

Dermatobiosis in *Panthera onca*: first description and multinomial logistic regression to estimate and predict parasitism in captured wild animals

Dermatobiose em *Panthera onca*: primeira descrição e regressão logística multinomial para estimar e prever o parasitismo em animais selvagens capturados

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Abstract

Dermatobia hominis is a parasite widely distributed in neotropical regions. The parasitic phase of the cycle is characterized by the formation of a subcutaneous nodule in the host, which can promote infestation by other dipterans and skin infections. The aim of this report is to register parasitism by *D. hominis* in free-ranging *Panthera onca* captured in the Brazilian wetland and to determine significant biological and meteorological factors that are likely to influence the presence of larval parasitism in captured wild jaguars. Between 2011 to 2020, 34 jaguars were captured and examined manually by searching for lesions characteristic of myiasis. By manual compression in the subcutaneous nodules, larvae morphologically identified as *D. hominis* (first and third instars) were collected from 13 jaguars. A multinomial logistic regression showed that adult jaguars had 16.49-fold higher odds of being parasitized than subadults. Thus, jaguars captured in the season of July–September have 34.01- and 11.42-fold higher odds of being parasitized compared to the seasons of October–December and April–June, respectively, which is associated with high total monthly precipitation in the previous season. The present study is the first to describe parasitism by *D. hominis* larvae in jaguars.

Keywords: *Panthera onca*, ectoparasite, botfly, dermatobiosis, conservation.

Resumo

Dermatobia hominis é um parasito amplamente distribuído nas regiões neotropicais. A fase parasitária do ciclo é caracterizada pela formação de um nódulo subcutâneo no hospedeiro, que pode promover infestação por outros dípteros e infecções cutâneas. O objetivo deste relato é registrar o parasitismo por *D. hominis* em *Panthera onca* de vida livre, capturado no pantanal brasileiro e determinar fatores biológicos e meteorológicos significativos que podem influenciar a presença de parasitismo larval em onças-pintadas selvagens capturadas. Entre 2011 e 2020, 34 onças-pintadas foram capturadas e examinadas manualmente em busca de lesões características de miíase. Por compressão manual nos nódulos subcutâneos, larvas classificadas morfologicamente como *D. hominis*

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(primeiro e terceiro instares) foram coletadas de 13 onças-pintadas. Uma regressão logística multinomial mostrou que onças-pintadas adultas tinham chances 16,49 vezes maiores de serem parasitadas do que subadultos. Assim, onças-pintadas capturadas na temporada de julho a setembro têm probabilidade 34,01 e 11,42 vezes maior de serem parasitadas em comparação com as temporadas de outubro a dezembro e de abril a junho, respectivamente, o que está associado à alta precipitação total mensal na temporada anterior. O presente estudo é o primeiro a descrever parasitismo por larvas de *D. hominis* em onças-pintadas.

Palavras-chaves: *Panthera onca*, ectoparasito, berne, dermatobiose, conservação.

Introduction

Dermatobia hominis (Linnaeus Jr., 1781) (Diptera: Oestridae) is a dipteran from the Oestridae family widely distributed in the neotropical region from southern Mexico to northern Argentina (Guimarães & Papavero, 1966). This ectoparasite develops a larval shape in the host's subcutaneous tissue and cause a primary furuncular myiasis, which is characterized by the presence of a subcutaneous nodule (Sancho, 1988).

It occurs in several domestic and livestock animals, and is of particular importance due to economic losses in relation to livestock, which reach US\$0.38 billion per year in Brazil (Grisi et al., 2014). Furthermore, it is a dermatozoonosis (Burns, 2010), with several records mainly in tourists from European and Asian countries visiting South America, and in indigenous people (Denion et al., 2004).

Although several studies reported the presence of *D. hominis* in wild animals, there are no concrete reports based on specific morphological identification or case reports in specific wild hosts, but only general references in the literature. Unlike other myiases that are reported in several species of wild animals, such as caused by insects belonging to the genera *Cochliomyia* in *Didelphis marsupialis* (Reis et al., 2008), *Galictis cuja* (Figueiredo et al., 2010) and *Chrysocyon brachyurus* (Cansi et al., 2011); *Chrysomya* in *Taurotragus oryx* (Obanda et al., 2013) and *Rusa unicolor* (Radhakrishnan et al., 2012); and *Lucilia* in *Gazella subgutturosa* (Gökçen & Sevgili, 2007), *Ramphocelus dimidiatus* (Bermúdez et al., 2010) and *D. albiventris* (Cansi & Bonorino, 2011).

