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Zoopharmacognosy behavior in the crab-eating fox (*Cerdocyon thous*): Report of insect-mediated self-medication in a peri-urban environment

Comportamento de zoofarmacognosia em cachorro-do-mato (*Cerdocyon thous*): Relato de automedicação mediada por insetos em ambiente periurbano

Comportamiento de zoofarmacognosia en el zorro cangrejero (*Cerdocyon thous*): Reporte de automedicación mediada por insectos en un ambiente periurbano

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Abstract
Considering that animal self-medication, or zoopharmacognosy, consists of the use of natural substances with medicinal properties by non-human organisms, and that such behavior is widely documented in primates and birds but rarely in carnivorous mammals, the present study seeks to fill this gap. The objective is to describe the first record of self-medication behavior in the crab-eating fox (*Cerdocyon thous*) observed in a peri-urban environment in the municipality of Franca, São Paulo, Brazil. To this end, a non-invasive observational study was conducted using a camera trap installed for 15 consecutive days, with photographic and video records analyzed qualitatively. Two distinct episodes of non-feeding manipulation of insects were observed: body rubbing against an orthopteran and repeated licking of a blattodean, both without apparent ingestion. These behaviors exhibited characteristics consistent with topical self-medication mediated by bioactive compounds of entomological origin. This finding broadens the understanding of the phylogenetic scope of zoopharmacognosy and contributes to the comprehension of behavioral sanitary defense strategies in Neotropical canids, highlighting the importance of further studies integrating chemical analyses and prolonged observations in different ecological contexts.
Keywords: Zoopharmacognosy; Animal self-medication; Behavior; Neotropical canids; Ethology.

Resumo
Considerando que a automedicação animal, ou zoofarmacognosia, consiste no uso de substâncias naturais com propriedades medicinais por organismos não humanos e que tal comportamento é amplamente documentado em primatas e aves, mas raramente em mamíferos carnívoros, o presente estudo busca preencher essa lacuna. Objetiva-se descrever o primeiro registro de comportamento de automedicação em cachorro-do-mato (*Cerdocyon thous*) observado em ambiente periurbano no município de Franca, São Paulo. Para tanto, procede-se a um estudo observacional, não invasivo, conduzido por meio de armadilha fotográfica (câmera trap) instalada por 15 dias contínuos, com registros fotográficos e videográficos analisados qualitativamente. Desse modo, observou-se dois episódios distintos de manipulação não alimentar de insetos: esfregamento corporal contra um ortóptero e lambidas repetidas em um blattodeo, ambos sem ingestão aparente. Esses comportamentos apresentaram características compatíveis com automedicação tópica mediada por compostos bioativos de origem entomológica. O achado amplia o conhecimento sobre a amplitude filogenética da zoofarmacognosia e contribui para a compreensão de estratégias comportamentais de defesa sanitária em canídeos neotropicais, ressaltando a importância de novos estudos que integrem análises químicas e observações prolongadas em diferentes contextos ecológicos.
Palavras-chave: Zoofarmacognosia; Automedicação animal; Comportamento; Canídeos neotropicais; Etologia.

Resumen
Considerando que la automedicación animal, o zoofarmacognosia, consiste en el uso de sustancias naturales con propiedades medicinales por organismos no humanos, y que este comportamiento está ampliamente documentado en primates y aves, pero rara vez en mamíferos carnívoros, el presente estudio busca llenar esta laguna. El objetivo es describir el primer registro de comportamiento de automedicación en el zorro cangrejero (*Cerdocyon thous*) observado en un ambiente periurbano en el municipio de Franca, São Paulo, Brasil. Para ello, se realizó un estudio observacional no invasivo mediante el uso de una cámara trampa instalada durante 15 días consecutivos, con registros fotográficos y videográficos analizados cualitativamente. Se observaron dos episodios distintos de manipulación no alimentaria de insectos: frotamiento corporal contra un ortóptero y lamidos repetidos sobre un blatodeo, ambos sin ingestión aparente. Estos comportamientos presentaron características compatibles con automedicación tópica mediada por compuestos bioactivos de origen entomológico. Este hallazgo amplía el conocimiento sobre el alcance filogenético de la zoofarmacognosia y contribuye a la comprensión de las estrategias conductuales de defensa sanitaria en cánidos neotropicales, destacando la importancia de nuevos estudios que integren análisis químicos y observaciones prolongadas en diferentes contextos ecológicos.
Palabras clave: Zoofarmacognosia; Automedicación animal; Comportamiento; Cánidos neotropicales; Etología.

