monitoring of sarcoptic mange in maned wolves, due to their high number of false negatives (Nwufoh et al. 2021). Combining skin scraping or histopathology with a highly sensitive test (e.g. serology), may increase the negative predictive value by increasing the overall sensitivity and decreasing the false negatives (Thrusfield et al. 2018).

Conclusions

The maned wolves affected by sarcoptic mange were classified according to the degree of disease manifestation, considering the percentage of the body affected and the clinical manifestation, as severity (A-C) and extension (I-IV). The first reported signs of sarcoptic mange in maned wolves occurred on the thoracic and pelvic limbs, progressing to the frontal region (snout, around the eyes, ears).

It was challenging to reach a definitive diagnosis of sarcoptic mange in this study. To increase the sensitivity and accuracy of the diagnostic protocol, future research or epidemiological surveillance should combine skin scrapings or histopathology with serology for *S. scabiei* as a diagnostic protocol.

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Author contributions Conceptualization: FF, RCP, and RAD; methodology: FF, RCP, and RLPB; formal analysis: FF and RAD; investigation: FF, RCP, and RLPB; resources: FF, RCP, RLPB, and RAD; writing-original draft preparation: RAD; writing-review and editing: FF, RCP, RLPB, and RAD; supervision: RCP and RAD; project administration: RCP, RLPB, and RAD; funding acquisition: RCP, RLPB, and RAD. All authors have read and agreed to the published version of the manuscript.

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Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Statement of animal ethics The procedures were carried out following the ethical principles of animal experimentation and were approved by the Ethics Committee on Animal Use at School of Veterinary Medicine of the University of São Paulo (protocol number 8983240322). The animal capture license was obtained at the Brazilian Ministry of the Environment and Climate Change (SISBio 61097 and 830092).

Competing interests The authors declare no competing interests.

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