The jaguar (*Panthera onca*) is the largest feline in the Americas, being vulnerable to extinction due mainly to poaching and habitat loss (Morato et al., 2013). Therefore, every parasitic or infectious agent with the potential to affect populations of this species deserves considerable study. In view of that, we describe here the parasitism by *D. hominis* in free-ranging jaguars and a multinomial logistic regression to estimate and predict parasitism in captured wild animals.

Materials and Methods

Study area

The present study was carried out in the Brazilian wetland region (Pantanal biome), located in the State of Mato Grosso do Sul. The captures were performed at the Caiman Ecological Refuge (CER), a privately-owned farm/natural reserve dedicated to wildlife tourism and cattle ranch. The period of captures was divided in January to March, April to June, July to September and October to December. Meteorological factors studied included monthly precipitation totals retrieved from manual measurement in the CER. Thus, access to the automatic station of the Instituto Nacional de Meteorologia (INMET, Brazil) in Miranda (code: A722, Latitude: -20.39555555 Longitude: -56.43166666) provided the mean monthly temperatures.

Captures

The captures and animal handling were performed following the ethical procedures of the Chico Mendes Institute for Biodiversity Conservation (ICMBio; permit #42093-1) and Research Comittee UFRGS (COMPESQ UFRGS; #38198).

Camera traps were used to check areas for jaguar movement, where foot snare traps were set up for the physical restraint of individuals (Frank et al., 2003). The captures occurred between October 2011 and June 2020. Once contained in the trap, they were sedated with a 5 mg/kg combination of tiletamine-zolazepam intramuscularly (Poole et al., 1993; Onuma et al., 2015) by CO₂ rifle dart in order to place the GPS collar and to collect biological material and biometric information.

Physical examination

The physical evaluation was carried out by professionals experienced in practical approaches to the evaluation of wild carnivores. Captured individuals received a radio telemetry (VHS) necklace and a unique identification, thus

enabling identification of recaptured animals. A general assessment regarding weight (kg), body condition and tooth wear to define age was performed.

An *in loco* observation was carried out, looking for subcutaneous nodules and lesions suggestive of myiasis in all body parts, cavities and orifices of individuals. After detection, the removal of larvae was performed through manual compression of the subcutaneous nodules. These larvae were conserved directly in 70% ethanol.

Morphological identification

The larvae of *D. hominis* were morphologically identified according to Guimarães & Papavero (1999) and Berne (2009). The larvae of *C. hominivorax* were identified according to Hall (1948). The *D. hominis* stages were identified according to Neiva (1914). The larvae were deposited in the Vector's Collection of the Laboratório de Protozoologia e Rickettsioses Vetoriais of Federal University of Rio Grande do Sul, under the registration numbers 02/2019 (third instar larva) and 01/2020 (first instar larva).

Statistics

A model was estimated to determine significant biological and meteorological characteristics that were likely to influence the presence of larval parasitism in captured wild *P. onca*. Jaguars lacking larval parasitism were considered the reference category. The factors included gender, age [subadult (up to 18 months old), adult (18 months old from to 10 years old) and old (over 10 years old)], capture season (January–March, April–June, July–September and October–December) and year. Covariates consisted of total precipitation (mm) and mean temperature (°C) in the month of capture. Multi-collinearity was tested using a linear model, and predictors with variance inflated factor (VIF) of ≥ 2 were excluded in a backward elimination. Multiple logistic regression used backward steps to define the final model. Model fit assessment used Pearson chi-square statistics, McFadden and Nagelkerke pseudo- R^2 . Ten-year (2011–2020) historic mean monthly temperatures and monthly precipitation totals were compared between different seasons by Kruskal–Wallis test, plus pairwise comparison with Bonferroni correction for multiple tests. The level of significance used as a criterion for the rejection of the null hypothesis was 5% ($p \leq 0.05$) and statistical analyses used IBM SPSS Statistics 22.0 software.