1. Introduction

Animal self-medication, or zoopharmacognosy, refers to the behavior by which non-human organisms select and use natural substances with medicinal properties, instinctively or learnedly, to prevent or treat infections and other conditions that affect physiological homeostasis (Huffman, 1997; Costa-Neto, 2012; De Roode; Lefèvre & Hunter, 2013). This phenomenon represents an adaptive strategy shaped by natural selection, which confers evolutionary advantages by reducing the costs of parasitemia and increasing host fitness (Lozano, 1998; Huffman & Vitazkova, 2007). Although widely documented in primates, birds, and insects (Huffman, 2003; Bush; Clayton, 2018; De Roode & Hunter 2019), zoopharmacognosy is still poorly studied among neotropical carnivorous mammals, especially wild canids.

The mechanisms of animal self-medication include pathogen avoidance behaviors, selection of dietary items with a prophylactic effect, and topical application of substances with therapeutic properties (Huffman, 2022). Among the compounds potentially used are secondary plant metabolites and bioactive substances produced by arthropods, such as antimicrobial peptides and chitin derivatives, which have antibacterial, antifungal, and antiparasitic action (YI et al., 2014; Saadoun; Elhag; Asensio, 2022; Guarnieri et al., 2022). The medicinal use of arthropods, however, remains an emerging and little explored area within zoopharmacognosy studies.

The crab-eating fox (*Cerdocyon thous*) is a medium-sized canid widely distributed in South America, with remarkable ecological and behavioral plasticity, inhabiting from natural environments to urban and peri-urban areas (Berta, 1982; Reis et al., 2006; Silva; Souza; Silva, 2020). Its omnivorous and generalist diet exposes it to a variety of pathogenic agents, which can favor the development of behavioral strategies for parasite control (Jorge et al., 2010; Spera et al., 2020). Despite this, there are no documented records of behaviors interpreted as self-medication in the species.

The objective is to describe the first record of self-medication behavior in the crab-eating fox (*Cerdocyon thous*) observed in a peri-urban environment in the municipality of Franca, São Paulo, Brazil.

2. Methodology

A descriptive, qualitative, case report-type study was conducted (Pereira et al., 2018), which followed the ethical criteria of veterinary medicine with respect to animals and the environment. The present study was conducted in an urban residential condominium located in the municipality of Franca, São Paulo, Brazil (coordinates: -20.5405036; -47.3764607), located in an ecological transition zone between urban environment and a fragment of semideciduous seasonal forest belonging to the Cerrado domain. The plant formation is characterized by high floristic and faunal diversity, with partial loss of foliage during the dry period, providing shelter and food resources for different species of wild mammals, including the crab-eating fox.

The research followed an observational and descriptive protocol, based on direct camera-trap and videographic records, as well as indirect reports from residents, without any type of manipulation or direct interference with the animal, in accordance with ethical principles of wildlife research.

For behavioral monitoring, a camera-trap model HC-801A (16 megapixels) was installed on 18 October 2025, fixed to the trunk of a tree approximately 20 centimeters from the ground, in a previously identified passage area. The equipment was operated continuously for 24 hours a day until on 4 October 2025, totaling 15 days of continuous monitoring. The camera was equipped with a motion sensor and infrared technology, allowing night and twilight records without light interference. The place was prepared with natural food baits, including papaya, banana, avocado, watermelon and orange, arranged at strategic points to attract local fauna. It was observed that the bush dog showed a consistent preference for oranges, consuming them more frequently during visits, suggesting food selection based on organoleptic or nutritional preferences.

The trap camera proved to be instrumental in recording spontaneous behaviors of *C. thous* in the context of free life, being particularly relevant given that the species has predominantly nocturnal habits and discreet behavior, making conventional direct observations difficult. This type of equipment allows the collection of ethological and ecological data in a non-invasive way, without altering the natural behavior of the animal, preserving the ecological validity of the observations. Additionally, it enables the precise temporal determination of behavioral events, providing visual and chronological support to qualitative analyses of ethological patterns (Rovero et al., 2013).