Results and Discussion

In total, 34 jaguars were captured between 2011 to 2020; 22 (64.70%) of these were recaptured, totaling 56 capture events. In the individual identification, 21 females and 13 males were captured and subdivided into the three age groups previously mentioned: subadult ($n=10$), adult ($n=23$), and old ($n=1$).

In 13 captures, larvae of approximately 20–30 mm were collected from different parts of the individuals' bodies, such as head, neck, upper lip, thorax and left anterior limb (Figure 1) (Table 1). The collected larvae were identified as belonging to the species *D. hominis* in the first and third instars due to their set of morphological characteristics (Figure 2).

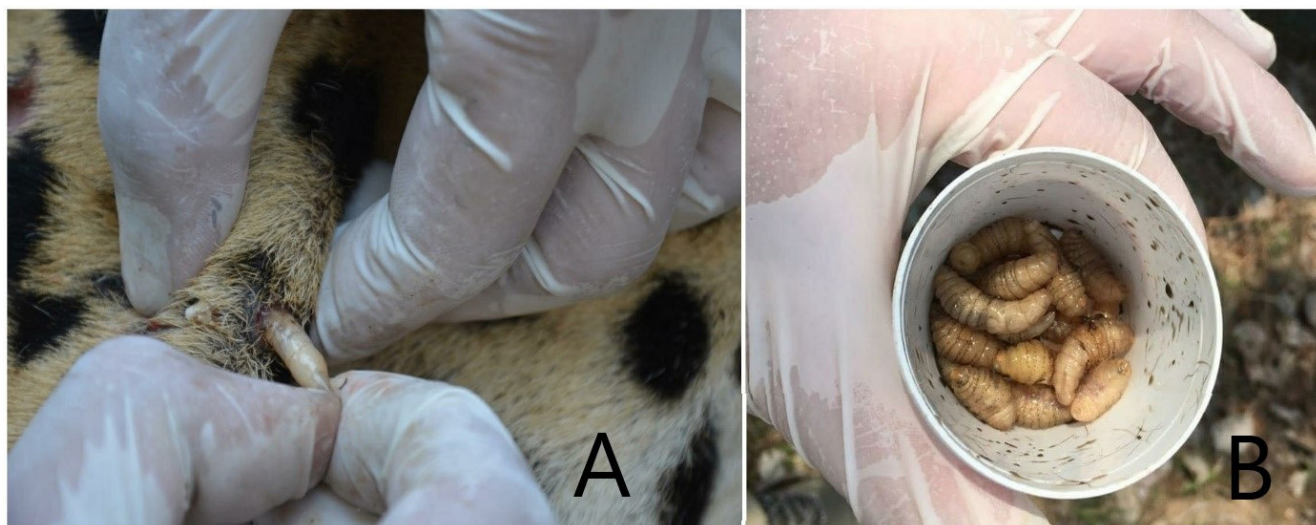


Figure 1. A: Removal of a larva of *Dermatobia hominis* (Linnaeus Jr., 1781) (Diptera: Oestridae) of an individual of jaguar (*Panthera onca*) captured in the present study. B: Larvae of *D. hominis* collected from jaguars.

Table 1. Respective data on gender, age, capture date and infestation local of *Dermatobia hominis* (Linnaeus Jr., 1781) (Diptera: Oestridae) in jaguars.

Capture identification	Age	Gender	Capture date	Infestation local
PO24	Adult	Male	September, 2016	Head, neck
PO30	Adult	Female	April, 2017	Head, neck
PO31	Adult	Male	April, 2017	Head, neck
PO24 ^a	Adult	Male	July, 2017	Head, neck
PO34	Adult	Male	July, 2017	Head, neck
PO36	Subadult	Female	September, 2017	Head, neck
PO37	Adult	Male	September, 2017	Head, neck
PO38	Old	Female	September, 2017	Head, neck
PO39	Adult	Male	March, 2018	Head, neck
PO24 ^a	Adult	Male	March, 2018	Head, neck, upper lip, thorax
PO44	Adult	Female	September, 2018	Head, neck
PO53	Adult	Female	December, 2019	Head, neck, left anterior limb
PO56	Adult	Male	June, 2020	Thorax

^a Recaptured jaguar.

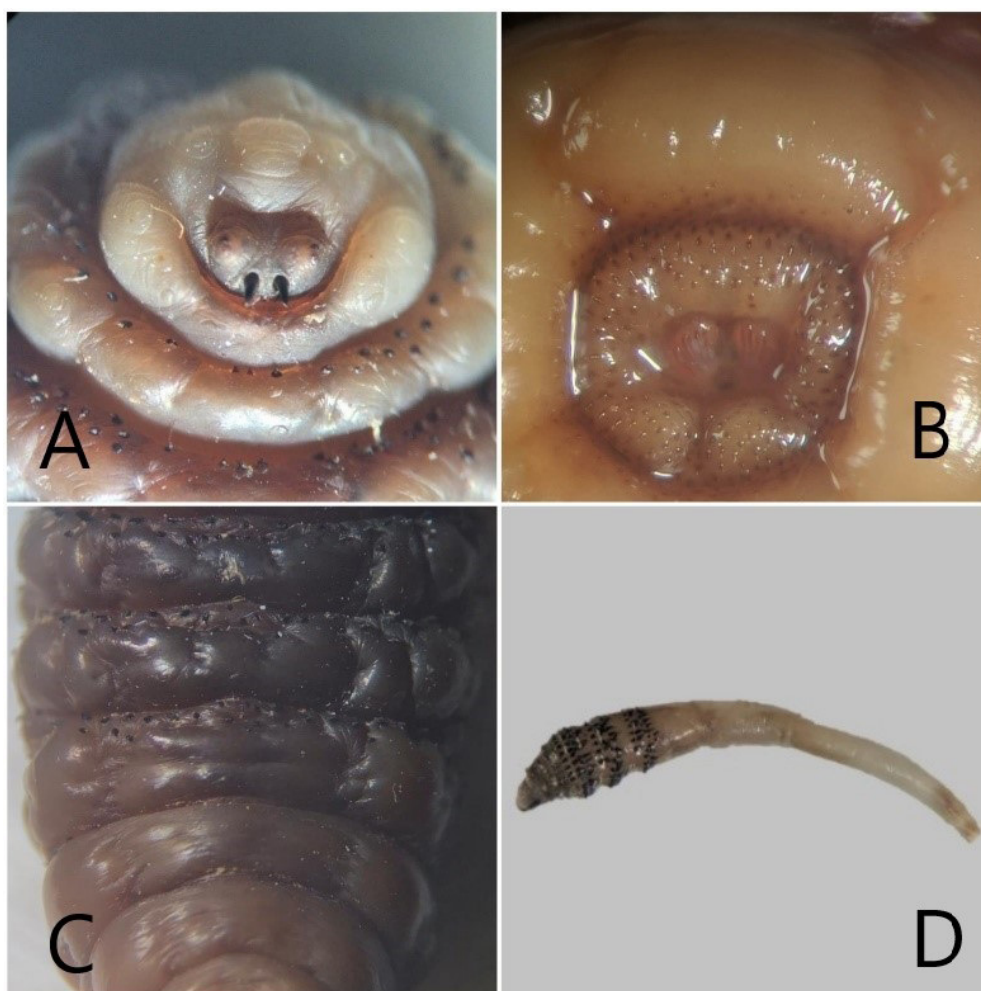


Figure 2. Important morphological structures for the morphological identification of *Dermatobia hominis* (Linnaeus Jr., 1781) (Diptera: Oestridae). In "A" two hooks at the mouth opening. In "B" two respiratory spiracles. In "C" and "D" spines covering the thoracic and abdominal portions of the larva's body. In "C" larva of the third instar and in "D" larva of the first instar.

Due to the impossibility of sending live larvae to complete the cycle under controlled laboratory conditions, during removal and storage, the larvae acquired an excessively dark color (Figure 3). In some cases, the presence of *Cochliomyia hominivorax* larvae were observed parasitizing the jaguars.



Figure 3. *Dermatitis hominis*' (Linnaeus Jr., 1781) (Diptera: Oestridae) larva of the present study showing too dark a color due to the technique of removal and storage.