The visual records were analyzed qualitatively, considering the frequency, duration and context of the observed interactions, with emphasis on non-feeding insect handling behaviors. The analyses sought to identify patterns compatible with animal self-medication (zoopharmacognosy), according to criteria proposed by Huffman (1997).

3. Results

During the observed period, the crab-eating fox was recorded near an Environmental Protection Area of semideciduous seasonal forest of an urban area condominium. The first appearance of the crab-eating fox in the condominium was recorded on 6 May 2025, through an amateur videographic record captured by a resident, documenting the animal's spontaneous displacement. Subsequently, multiple episodes were compiled by analyzing the trap camera files, documented between 8 October and 18 October 2025. The first camera trap recording occurred on 8 October 2025, at 7:20 p.m., documenting the individual in displacement and exploratory behavior **(**Figure 1).

Figure 1 - Trap camera record of the crab-eating fox (*C. thous*) in movement and exploratory behavior in an urban condominium in the municipality of Franca-SP in October 2025.

Source: Veronez (2025).

Secondary records were obtained on 9 October 2025, at 8:06 p.m., documenting nighttime activity. The last visual record obtained by the trap camera occurred on 18 October 2025, at 6:43 p.m. Additionally, a report of sighting by residents of the condominium was recorded on 26 October 2025, around 11 pm, indicating prolonged stay of the individual in the study area.

During the monitoring period, two distinct episodes of behavior interpreted as zoopharmacognosy were documented, both occurring on 10 October 2025. In the first episode, recorded at approximately 5:30 p.m., the animal was observed actively rubbing parts of the body, particularly the rostral and lateral region of the thorax, against an orthopteran insect (*Orthoptera sp*., cricket) (Figure 2).

Figure 2 - Photographic record of the crab-eating fox (*C. thous*) rubbing its body in *Orthoptera sp.* (cricket) in an urban condominium in the municipality of Franca-SP in October 2025.

Source: Veronez (2025).

This behavior was characterized by deliberate manipulation and repeated contact between the animal's body surface and the insect, performed in a rhythmic and persistent manner, with no evidence of predatory intent or ingestion of the arthropod. The animal maintained the behavioral pattern for approximately two minutes, after which it moved away from the insect, leaving the cricket alive and mobile in place.

In the second episode, recorded at approximately 7 p.m. on the same day, the crab-eating fox was observed interacting with a blattodean (*Blattodea sp*., a cockroach) carrying the insect in its mouth, exhibiting repeated licks on the surface of the arthropod, particularly directed at the ventral and dorsal regions of the cockroach **(**Figure 3).

Figure 3 - Photographic record of the crab-eating fox (*C. thous*) carrying the blattodeo insect (*Blattodea sp*., cockroach) in its mouth in an urban condominium in the municipality of Franca-SP in October 2025.

Source: Veronez (2025).

The behavioral pattern was similar to that observed with crickets, with a clear absence of chewing or ingestion, suggesting deliberate topical manipulation of the arthropod against oral mucous membranes and integument (Figure 4).

Figure 4 - Photographic record of the crab-eating fox (*Cerdocyon thous*) licking the blattodeo insect (*Blattodea sp*., cockroach), with no apparent intention of ingestion, in an urban condominium in the municipality of Franca-SP in October 2025.

Source: Veronez (2025).

The behaviour was non-aggressive and lasted approximately two to three minutes, culminating in the animal releasing the insect still alive, which subsequently moved away. The animal did not resume interaction with the insect after releasing it.

The analysis of videographic and photographic records was conducted in a qualitative and descriptive way, focusing on the identification of behavioral patterns, environmental contexts, temporal sequences of actions and characteristics of interactions with insects. The investigation followed the methodological principles proposed by Huffman (1997) and Engel (2002) for observational ethological studies of zoopharmacognosy in wildlife, incorporating criteria such as intentionality of action, repeatability of the behavioral sequence, appropriate ecological context and absence of direct anthropic mediation.

4. Discussion

The present report documents, for the first time in the scientific literature, a case of zoopharmacognosy behavior in crab-eating fox (*C. thous*) involving non-feeding interaction with arthropod insects, specifically orthoptera and blattodeans, in the context of a peri-urban environment. The two behavioral episodes recorded presented characteristics compatible with the criteria established by Huffman (1997) for the identification of self-medication in wildlife, including intentionality of the action, deliberate manipulation of the medicinal organism, absence of apparent nutritional consumption and ecological context appropriate to the selective pressure for parasite control.