No factors are excluded when checking for multicollinearity and p value of backward pairwise exclusion is show in Table 2. Age showed a significant association to larval parasitism.

Adult captured jaguars had 16.49-fold higher odds the odds of being parasitized compared to subadults while controlling for season (Table 3).

While controlling for age, jaguars captured in the season of July–September had 34.01- and 11.42-fold higher odds of being parasitized compared to those captured in October–December and April–June, respectively (Table 3). The season of July–September had the lowest monthly precipitation totals (Figure 4) (Table 4). An increase in precipitation totals during previous months, rather than in the current month, is associated with the presence of *D. hominis* larval parasitism in cattle (Brito & Moya Borja, 2000). In our study, the months April–June showed a higher precipitation total than July–September, which can favor posterior observation of larval parasitism in the next season, which are probably associated with larval parasitism ranging from 34 to 78 days (Neiva & Gomes, 1917; Villalobos et al., 2016). The final model using capture months and jaguar age are acceptable (Table 4).

In our study, the mean monthly temperature was excluded from the model; in addition, April–June and July–September temperatures did not differ and could not help explain the parasitism association to specific months. Mean monthly temperatures equal to or higher than 25 °C are associated with increased parasitism in slaughtered cattle (Brito & Moya Borja, 2000). Lack of association with temperature could be linked with the method of jaguar sampling, which follows the convenience of individual entrapment and which can differ from the systematic monthly observation of several herds in a slaughterhouse.

Health assessments in wild animals are important in the context of the epidemiology of ectoparasites, zoonosis and vector-borne diseases. This first assessment in jaguars is also important to the touristic region's public health, considering that dermatosis is widely observed in travelers of other continents (Caumes et al., 1995).

A possible visual record of infestation was observed by camera traps according to the thesis of Harmsen (2006), in which he suggested that swelling and scarring on the skin of individuals of *P. onca* observed in his study arose from the presence of *D. hominis*. In another thesis, Furtado (2010) observed parasitism by dipteran larvae in jaguars from Pantanal and Amazon biomes in Brazil; however, in both reports there was no morphological evaluation of the larvae (unpublished data), unlike the present study, which allowed the confirmation of the species involved in the parasitism.