The observed behavior differs significantly from the known behaviors of entomophagy and predatory capture in *C. thous.* While insects are consumed by the crab-eating fox as a legitimate dietary component, as documented in studies of stomach contents that revealed the presence of invertebrates in 9% of the samples analyzed (Dutra-Vieira et al., 2021), the behavioral pattern documented in this case was characterized by the absence of chewing, ingestion, or swallowing. Instead, the animal actively rubbed body parts, particularly the rostral and lateral region of the thorax, against the orthopteran insect and repeatedly licked the surface of the blattodeo insect without subsequent consumption, suggesting a topical, non-entomophagous objective. This behavioral pattern is consistent with self-medication mechanisms described in the literature, particularly those involving deliberate manipulation of arthropods for parasite or antimicrobial control purposes (Huffman, 2003; Of Roode; Lefevre & Hunter, 2013).

Arthropod-mediated zoopharmacognosy remains widely documented in non-human primates, especially in chimpanzees (*Pan troglodytes*), where researchers observed in 19 distinct episodes over 15 months the application behavior of captured insects to open wounds, both in contexts of self-medication and proenvironmental behavior in relation to conspecifics (Mascaro et al., 2022). However, equivalent reports in wild carnivorous mammals, particularly in neotropical Canidae, remained absent in the scientific literature prior to the present study. This gap represents an important limitation in understanding the phylogenetic distribution of self-medication behaviors and their evolutionary relevance in different ecological strategies (Huffman, 2022).

The mechanistic hypothesis for the observed behavior is based on the known bioactive properties of insects (Arthropoda). Insects and other arthropods produce a wide variety of AMPs, more than 150 types identified to date, including defenins, cecropins, lebocins, and glyverins, with proven antimicrobial activity against Gram-positive and Gram-negative bacteria, filamentous fungi, and parasitic protozoa (Yi et al., 2014; Sahoo et al., 2021). The mechanism of action of these peptides involves electrostatic interaction with negatively charged bacterial membranes, followed by pore formation in the membranes, permeabilization, and subsequent cell death (Boulanger et al., 2016). Additionally, chitin and its derivatives present in the cuticle of insects have intrinsic antimicrobial and antifungal properties, potentially relevant to the control of ectoparasites and dermal infections (Guarnieri et al., 2022).

The topical manipulation of insects by the crab-eating fox may represent a strategy of topical self-medication, with the animal taking advantage of the bioactive compounds present in the insects to protect against ectoparasites or skin infections. The rostral and lateral region of the thorax, areas selected primarily by the animal, are typical locations for the accumulation of ectoparasites in wild mammals, including mites, fleas, and lice (Bush; Clayton, 2018). Alternatively, the oral application of insects to the oral mucous membranes, as observed in the second episode, may represent a strategy of topical inoculation of antimicrobial compounds with the objective of controlling pathogenic or parasitic microorganisms residing in the oral structures and digestive tract (Huffman, 2003).

Parasitic pressure on *C. thous* in peri-urban environments is documented to be intense. Exposure of the species to various pathogens, including viruses (parvovirus, distemper, rabies), bacteria (*Ehrlichia spp., Hepatozoon spp.*), protozoa (*Leishmania spp.*), and helminths, many of which are transmitted by contact with domestic dogs in urban areas, creates substantial selective pressure for the evolution of behavioral health defense strategies (Spera et al., 2020; Jorge et al., 2010). The generalist and opportunistic nature of the *C. thous* diet, although conferring feeding advantages in anthropic environments, exposes the animal to a wide diversity of pathogens through the consumption of contaminated food, water, and contact with intermediate hosts (Rocha et al., 2004). This continuous parasitic pressure may have favored the evolution of multiple behavioral strategies of self-medication, of which the topical manipulation of insects may represent only one component (Lozano, 1998).

It is relevant to note that the ecological and behavioral plasticity characteristic of *C. thous* in peri-urban environments can facilitate the expression of previously latent or infrequently expressed self-medication behaviors (Silva; Souza; Silva, 2020; Pereira et al., 2024). The coexistence of the animal with a diversity of insects in an urban environment, combined with the prolonged observational opportunity provided by the trap camera installation, created ideal conditions for documenting rare or episodic behaviors. Studies in "pure" wild environments may underestimate the frequency of self-medicating behaviors in C. thous, given that the diversity of potentially medicinal arthropods may be greater in anthropized environments with less interspecific competition and greater availability of refugee niches (Ferraz et al., 2010).

The behavioral distinction between self-medication and casual entomophagy is critical for data interpretation. Although *C. thous* is known to capture and consume insects, the behavioral characteristics documented in the present case, prolonged careful handling, absence of predation, release of the insect while still alive, repetition of the pattern with multiple species of

insects in a short time interval, suggest a behavioral mechanism different from that involved in conventional food capture (Facure; Giaretta, 1996). The absence of aggressive predatory behaviors, violent chewing, or rapid ingestion differentiates the observed behavior from typical feeding patterns of the species (Gatti et al., 2006).

Documenting this behavior in a peri-urban environment raises important questions about interfaces between urbanization and wildlife ethology. Peri-urban environments often concentrate greater diversity of arthropods than rural or fully urban environments, due to the coexistence of multiple plant formations and refuge niches. The greater exposure of *C. thous* to these intermediate environments may have amplified both the opportunity for contact with potential medicinal substances and the selective pressure for the development or refinement of self-medication behaviors. Additionally, the presence of researchers equipped with non-invasive monitoring technology (trap camera) created a favorable observation context that would have been impossible through conventional methodologies, highlighting the importance of methodological innovations in wildlife ethology (Rovero et al., 2013).

Compared to the literature on self-medication in primates, the behavior documented in *C. thous* demonstrates remarkable evolutionary convergence. Just as chimpanzees use plants with antiparasitic properties (Huffman, 2003) and insects for wound treatment (Mascaro et al., 2022), the crab-eating fox apparently uses insects for apparently prophylactic or therapeutic purposes. This convergence suggests that arthropod-mediated self-medication may represent an evolutionarily advantageous strategy that transcends taxonomic lines, emerging independently in distinct phylogenetic groups subjected to similar parasitic pressures (De Roode; Hunter, 2019). The phylogenetic breadth of self-medication in wildlife, from primates to social insects, indicates that this phenomenon represents a fundamental adaptive solution to universal problems of parasite control in wild environments (Huffman, 1997).

The limitations of the present study should be acknowledged. The documented behavioral frequency (two episodes in 15 days of continuous monitoring) is consistent with rare episodic behavior, precluding statistical conclusions about prevalence or temporal patterns of expression. The impossibility of capturing the insects used by chemical analyses compromises the ability to confirm mechanistic hypotheses about specific bioactive properties. In addition, the spatially limited monitoring of a residential condominium in a circumscribed period does not allow generalizations about frequency or geographic distribution of behavior in the species. Long-term prospective studies at multiple geographic sites would be necessary to establish whether this behavior represents a common pattern in *C. thous* populations or a rare event documented by circumstantial opportunity (Huffman & Vitazkova, 2007).

Despite these limitations, the present report contributes significantly to the knowledge about zoopharmacognosy in wild South American Canidae and expands the scope of understanding about ethological mechanisms of health defense in wildlife. The results reinforce the importance of systematic behavioral observations in peri-urban environments for documenting ethological phenomena that may remain latent or rarely expressed in purely wild contexts (Engel, 2002). Future studies should emphasize prolonged behavioral monitoring at multiple sites, capture and chemical analysis of insects used, and experimental investigation of antimicrobial properties of local arthropoda species relevant to the ecology of *C. thous* (Costa-Neto, 2012).

In summary, this study provides the first documented evidence of arthropod-mediated topical self-medication in *Cerdocyon thous*, expanding the understanding of behavioral diversity and adaptive health defense mechanisms in wild mammals.

5. Conclusion

The present report documents, for the first time in the scientific literature, a case of zoopharmacognosy behavior in crab-eating fox (*C. thous*) through non-feeding manipulation of insects in a peri-urban environment. The behavioral episodes

recorded, body rubbing against an orthopteran insect and repeated licking of a blattodeo insect, present ethological characteristics compatible with topical self-medication mediated by bioactive entomological compounds. This finding expands the known phylogenetic range of self-medicating behaviors in wild mammals and fills an important gap in the understanding of behavioral health defense strategies in neotropical Canidae.

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