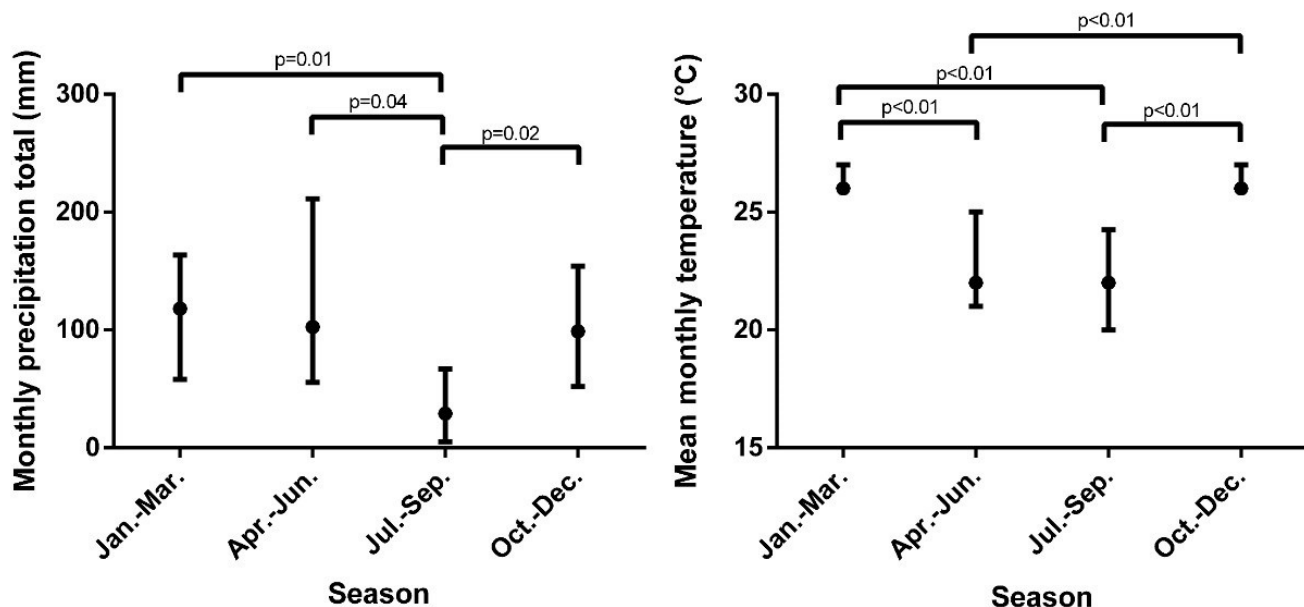


Figure 4. Median (interquartile range: 25-75%) of historic monthly precipitation total and mean monthly temperature according to the season (2011-2020).

Table 2. Factors and covariates descriptive statistics and backward stepwise *p* value.

Factors		Parasitized (13)	Non-parasitized (43)	<i>p</i> value
Gender	Female	5 (38.5%)	33 (76.7%)	0.99
	Male	8 (61.5%)	10 (23.3%)	
Age	Subadult	1 (7.7%)	11 (25.6%)	0.12
	Adult	11 (84.6%)	32 (74.4%)	
	Old	1 (7.7%)	0	
Captures seasons	January–March	2 (15.4%)	4 (9.3%)	0.10
	April–June	3 (23.1%)	16 (37.2%)	
	July–September	7 (53.8%)	8 (18.6%)	
	October–December	1 (7.7%)	15 (34.9%)	
Capture year	2011	0	2 (4.7%)	0.47
	2012	0	3 (7.0%)	
	2013	0	6 (14.0%)	
	2014	0	1 (2.3%)	
	2015	0	3 (7.0%)	
	2016	1 (7.7%)	9 (20.9%)	
	2017	7 (53.8%)	6 (14.0%)	
	2018	3 (23.1%)	6 (14.0%)	
	2019	1 (7.7%)	5 (11.6%)	
	2020	1 (7.7%)	2 (4.7%)	
Recapture	Yes	4 (30.8%)	18 (41.9%)	0.10
	No	9 (69.2%)	25 (58.1%)	
Monthly precipitation total (mm)		95 (40–201)	96 (50–135)	0.99
Mean monthly temperature (°C)		24 (21.5–27)	26 (22–27)	0.96

Table 3. Parasitized *Panthera onca* associated factor in multinomial logistic regression analysis.

	Factor	b	Adjusted OR (95% C.I.)	p value
Age	Adult vs. subadult	2.803	16.49 (1.22–222.62)	0.02
Seasons	July–September vs. October–December	3.526	34.01 (2.54–454.90)	0.01
	July–September vs. January–March	1.645	5.18 (0.49–54.34)	0.17
	July–September vs. April–June	2.435	11.42 (1.49–87.11)	0.02

Table 4. Assessment of final model.

Tests	Result
Pearson chi-square statistic (p value)	0.97
Nagelkerke (pseudo R ²)	0.42
McFadden (pseudo R ²)	0.30

Jaguars have wide home ranges of between 38 and 68 km² (Azevedo & Murray, 2007); these animals can act in the dispersion of *D. hominis*. In addition, *D. hominis* is a dipteran native to the neotropical region (Guimarães & Papavero, 1999), and a knowledge of its natural hosts that maintain its lifecycle is essential in understanding its epidemiology and preventing cases of dermatobiosis.

From another perspective, parasitism by *D. hominis* in cattle has been an important cause of economic losses in Brazilian production. It is estimated that 100 million cattle are exposed to parasitism by this dipteran (Grisi et al., 2014). Knowing this, it can be considered that parasitism by *D. hominis* of jaguars that live near livestock areas can be aggravated by the extensive herds of cattle in the region.

Dermatobiosis in endangered species populations is an aggravating factor, as the lesions caused by *D. hominis* larvae can promote the development of other myiasis, such as by *C. hominivorax* larvae (Grisi et al., 2014) as noted in the present study, leading to the development of injuries to jaguars that may impair their hunting habits, the defense of their territory, or even the death of individuals in an already vulnerable population.

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